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Review

Locoregional and systemic effects of TECAR therapy on hypertension

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Abstract: Arterial hypertension is the most common comorbidity encountered in patients with musculoskeletal diseases requiring rehabilitation. Blood pressure can be influenced by the used physical thermal agents, such as targeted radiofrequency therapy, also known as transfer energy capacitive and resistive therapy (TECAR). This study aimed to investigate the local and systemic physiological effects of endothermy and its potential influence on blood pressure. We conducted a literature search for randomized controlled trials in the most recent PubMed database, the Cochrane Library, Scopus, Google Scholar, and certainly, books in the rehabilitation field. In the study, we included 19 papers in the last 20 years. The number of accurate clinical studies investigating the effects of TECAR therapy is limited, with most studies conducted on a small number of healthy adults or patients with musculoskeletal diseases but without cardiovascular impairment. At the locoregional level, it has been demonstrated that the vasodilation produced promotes tissue healing processes by stimulating biotrophy, analgesia, venolymphatic drainage, and muscle relaxation. We believe that future research is necessary in this field because the effects of therapy, particularly at the systemic level, remain unclear, and no study has monitored blood pressure during endothermic treatment. On the other hand, hypertension is often undiagnosed in time, an estimated of 46%. Diagnosed patients most often follow a treatment that involves drug associations that can have repercussions at the vascular level when deep endothermy is applied.

Keywords: diathermy; targeted radiofrequency; capacitive and resistive electrical transfer; CRET; TECAR therapy; hypertension; blood pressure;

1. Introduction

In 2023, WHO launched the first global report on hypertension, highlighting the urgent need to address hypertension and its associated complications. Hypertension affects over one billion people globally, with only 54% diagnosed, 42% receiving treatment and only 21% having their blood pressure under control [1]. It is estimated that one in three adults aged 30 to 79 years is living with hypertension without knowing it. Furthermore, the most recent report by the World Health Organization, highlights the fact that musculoskeletal disorders affect 1.7 billion people globally [2]. Given the high incidence of both pathologies, most often they are associated. In these circumstances, attention is drawn to the need for rehabilitation as a new strategic approach, with multidisciplinary teams and specific therapeutic interventions [3].

Physical agents used in rehabilitation, which produce a therapeutic response in musculoskeletal tissues, can be divided into 2 categories: heat-based - thermotherapy or cold-based - cryotherapy. Both treatment methods have an analgesic effect and reduce muscle spasms, but at the cellular level (tissue metabolism, blood flow, inflammation, edema and tissue extensibility) the effects are opposite [4].

Thermotherapy can be classified according to the degree of thermal energy penetration into the tissue. Superficial therapy - such as paraffin wraps, radiant heat-light lamps, fluid-bath therapy - which produce changes, such as vasodilation and increased temperature in the skin or subcutaneous tissue. Deep therapy - such as high-frequency current - long waves, short waves, ultrasound - which produces the same changes but in deep tissues [5].

TECAR is an endothermic energy transmission, using radiofrequency (RF) 0.5 MHz (400-600 kHz depending on the electrophysical device manufacturer), with a power of 324 W, so it is considered a long-wave diathermy with deep heating in musculoskeletal structures [6].

The therapy can be applied in two ways: capacitive or resistive, depending on the tissue selectivity. This is done using two different active electrodes (capacitive and resistive) and an inactive reference electrode, used as a conductor [7]. The capacitive applicator acts as a dielectric capacitor, only at the level of superficial tissues, with low resistance, rich in water and proteins, such as muscles, vasculo-lymphatic structures, adipose tissue, visceral organs [8,9,10,11]. On the other hand, the resistive applicator, without a dielectric capacitor, will produce thermal energy, at the level of muscle fascia, tendon, bone, cartilage, high impedance tissues with low water content [8,9,10,11]. Therefore, when lower frequencies are used, heat is delivered to the deep tissues but when higher frequencies are used, heat is distributed to the superficial tissues.

2. Materials and Methods

We included in this review original studies referring to the physiological effects of endotermy, especially TECAR therapy. We analyzed articles published in the last 20 years, from 2004 to 2024, on PubMed, Scopus, Cochrane, Google scholar, but only 19 papers were included in our research, respecting the inclusion criteria: publication in English, academic journal articles, full text available, experimental studies on human tissues, in vitro studies, adult patients. Exclusion criteria were: duplicate articles, abstracts without extended form, and studies on cadavers and animals. The keywords used was: "diathermy", "targeted radiofrequency", "capacitive and resistive electrical transfer", "CRET", "TECAR therapy", and compound searches associating "blood pressure", "hypertension". At the same time, we utilized information from specialized books, including Physical and Rehabilitation Medicine by R. L. Braddom, Electrotherapy by A. Radulescu, and Electrotherapy: Practical Principles by C. Daia.

3. Results

The human body, viewed as an electrical conductor, has different degrees of conductivity depending on the tissue structures traversed by the current: blood, lymph, cerebrospinal fluid are very good conductors (grade I) [12]. Muscles, subcutaneous tissue and internal organs are good conductors (grade II). Nerves, adipose and bone tissue are poor conductors (grade III). Hair and epidermis are very poor conductors (grade IV) [12]. Tissues are considered "inhomogeneous stratified electric circuits", being composed of electrically conductive liquids, delimited by poorly conductive membranes [12]. The biggest challenge of the researchers was to find a current that could penetrate the skin and the subcutaneous tissue, without overheating them, without causing burns but in the same time heating the deep tissues, like muscles, ligaments, tendons, even bones.

The high-frequency current (HFC) easily passes through the skin, due to its low impedance, heating the subcutaneous tissue. According to Faraday's law, high frequency currents produce marked inductive and capacitive phenomena, easily traversing tissues that low frequency currents are unable to penetrate, strongly heating up metallic bodies and electrolytic solutions. This type of currents produce electrical energy that is transformed into caloric energy - diathermy/endothermy - depending on the dielectric constant, electrical conductivity, tissue resistance and the geometric arrangement of the layers through which the current must pass[13]. At the level of HFC liquids it produces caloric energy but at the level of membranes it behaves as a displacement current, without producing thermal energy [12]. The resistance of the skin and the accumulation of caloric energy in the deep tissues can also be influenced by other factors such as: increased humidity of the skin due to excessive sweating, the layer of adipose tissue, the degree of vascularization.

We analyzed 19 articles, which involved the participation of 591 adults, men and women, over 18 years old. Of this number, 94 adults were healthy and 497 adults had musculoskeletal disorders. The studies on patients are divided into 2 categories: one part does not specify the existence of comorbidities, and the other part excluded comorbidities, such as cardiovascular disease, through inclusion/exclusion criteria.

Table 1 presents the physiological locoregional effects of TECAR therapy in healthy adults and patient with musculoskeletal disorders. Thus, the thermal factor acts at the level of the application, so locoregionally, as well as at the level of the whole body, thus stimulating thermoregulation processes in order to maintain homeostasis the internal environment of the body [14].

Table 1. Physiological locoregional effects of TECAR therapy

Study	No. participants	Patollogy	Area application	Parameters	Effects
Kumaran et al., 2015, [15]	15	healty adults	lower thigh region	not mention	increase skin temperature up to 45 min after application
Osti et al, 2015, [16]	66	low back pain	lower paraspinal muscle	not mention	reduce pain
Tashiro et al., 2017, [5]	13	healthy adults	lower paraspinal muscle	5 min capacitive and 10 min resistive	increase blood flow-superficial and deep, with increased haemoglobin saturation and skin temperature
Notarnicola et al, 2017, [17]	60	low back pain	lower paraspinal muscle	10 min capacitive mode and 10 min resistive mode	reduce pain, anti-inflamatory, muscle relaxation
Yokota et al., 2018 [11]	22	healthy adults	cvadriceps muscle	5 min capacitive and 10 min resistive	increase flexibility
Kumaran et al., 2019, [9]	45	knee osteoarthritis	knee	not mention	reduce pain
Cau et al., 2019, [18]	48	lymphedema on severe obese adults	lower limb	45 min capacitive mode	circulative activation, resorbtive, reduce pain
Coccetta et al., 2019, [19]	53	knee osteoarthritis	cvadriceps and knee	5 min capacitive mode and 10 min resistive mode and 5 min capacitive mode	reduce pain, increase flexibility
Paolucci et al., 2019, [20]	46	impingement syndrome and shoulder pain (Neer stage 2 and 3)	shoulder	10 min capacitive mode and 10 min resistive mode	reduce pain, muscle relaxation, increase flexibility
Clijsen et al., 2020, [10]	10	healthy adults	right forearm	8 min capacitive or resistive mode	increase local skin microcirculation and intramuscular blood flow only on proximal forearm after RES mode
Fousekis et al., 2020, [21]	10	healthy adults	posterior thigh	5 min capacitive mode and 10 min resistive mode	increase skin temerature , blood circulation and metabolism

Davari et al., 2021, [22]	23	lateral ankle ligament sprain on athletes adults	lateral ankle ligament	not mention	increase blood and lymph flow, reduce edema, reduce pain, increase flexibility
Yeste-Fabregat et al., 2021, [23]	32	myofascial pain syndrome on athletes adults	medial gastrocnemius	15 min mode capactive and 10 min resistive mode	increase skin temperature, reduce pain , increase local sensitivity 30 min after application, no influence in ankle flexibility
Iacob et al., 2021, [24]	24	hamstring strain on adult football players	hamstring	not mention	reduce pain, increase flexibility and knee mobility
De Sousa et al., 2022, [25]	6	paralymic healty adults swimmers	upper limbs	20 min resistive mode	increase temperature
Nakumara et al, 2022, [26]	28	healthy adults	cvadriceps muscle	10 min capacitive mode and 20 min resistive mode, 48 h after eccentric exercise of cvadriceps	reduce pain, increase flexibility and muscle strenght
Wachi et al, 2022, [27]	24	low back pain	lower paraspinal muscle	5 min capacitive mode and 10 min resistive mode	reduce pain, muscle relaxation
Kasimis et al, 2023, [28]	60	chronic low back pain	lower paraspinal muscle	resistive electrode bracelet	reduce pain
Pietka et al, 2024, [29]	6	myofascial syndrome	upper trapezius muscle	10 min capacitive mode	increase temperature in controlateral muscle

3.1. Locoregional effects of TECAR therapy:

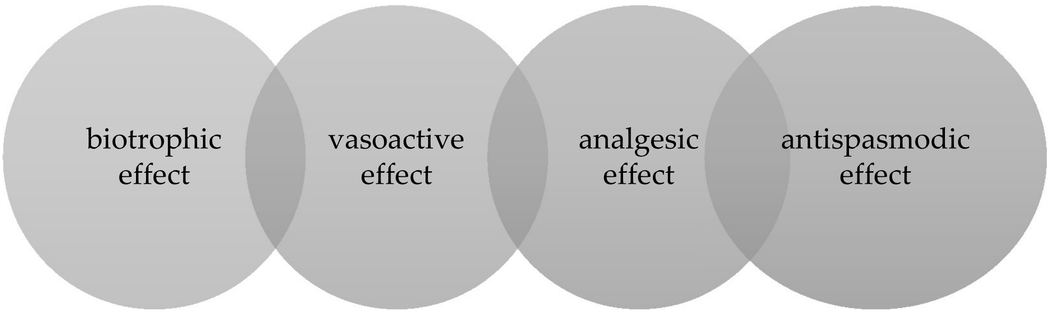

Figure 1. Locoregional effects of TECAR therapy

3.1.1. Biotrophic- metabolic biostimulation and tissue regeneration

In vitro studies have shown that the amount of mesenchymal cells grow after exposure to TECAR, using growth factors as well, like TGFβ and bone morphogenetic proteins, thus demonstrating the ability to regenerate connective tissues and repair tissue lesions [30,31]. According to the latest article published in 2024 by Mazurek et al., a 448 kHz electrical pulse applied to mesenchymal cells collected from the adipose layer of the affected tissue, causes them to proliferate, while maintaining the ability to differentiate into adipocytes, myocytes, osteoblasts, chondrocytes, neuronal cells and keratinocytes [32]. Capacitive stimulation causes chondrocyte proliferation in the presence of chondroitin sulfate and glucosamine glycans, although cartilage is a poorly vascularized tissue with low resistance. On the other hand, resistive stimulation causes chondrocyte and osteoblast proliferation, with alkaline phosphatase activation and bone mineralization. Thus, in musculoskeletal injuries, the healing process of tendons, cartilage and bone callus formation is initiated and accelerated [33].

The biochemical processes occurring at the intercellular and intracellular levels are due to the activation of the ion pump with the restoration of the membrane potential [32]. At higher frequencies, the ions rotate around their axis causing a strong thermal effect, which causes the activation of microcirculation, tissue oxygenation with the improvement of venous and lymphatic return [16]. Local vasodilatation causes an increase in temperature at the tissue level and for each additional degree Celsius there is associated a 10-15% increase in local metabolism, activating the catabolic and anabolic reactions necessary to repair the injuries [34].

Moreover, the new TECAR of pulse width modulation technology property ensures continuous measurement of tissue impedance and modulates the absorbed power, aiming respiration at the cellular level, as well as the repair processes through the release of fibroblasts [35]. This option allows continuous power adjustment and control of tolerated heat, eliminating patient discomfort when the high-frequency current passes through tissues with different impedances [6].

3.1.2. Analgesic

According to the International Association for the Study of Pain, tissue damage causes a sensory response called pain—by activating specialized nerve endings called nociceptors . Nociceptors transmit information via slow-conducting unmyelinated Aδ and C fibers that travel through the spinal cord to the cortex, where the sensation of pain is recognized [6]. Sensory information from the electrodes is transmitted via fast-conducting Aβ nerve fibers, blocking the transmission of the pain impulse to the spinal cord through the phenomenon of presynaptic inhibition [14]. This represents the "medullary blocked gate theory" and is a direct route to analgesia. At the same time, changes in skin temperature activate thermoreceptors, causing nerve signals that stop nociception in the spinal cord [36]. On the other hand, there is also an indirect route of analgesia, by modulating circulation, increasing oxygen and nutrient intake and decreasing oxidative stress, removing pain mediators by releasing endorphins [8]. The vasodilation produced decreases local ischemia and pain-causing spasticity by compressing blood vessels [37]. Therefore, temperature changes, at the level of the peripheral nervous system, increase nerve conduction velocity and excitability, decrease rheobase and shorten chronaxie [12] , finally with the increase in pain sensitivity threshold.

According to a study looking the brain imaging through tactile and thermal stimulation, the exteroreceptors relieving pain are activaited through a central effect at the level of the thalamus, the posterior islet of the brain and the cerebral cortex [15].

There is evidence that applying heat to the skin improved low back pain, with the effect being maintained even 2 days after discontinuation of treatment, compared to the administration of nonsteroidal anti-inflammatory drugs such as ibuprofen (>56%) or analgesics such as acetaminophen (>34%) [5]. Heat also had a superior effect in terms of flexibility, muscle relaxation and reduction of disability .

Kasimis' study analyzed 60 patients with low back pain, 20 of whom were treated with manipulations using a resistive electrode bracelet attached to the physiotherapist's hand. Thus, there is both thermal and mechanical stimulation with a positive impact on pain, flexibility and local sensitivity [28].

3.1.3. Vasoactive - circulative activation, resorbtive

According to Joule's law, when an electric current passes through a conductor, the heat released is proportional to its resistance. Thus, the tissues heat up unevenly, depending on the degree of vascularization. Blood has a strong refractive effect due to the structure of red blood cells, which are good intracellular conductors, surrounded by an insulating cell membrane with ohmic resistance [5]. The heat produced will cause vasodilation with increased blood flow, stimulating circulation.

There are 3 levels of dose adjustment regarding current intensity: athermic doses - below 35 degrees, oligothermic between 35-38 degrees and hyperthermic above 38 degrees. Low doses cause non-thermal effects, which promote cellular metabolic activity, even with temperature changes of a fraction of a degree Celsius. Moderate and high doses cause thermal effects, which occur when there are temperature changes of at least 2 degrees Celsius [38]. The thermal or non-thermal effect is also influenced by other parameters, such as: frequency, duration of exposure, treated area, size of electrode.

According to Kumaran et al, the improvement of inflammation occurs when the temperature of the tissues increases by 1 degree Celsius, analgesia and muscle relaxation at 2-3 degrees Celsius, and the increase in elasticity above 3-4 degrees [9]. These changes occur due to the stimulation of thermoreceptors at the skin level with the activation of microcirculation, the release of oxyhemoglobin and increased oxygen saturation, increased nerve conduction and enzymatic activation, specially colagenase[38]. When tissues are not adequately oxygenated, the hypoxic state induces the release of substances with an algesic role, such as substance P, causing peripheral sensitization, then central, finally with the appearance of pain. Their exposure to heat causes the activation of the HIF-1 gene, with decreased oxygen consumption and reduced hypoxia, analgesia, muscle relaxation [5].

Hyperemia is obtained both by direct local action and by reflex, with suppression of the sympathetic nervous system and releasing vasoactive substances, like prostaglandin and histamine. Increased blood flow has many benefits: it increases the percentage of hemoglobin in the arterial blood that is saturated with oxygen [5], increases the intake of nutrients, removes secondary metabolic products with the help of leukocytes and antibodies [8], facilitates venolymphatic drainage with the regression of inflammation and implicitly reducing edema. Acute inflammations do not react favorably to endothermy, causing increased edema, bleeding and exacerbation of inflammatory phenomena. In contrast, chronic inflammations react favorably to endothermy, facilitating resorption of fluids. In the treatment of lymphedema of the lower limb on morbid obesity pacients, the TECAR proved to be more efficient and faster in reducing edema (objectified by the decrease in the circumference of the member) than manual lymphatic drainage or pressure therapy [18].

Tashiro's study demonstrated increases in oxyhemoglobin and total hemoglobin, without changes in deoxyhemoglobin, even 30 minutes after applying TECAR therapy, 5 min capacitive mode and 10 min resistive mode, in 13 healthy men. The temperature was measured at the skin level and at the depth of 10 and 20 mm after the application of RF, increasing with a variation of 3-4 degrees Celsius [5]. Moreover, the temperature change was maintained, in one evaluation, up to 164 min after dinamic TECAR application at the posterior thigh [21]. In another study from 2015, on 15 healty man, the highest temperature recorded at the skin level in applications to the calf and knee in CAP and RES mode was 37.4 °C respectively 37.0 °C [15]. Accordingly, we can say that the hyperthermia threshold is not reached, skin temperatures being below 40 degrees. The optimal therapeutic temperature is up to 45 degrees Celsius, considered the thermal pain threshold, above which it could cause tissue damage, even thermal ablation. Thus, the intensity can be dosed depending on the perception of pain in people without sensitivity disorders. The perception of pain is influenced by several factors: the amount of nociceptors present at the level of the treated segment, the method of applying the therapy, capacitive or resistive, static or dynamic, the size of the electrodes and the layer of conductive cream used.

According to the study by Clijsen et al, published in 2020, conducted on 10 healthy subjects, to whom TECAR was applied for 8 min in one of the 2 modes, intramuscular blood flow (IMBF) measured in the proximal arm increased 10 min only after application in the resistive mode [10].

On the other hand, a study published in 2016 demonstrates that HFC applied to the affected calf, in patients with complex regional syndrome, increased blood flow to the controlateral calf [40]. Furthermore, another article recently appeared that tracked the response of the upper trapezius muscle using thermal imaging when active and latent trigger points in the contralateral upper trapezius muscle were treated [29]. According to the energy crisis theory, these contracture points are formed by increased metabolism with local ischemia, followed by hypoxia of the muscle tissue, release of pro-inflammatory substances and peripheral sensitization through nociceptors. The authors concluded that the isotherm zones are almost symmetrical, and 45 minutes after application, the change in the isotherm of the untreated muscle is greater [29]. This explains the term "cross-education", which assumes the existence of a contralateral effect when using thermotherapy, through thermoreceptors, resulting in skin vasodilation and increased peripheral blood flow and cardiac output. This phenomenon has also been observed in case of neuromuscular electrostimulation, percutaneous electrolysis, and acupuncture [41].

3.1.4. Antispasmodic

And this time it is the caloric effect that determines the changes induced in the muscles: decreased muscle tone with the relaxation of antagonists, increased enzymatic activity of adenylpyrophosphatase with repercussions on contractile performance[20] and of collagenase with repercussions on the elasticity of connective tissues. Although the tendons are poorly vascularized, their nutrition being due to the synovial fluid, it was proven that the extensibility increased after the application of the TECAR therapy,stretching being associated at the end espacially [16]. Nakamura et al. demonstrated that TECAR therapy relieves pain and muscle temperature, improving muscle strength at the knee level in healthy subjects [26], Yokota et al. showed improvement in range of motion by increasing extensibilitty, flexibility and muscle relaxation changing the activity of alpha and gamma motor neurons, with an increase in the discharge rate of fibers from group Ia and Ib, and a decrease in the discharge rate of fibers from group II [11]. Burcea et all, demonstrated that TECAR therapy associated with physiotherapy brought greater improvements in range of motion and muscle strength in patients with proximal humerus fracture [42]. In another study conducted on 46 patients with impingement syndrome and shoulder pain, after 9 treatment sessions, 10 minutes in capacitive mode and 10 minutes in resistive mode, the VAS score decreased and the functionality of the joint increased [20]. Once again, it was proven that hyperthermia supports the anabolic processes necessary for tissue repair.

3.2 Systemic effects of TECAR therapy

Only one study measured blood pressure and heart rate after applying TECAR in capacitive or resistive mode for 8 min on 10 healthy adults, with no significant increase [10]. We cannot take these results into account, considering that the sample is limited. More than that, no measurements were made in patients with known hypertension

The body's reactivity requires the integrity of the central nervous system, manifesting itself through the dermovascular reaction, changes in heart rate, breathing rate and intensity of the patient's subjective reaction to the application of the stimulus. No study has monitored these reactions. No study has monitored these reactions, so future research is needed regarding the influence of endothermy on the systemic vascular response, especially in patients with hypertension who are under treatment.

4. Discussion

In the last 20 years, TECAR therapy demonstrates that produce deep endothermy with superficial and deep vasoactive effects in healthy adults or those with musculoskeletal conditions but without cardiovascular disease. There are no studies that monitor blood pressure in patients undergoing deep endothermy and diagnosed with hypertension.

According to the latest World Health Organization guideline, antihypertensive medications used as first line agents or in combination therapy should be chosen from the following three drug classes: diuretics (thiazide or thiazide-like), angiotensin-converting enzyme inhibitors/angiotensin- receptor blockers, and long-acting dihydropyridine calcium channel blockers [1].

There are many questions that arise regarding the influence of TECAR on antihypertensive medication. For example, if HFC is applied to the lumbar level, could it influence the increase in blood flow in the renal arteries? What repercussions could this have on the glomerular filtration rate when the patient is on diuretics or ACE inhibitors? Can the vasodilation produced by endothermy act synergistically with ACE inhibitors or dihydropyridine calcium channel blockers, which decrease peripheral vascular resistance? Could the patient sweat excessively so that hydroelectrolytic imbalances, such as hyperkalemia or hypokalemia, occur, determined by dehydration and antihypertensive medication? Could the application of therapy to the ankles cause peripheral edema in patients on calcium channel blockers? Is there a risk of reflex tachycardia due to a sudden increase in heart rate? Is there a risk of hypotension? We believe that further studies are needed to answer these questions, studies on patients with treatment for hypertension. We also believe that the method of application, static or dynamic, capacitive or resistive mode, the intensity of the electric field, the time of administration and the treated region, in the vicinity of large vessels, are important.

Tecar therapy has multiple benefits, due to the hyperemia produced: it facilitates tissue healing, activates metabolism, relieves ischemic pain and decreases conduction velocity in the fibers that mediate pain, relaxes muscles, improves flexibility, and increases collagen extensibility. Considering the proven local effects on peripheral blood flow by stimulating the production of nitric oxide that favors the relaxation of vascular walls, the regulation of the activity of the autonomic nervous system, the decrease in the level of pro-inflammatory cytokines with a protective effect on the vascular endothelium, it is necessary to prove, through future studies, the systemic effects on blood pressure. TECAR therapy could also have a beneficial role in the management of blood pressure, and why not, used as an adjuvant treatment.

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