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# Applications of Iontophoresis and Phonophoresis

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*University of North Dakota*

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APPLICATIONS OF IONTOPHORESIS AND PHONOPHORESIS

by

Craig Hahn  
Bachelor of Science in Physical Therapy  
University of North Dakota, 1995



An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

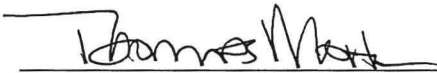
for the degree of

Master of Physical Therapy


Grand Forks, North Dakota

May  
1996

This Independent Study, submitted by Craig Hahn in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

  
\_\_\_\_\_  
(Faculty Preceptor)

  
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(Graduate School Advisor)

  
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## PERMISSION

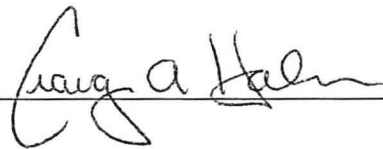
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A handwritten signature in cursive script, appearing to read "Craig A. Halen", written over a horizontal line.

Date

4/30/96



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## ABSTRACT

Many different drugs are used topically for treatment by the medical field. The benefit of some of these drugs can be enhanced by the use of ultrasound (phonophoresis) or electric current (iontophoresis). These methods have been used for many years by such disciplines as ophthalmology, dermatology, dentistry as well as physical therapy. With the inherent risks of blood borne pathogens, these methods are a great alternative to the injection of drugs into the system.

The purpose of this paper is to review the literature regarding iontophoresis and phonophoresis and present the results as a guide for the practicing physical therapist. The most common use of iontophoresis and phonophoresis is for the control of pain and inflammation. Some scientific studies have been conducted using either a dexamethasone/lidocaine combination or hydrocortisone. Both of these have shown outstanding results. Studies and case reports have also shown positive results for the use of iontophoresis and phonophoresis in the treatment of burns, open wounds, calcium deposits, anesthesia, and various skin conditions. Most of these studies, however, have lacked good scientific design or have not been tested at

all. There is clearly a need for more research in the use of some of these promising drugs.

## CHAPTER I

### INTRODUCTION

#### **Transcutaneous Drug Delivery**

Because of the recent fear of blood borne pathogens, there has been a growing interest in the use of drug infusion through the intact skin.

Iontophoresis and phonophoresis are two popular methods for enhancing the effectiveness of topically applied medications. The purpose of this paper is to review the current research and discuss the effectiveness of the different medications with regard to the field of physical therapy. Its intent is to provide practicing physical therapists with an easy guide to the use of phonophoresis and iontophoresis.

Many drugs are topically applied to get a local response or a system wide affect. There are many advantages to delivering a drug topically as opposed to either injection or oral administration. These include (1) reduction by metabolism of the drug because the liver is initially bypassed, (2) elimination of the fear of infection from needle pricks, (3) absence of absorption by the digestive system, and (4) localization of the medication.<sup>1</sup> Pharmaceutical companies are continually involved in research to try to find new ways to enhance the delivery of topical drugs.<sup>2</sup> Although chemical agents have been used as enhancers, physical agents, such as electricity and ultrasound, are becoming increasingly popular.<sup>2</sup> The use of electricity for enhancement is termed iontophoresis and phonophoresis refers to the use of ultrasound to move the drug through the skin.

## **Iontophoresis: History and Theory**

The first scientific studies that described the use of electricity to introduce drugs through the skin were performed by LeDuc in 1908.<sup>1,3-5</sup> In studies done on two rabbits, strychnine and cyanide were introduced into the animals.

Iontophoresis has been since used in research and clinical practice in physical therapy as well as other disciplines, such as dermatology, otorhinolaryngology, ophthalmology, and dentistry.<sup>1</sup> Iontophoresis involves the passing of a current through the tissues of the body. The current of choice is a direct, galvanic (unidirectional) continuous flow. Sine wave, high voltage pulsed, and inferential currents are not effective for use in iontophoresis. The procedure includes a generator and two electrodes (one is the active electrode and the other is called the dispersive) connected by lead wires. The electrodes must be at least 18 inches apart for proper conductance.

Iontophoresis is based on the theory that electrically charged electrodes will repel similarly charged ions.<sup>1,3,4</sup> Water does not conduct electricity; ions dissolved in water do. Solutions with free floating ions are called electrolytes. Ionizable substances dissociate in solution releasing ions and radicals to float towards opposite poles when an electrical current is passed through the solution. The positive ions will be attracted towards the negative pole and the negative ions will be attracted towards the positive pole. When a direct current is passed through the body, a chemical reaction called electrolysis takes place. In this reaction, at the cathode (or negative electrode), sodium chloride in the body is broken down and results in a rise in the pH level of the skin. Similarly, at the anode (positive electrode), hydrochloric acid is formed which results in a lowering of the pH. At the cathode, the alkaline reaction produces a softening effect along with a mild heating effect. Conversely, at the anode, hardening of

the skin takes place along with a mild heating of the skin. The heat is a result of the vasodilation of the vessels of the skin. The change in pH at the electrodes facilitates the flow of ions in the drug solutions. The lowering or rising of the pH enhances the migration of ions at the cathode and anode respectively.<sup>2,5</sup>

The skin is permselective in nature, which means it will allow some substances to pass through while restricting others. The skin consists of the epidermis and the dermis. The stratum corneum is the outermost layer of the avascular epidermis.<sup>1</sup> It is the protective layer that prevents the entry of noxious substances from the environment and also is the rate limiting barrier. The stratum corneum is punctured by pores of the sweat glands, hair follicles, and sebaceous glands. These structures provide gaps for the introduction of ions into the body. The normal response of the skin under the electrodes is a slight reddening which disappears within a couple hours.<sup>5,8</sup>

Burns, both chemical and heat related, are a major concern with iontophoresis and have at times been a reason that iontophoresis was out of favor among practicing physical therapists. Chemical burns usually occur at the cathode and are a result of the formation of sodium hydroxide at the cathode.<sup>1,4</sup> They will appear as a raised pink lesion that shows immediately after the treatment. Hours later, this will turn into a gray open wound.<sup>1</sup> Burns under the anode are rare because of the polarity.<sup>1,4</sup> The best method to avoid burns is to decrease the current density under the cathode.

Current density is related to the duration of treatment times and the current intensity. If both electrodes are equal in size, current density will be equal under each electrode. If the electrodes are of unequal size, current density will be greatest under the smallest electrode. The general rule of thumb is that the surface area of the cathode should be at least twice that of the anode



at all times (this is true even if the cathode is not the active electrode).<sup>1,6</sup> As the duration of the treatment increases, skin impedance decreases and the chance of electrical burns intensifies. Patients should be checked every three to five minutes to avoid burns of this nature. According to a study by Sabbahi et al<sup>9</sup> reversal of the current flow for sixty seconds every five minutes of treatment will significantly reduce the chance of chemical irritation/burn on the patient's skin. In other studies, this technique has not proven to be effective. Heat burns can be produced in areas of excessive heat buildup because tissue resistance is high. The causes of this type of burn can be from lack of moisture on the electrodes or wrinkles present under the electrodes which produce air spaces. The patient should be positioned in such a manner so as not to have full body weight on the electrodes.

The effectiveness of the introduced ions is determined by (1) the number of ions transferred, (2) depth of penetration, (3) whether ions combine chemically with other substances in the skin and precipitate, and (4) whether the ions enter the capillaries and are carried away from the site of application by the blood.

The number of ions transferred into the body by iontophoresis is related to (1) current density at the active electrode, (2) duration of current flow, and (3) concentrations of ions in solution.<sup>1</sup> Research has shown that low-level intensities are more effective as a driving force than high-current densities. Higher level amperages apparently hinder the number of ions that penetrate the skin.<sup>6</sup> An intensity of between 2 and 5 mA is suggested for most drug applications. Treatment duration varies according to the amperage used. Treatment time should be between 15 and 30 minutes. As for concentration, a lower ion concentration is usually more conducive to effective results. The less

ions in solution make for less competition for flow through the pores of the skin. According to Kahn,<sup>6</sup> ion concentrations should be between 1 to 5 %, while Cummings<sup>1</sup> suggests that solutions less than 1% are just as efficient as solutions of 1 to 2%.<sup>1,2</sup>

There is disagreement in the literature as to the concentration of the drug in the tissue as well as depth of penetration of the ions. According to some researchers, the ions are removed by the circulatory system immediately and are carried throughout the body.<sup>5</sup> Other researchers have shown that the drugs do penetrate and concentrate directly below the application electrode. Costello<sup>8</sup> has shown in laboratory animals a depth of penetration of at least one centimeter using lidocaine into the gluteal muscles. In contrast, Kahn<sup>6</sup> found penetration to be generally less than one millimeter. If the concentration of ions is too strong, the ions may combine with substances in the skin and precipitate out of solution and plug the pore.<sup>1</sup>

When applying iontophoresis, the general rule is not to use two separate chemicals simultaneously under the same electrode. Mutual repulsion may diminish penetration of the ions. It is also not advisable to use ions with opposite polarities during the same treatment session.<sup>3</sup>

### **Phonophoresis: History and Theory**

Phonophoresis is the introduction of substances into the body by the use of ultrasonic energy. Unlike iontophoresis which delivers ions into the tissues, phonophoresis transmits molecules. These molecules are then broken down into component parts to be distributed into the tissues.<sup>10,11</sup> Nyborg and Ziskin<sup>10,11</sup> claim a depth of penetration of four to six cm. However, there does not appear to be any clinical evidence of depths of greater than one to two millimeters.<sup>6</sup> With phonophoresis, the drug is placed on the skin in the form of a gel, cream,

or ointment. It is used in conjunction with an ultrasound transmission gel. Drug solutions do not work well with phonophoresis. Phonophoresis is also not effective when used in an underwater treatment method.

Ultrasound is a modality which involves the generation of high frequency sound waves and their transmission through the skin to the structures to be affected. Ultrasound is best known for its ability to create a heating affect on the deep tissues of the body. Techniques for the use of phonophoresis is the same as the standards used in ultrasound administration.<sup>6</sup> Phonophoresis is a good alternative to injecting drugs for the following reasons: (1) topically applied drugs avoid the risks and inconveniences of intravenous therapy, (2) the drugs bypass the liver and reduce elimination from the body, (3) there is less chance of an overdose or underdose, (4) it allows for easy termination; (5) they permit both local and systemic treatment affects.<sup>2</sup>

With phonophoresis, the molecules are thought to enter the body by means of diffusion through the stratum corneum.<sup>2</sup> The stratum corneum is neither continuous nor homogeneous throughout the body. The extensor surfaces of the body are generally thinner and well supplied by hair follicles and sebaceous glands. On the flexor surfaces of the body, the skin is thicker and rich with sweat glands. Hydration of the stratum corneum is critical for effective transcutaneous drug delivery. The human skin changes dramatically with age and with some disease states. The aged skin is much dryer than that of the younger healthy adult.<sup>12</sup> To hydrate the skin and thus increase drug transmission, it is best to use lightly applied occlusive dressings after the application of phonophoresis.<sup>2</sup> Denuded skin (as occurs with abrasions, with dry skin, or with shaving) also demonstrates a greater potential for drug diffusion.<sup>2</sup> Diffusion is easiest through the hair follicles (primary means), the sebaceous

glands, and the sweat ducts. The human skin also has a reservoir effect which was first demonstrated by Guillot.<sup>12</sup> When an occlusive bandage is used after treatment, the healing effect of the drugs is seen for between 48 and 72 hours.

Heating of the area to be treated before the use of phonophoresis has the effect of dilating the hair follicles, increasing the kinetic energy and movement of the particles in the area, and facilitating drug absorption. Conversely, heating the area after topical application will increase the systemic distribution of the drug, but will decrease the local effect.<sup>2</sup>

Phonophoresis is used to alter the nature of the stratum corneum to ease the diffusion of transcutaneous drugs. It allows the drugs to diffuse actively and quickly but does not deactivate the molecules, damage healthy epidermis, cause pain, or have toxic side effects. The first published reports of ultrasound as an enhancer for drug delivery was in 1954.<sup>2</sup> Both the thermal and non-thermal characteristics of high frequency sound waves can enhance the diffusion of topically applied drugs. The simplest explanation for the effectiveness of ultrasound as an enhancer of drug delivery is based on its heating effects. Heat increases the kinetic energy of both the drug molecules and the proteins, lipids, and carbohydrates in the cell membrane. Temperature changes of 5°C are necessary to cause measurable changes in the cell membrane permeability.<sup>13</sup> An intensity level of 1.5 w/cm<sup>2</sup> or higher is needed for this amount of temperature change. The mechanical characteristics of the sound waves also enhance the diffusion of topically applied drugs by oscillating the cells at high speeds, changing the resting potential of the membrane, and potentially disrupting the cell membrane of some of the cells in the area of treatment. Whether the sound waves actually push the drugs into the tissue is not known.<sup>13</sup>

## CHAPTER II

### RESEARCH STUDIES

Iontophoresis and phonophoresis have been used to treat many different types of conditions in the physical therapy clinic. The purpose of this paper is to present a literature review on the effectiveness and techniques of using iontophoresis and phonophoresis in the clinical setting.

#### **Inflammatory Conditions (Iontophoresis)**

##### Human Studies

In a study conducted by Harris,<sup>14</sup> fifty patients with various inflammatory conditions of the musculoskeletal system were treated with iontophoresis. The drug administered was one cc of .4% dexamethasone combined with two ccs of 4% xylocaine. The current was started at one milliamp and increased one milliamp per minute for five minutes. Total treatment was twenty minutes. The patients were evaluated based on three criteria: (1) range of motion, (2) degree of tenderness, swelling, and temperature, and (3) functional use of that body part. Seventy-five percent of the patients showed excellent to good results, 14% had significant relief of pain and an increase in strength and range of motion, and 11% had little or no relief of pain or symptoms. None of the fifty patients showed any side effects from the treatment.

In a study conducted by Delacerda,<sup>15</sup> 23 assembly line workers with jobs requiring repetitive shoulder movements were compared using three different methods of treatment. All of the subjects were diagnosed with shoulder myofascial syndrome. Seven of the patients were treated with a muscle relaxant

and analgesic medications only. Eight subjects received hot packs followed by ultrasound to the tender trigger point. The ultrasound was administered at between 1.25-1.50 w/cm<sup>2</sup> for four minutes. The remaining eight patients were treated with iontophoresis using one cc of .4% dexamethasone sodium phosphate and two ccs of 4% lidocaine hydrochloride. The current was started at one milliamperes and raised to five milliamperes and maintained there for 15 minutes. The subjects were initially measured in range of motion for shoulder abduction and evaluated daily for a ten-day period. The results of this study showed iontophoresis to be the most effective of the three treatments with its ability to decrease pain and regain functional range of motion. Delacerda<sup>16</sup> also ran a study of 12 subjects with diagnosis of shin splints to determine the effectiveness of locally applied hydrocortisone coupled with iontophoresis enhancement. The patients were all college athletes who were currently active in their sports. Treatment intensity of five milliamps was used over a .5% hydrocortisone cream for 20 minutes. The iontophoretic application of hydrocortisone to reduce inflammation was shown to be very effective in reducing the pain and swelling of shin splints.

Using a double blind study, Bertolucci<sup>17</sup> studied the effectiveness of iontophoresis with dexamethasone accompanied by lidocaine. The study was conducted on 53 subjects with various diagnoses of ongoing degenerative disease processes. The conditions seen were: (1) tendinitis of the supraspinatus, infraspinatus, and biceps tendon, (2) lateral epicondylitis, and (3) sacroitis. The patients received either the dexamethasone/lidocaine combination or a placebo of sodium chloride. The patients had all undergone prior medications that were unsuccessful before they entered the study. The results of the study showed excellent outcomes for the 18- to 34-year-old

category, and significantly beneficial results for the 35- to 44-year-old group. However, the 45-year-old and older group did not show positive results. The placebo group showed no benefits or decrease in their symptoms.

### Animal Studies

Glass and associates<sup>18</sup> conducted a series of studies on Rhesus monkeys to determine the quantity of dexamethasone that was actually delivered to the tissues using radio labeled drugs. One monkey was iontophoresed first with a combination of dexamethasone or hydrocortisone with lidocaine in eight different locations on the animal. Treatment time was 20 minutes. The amount of dexamethasone that penetrated to significant depths was tenfold greater than the hydrocortisone. In a second trial using another monkey, hydrocortisone was abandoned and only the dexamethasone was used under the positive electrode. The monkey was again treated over many different locations and after treatments was sacrificed and the skin and tissue under each electrode was examined. The active sites were compared with the inactive sites in determining the amount of drug delivered. Detectable amounts were found under all the electrodes and in all the layers down to the cartilaginous and tendon structures.

### Case Studies

In a case study conducted by Hasson et al,<sup>19</sup> the effects of dexamethasone in combination with exercise training for the treatment of Rheumatoid Arthritis (R.A.) were examined. The subject was a 37-year-old female with a four-year history of R.A. The study was carried out in three phases over a 68-week interval. The results showed dexamethasone in combination with exercise may be an effective way for improving muscle strength, joint range of motion, joint swelling, and cardiorespiratory endurance in R.A. patients.

Treatment of the TMJ by iontophoresis was examined in separate case studies by Braun<sup>20</sup> and Lark and Gangarosa.<sup>21</sup> In Braun's report, dexamethasone was used in combination with lidocaine on a 71-year-old woman with TMJ pain. The results were positive, showing an increase in jaw range of motion as well as a decrease in pain. Lark and Gangarosa presented an extensive background on TMJ problems and went on to present five case studies. The overall results of their treatments showed patients who obtained pain relief and more functional use of their jaw.

Weinstein and Gordon<sup>22</sup> discussed 50 cases of treating patients with subdeltoid bursitis using magnesium sulfate. They reported good results in most cases and recommended its use. The magnesium sulfate was iontophoresed under the positive electrode with an intensity between one and two milliamps for ten minutes.

In a case report by Kahn,<sup>23</sup> he described the use of lithium iontophoresis in the treatment of gouty arthritis. Using paper towels and aluminum foil for electrodes, he used lithium chloride using the positive lead with five milliamps of current for 20 minutes. Following iontophoresis, he used continuous sine wave for relaxation of the musculature. The patient received one treatment per week for four weeks and reported significant reduction in painful symptoms.

### **Inflammatory Conditions (Phonophoresis)**

#### Human Studies

Hydrocortisone is a corticosteroid that is useful in the treatment of inflammatory conditions. Hydrocortisone phonophoresis is indicated for a number of conditions such as strains, sprains, tendinitis, bursitis, arthritis, fasciitis, condylitis, and other inflammatory processes.<sup>24</sup>



Kleinkort and Woods<sup>25</sup> compared 285 patients treated for a variety of inflammatory conditions and compared the results using 1% hydrocortisone to 10% hydrocortisone. The method of treatment was identical except for the different concentration of cream. Duration of treatment was six minutes with a dosage of between 1.0 to 2.0 w/cm<sup>2</sup> used. The results were determined by reduction of pain and an increase in range of motion. The 10% concentration proved to be more effective in most cases and greatly reduced the number of treatments needed. Three conditions, trochanteric bursitis, subscapular bursitis, and plantar fasciitis, did not respond to either treatment. Overall results were excellent for the 10% hydrocortisone cream.

In a study by Stratford and associates,<sup>26</sup> the use of hydrocortisone phonophoresis was compared to using ultrasound alone in the treatment of patients with lateral epicondylitis. Forty patients were entered into the study, which also compared friction massage to no friction massage. Dosage varied between 1.3 w/cm<sup>2</sup> continuous to .5 w/cm<sup>2</sup> pulsed output for six minutes. Neither the patient nor the physical therapist was aware of whether or not hydrocortisone was in the medium used for application. Five outcome measures were used to evaluate the patients. The outcome was analyzed using the Chi square test. The findings of the study showed that phonophoresis was not significantly different from the ultrasound in the treatment of lateral epicondylitis of the elbow. In a similar study by Halle and associates,<sup>27</sup> four treatments were compared as to their effectiveness in the treatment of lateral epicondylitis of the elbow. The four protocols examined were: (1) ultrasound with a home program, (2) phonophoresis with 10% hydrocortisone and a home program, (3) a TENS unit and a home program, and (4) a subcutaneous injection with a steroid and a home program. A total of 48 subjects were used with 12 in each group and the

age ranging between 20 to 59 years old. Patients were initially assessed for pain using the McGill pain questionnaire. The patients were randomly assigned to one of the four groups. The patient and the therapist were both blind to whether ultrasound was being used alone or with hydrocortisone. The patients were treated for five consecutive days except for the injection which was utilized just once. The results showed that all four treatments were successful in improving the pain indexes, but no protocol was significantly better than the others. It was concluded that treatment of choice should be based on clinical considerations such as cost and availability of modalities.

Smith and associates<sup>28</sup> examined the difference of effectiveness of four modalities on the treatment of shin splints. Fifty military recruits were randomly assigned to one of five groups: (1) ice massage, (2) ultrasound, (3) iontophoresis of dexamethasone and lidocaine, (4) phonophoresis of dexamethasone and lidocaine, and (5) no modalities.

All the groups were instructed to perform active heel cord stretching in addition to the modality treatment. The results showed a decrease in pain in all the groups. Ice massage, phonophoresis, and iontophoresis all greatly increased the lower extremity range of motion, but there was no one best treatment of the three. All four modalities were considered effective in treating shin splints with none clearly superior to the others.

In a study conducted by Antich and associates,<sup>29</sup> 64 patients with a diagnosis of one type of knee extensor disorder (chondromalacia patella, infrapatellar tendinitis, or peripatellar inflammation) were compared in four different treatment protocols. These were: (1) ice, (2) phonophoresis with corticosteroids, (3) iontophoresis with corticosteroids, and (4) ultrasound/ice contrast. The patients were given strength and stretching exercises and then

treated with one of the four modalities for pain relief and inflammation. The patients were reassessed after four treatment sessions. Subjectively, the greatest improvement in pain relief and inflammation reduction was reported by using the ultrasound/ice combination. This modality in combination with lower extremity stretching and strengthening exercises was found very effective for knee extensor disorders.

In a study conducted by Griffin and associates,<sup>30</sup> they compared results of using ultrasound alone versus using phonophoresis of cortisol. The patients had diagnosis of rheumatoid arthritis, osteoarthritis, or some other inflammatory condition. Neither the referring physician, the patient, nor the physical therapist had any knowledge whether ultrasound was being used alone or with hydrocortisone. The method used was continuous ultrasound never exceeding  $1.5 \text{ w/cm}^2$  treated one time a week for three weeks. The patients were rated after the treatment as improved (decrease in pain and substantial increase in active range of motion), partially improved (decrease in pain but with some pain remaining and some gain in active range of motion but significant limitations still present), or unimproved (little or no decrease in pain and little or no gain in range of motion). In the phonophoresis group, 68% were improved with another 18% partially improved and 7% showed no change. In the ultrasound only group, 28% had marked improvement, 17% were partially improved, and 55% had no relief of pain or increase in range of motion. In this study, phonophoresis showed to be superior to ultrasound used alone.

Benson, McElnay, and Harland<sup>31</sup> presented a study showing the influence of ultrasound on the percutaneous absorption of benzydamine. Benzydamine is a nonsteroidal anti-inflammatory drug that is relatively void of negative side effects. Ten healthy subjects took part in the study. A 3% gel formula was used

and six different ultrasound combinations were randomly used (frequency and mode). The findings of this study showed that ultrasound does not enhance the absorption of benzydamine and it is not suitable for phonophoretic use.

#### Animal Studies

In a study conducted by Byl and associates<sup>32</sup> on mini pigs, they examined the ability of ultrasound to enhance the diffusion of drugs into the tissues. Dexamethasone and hydrocortisone were tested for their transmission ability. Five adult Yucatan pigs were used in the study as swine skin is similar to human skin, but it is more variable and slightly thicker. The amount of corticosteroids delivered was less than expected and raised questions as to the effectiveness of hydrocortisone as a viable drug with phonophoresis use.

#### Case Studies

Wing<sup>33</sup> presents a case study of a 35-year-old male with a diagnosis of TMJ dysfunction. He was treated for pain relief and to increase range of motion with 10% hydrocortisone phonophoresis. The patient received a total of ten treatments. The patient received good results in pain reduction as well as an increase in range of motion.

### **Burns, Skin Conditions, and Wound Care (Iontophoresis)**

#### Human Studies

Management of the burned or infected ear is a challenging problem for the medical field. Iontophoresis is one of the methods often used for this treatment. In a retrospective study by Rigano et al,<sup>36</sup> treatment using iontophoresis of potassium penicillin and gentamicin sulfate was explored. The negative electrode was used to disperse the penicillin, where as the positive electrode was used with the gentamicin. The incidence of wound infection, conversion from partial-thickness to full thickness burn, and the need for surgical

procedures were all reduced significantly for the antibiotic iontophoresis treated ear burns. The time for complete healing of wounds was also reduced.

In a study by Abramson et al,<sup>37</sup> both experimental and clinical research were run to determine the effectiveness of histamine when used on the ulcers of the extremities. In the experimental study of 16 normal males, histamine iontophoresis was applied by use of the positive pole for 20 minutes. The rate of blood flow before and after administration was graphed, as was the oxygen uptake. The results showed an increase in blood flow throughout treatment and for an average of 65 minutes afterwards. In the clinical study, 15 patients were treated for ulceration of the lower extremity. The method used was total immersion of the limb into a plastic container filled with histamine diphosphate. Treatment was given two to three times a week for five- to twenty-minute sessions. The clinical results showed some positive benefits in the treatment of chronic indolent ulcers, progressive systemic sclerosis, sickle cell anemia, neuropathy, and venous stasis ulcers. No value was demonstrated in the treatment of ischemic ulcers.

Treatment of fungi infections of the feet and hands by the use of copper iontophoresis was studied by Haggard and associates.<sup>38</sup> Using 37 patients with a diagnosis of dermatophytosis, treatment was done with the positive electrode pole using a frequency of four to six milliamps. Twenty six out of 37 or 70% of those given treatment obtained a clinical cure.

### Case Studies

In a case study presented by Cornwell,<sup>39</sup> a 71-year-old with ischemic ulcers on both tibial crests was discussed. The patient had bilateral below knee amputations secondary to diabetes and PVD. The patient was first treated by whirlpool with Belasdyne additive to cleanse the wound. Next, the patient was

treated with a .1M solution of zinc oxide under the positive electrode in 15-minute treatment sessions with four to five mA current used. The results were very positive on the closure of the wound by the introduction of zinc oxide into the wound.

In another case study presented by Balogun, Abidoeye, and Akala,<sup>40</sup> a 22-year-old male with osteomyelitis of the tibia and fibula was treated with zinc iontophoresis. After four days of treatment, the wound was clean in appearance and showed positive signs of granulation tissue. At the end of the second week of treatment, the wounds were good in appearance and were 92% closed.

In a case report by Gangarosa and associates,<sup>41</sup> treatment of herpetic whitlow by iontophoresis of idoxiurdine, an anti-viral drug, was explored. The authors present two cases of medical personnel who had contracted herpetic whitlow on the hands. Herpetic whitlow is a viral infection often contacted by health personnel that presents as a painful, tingling, pus-producing lesion, most often on the hands. In both cases, treatment was effective resulting in the reduction of the duration of the disease and quick resolution of the symptoms.

#### Animal Studies

In a study by Rapperport et al,<sup>42</sup> 25 rats were tested to determine the effectiveness of penicillin induced by iontophoresis into the burn eschar. The negative pole was used and the amperage varied from .5 to 5 mA and duration from 5 to 20 minutes. The study also included human burn subjects in which the same procedures were followed. The results of the study showed the penicillin penetrated through the burn eschar and into the underlying tissue. They also found the best current range for use with penicillin was 5 to 10 mA range for both the animals and humans.

## **Burns, Skin Conditions, and Wound Care (Phonophoresis)**

### Human Studies

In a translated abstract from a study from Martinian and associates,<sup>43</sup> the authors studied the effect of papain and dimethyl sulfoxide (DMSO) phonophoresis on the course of purulent wounds and the inflammatory processes in patients. It was shown that a 1% solution of papain together with DMSO enhanced by ultrasound was very effective in the healing of purulent wounds. The size of the wounds were reduced by an average of 1.8 times that of control groups.

### Animal Studies

Romanenko and Araviiskii<sup>44</sup> performed a study comparing phonophoresis of amphotericin B (an antifungal agent) with application locally with no enhancement. The skin was treated preliminarily with DMSO and then followed by an amphotericin ointment in some groups and only with amphotericin in the other groups. The authors found that both ultrasound and DMSO were effective enhancers of drug delivery. DMSO served as a quick short-lived enhancer and ultrasound had a more long-lasting effect.

## **Scar Tissue/Calcium Deposits (Iontophoresis)**

### Human Studies

A study by Psaki and Carroll<sup>45</sup> was undertaken to determine the absorptive effects of acetic acid upon calcified tendinitis of the shoulder. Twelve white males between the ages of 28 to 55 participated in the study. The subjects were tested at the beginning of the study and at three-month intervals over a period of one year. Tests were taken in the following areas: (1) tenderness--subjective findings upon palpation, (2) range of motion, (3) pain--point where pain is first felt in the range, (4) skin condition, (5) absorption of



calcium--measured by x-ray. A 3% solution of acetic acid was used; the negative electrode was the active site and a duration of 30 minutes was used. The iontophoresis was followed by an application of sine wave electrotherapy to the muscles of the shoulder girdle for five minutes. The procedure was administered three times a week for two weeks, then two times a week for four weeks. The results were as follows: (1) tenderness disappeared within two weeks in all cases, (2) improvement in ROM was measured in all cases, (3) pain was not evident by week four in all cases, (4) moderate hyperemia was present but it left within three hours in all cases, and (5) absorption of the calcium deposits in some cases with break-up of the deposit in all of the cases.

#### Case Studies

The use of acetic acid iontophoresis is described in an article by Kahn.<sup>46</sup> He reports outstanding results using this treatment in the clinic. Wieder<sup>47</sup> reported using acetic acid iontophoresis to treat a sixteen-year-old boy with myositis ossificans. The patient was a male soccer player who had received a traumatic blow to the quadriceps. Along with a doctor's prescription of rest and inactivity, he was treated with a 2% acetic acid solution with four mA for 20 minutes. The treatment was followed by eight minutes of pulsed ultrasound to further disperse the acetic acid. The treatment protocol was followed three times a week for three weeks. At the end of the nine treatments, the mass was reduced by 98.9% and the patient had regained full ROM at the knee and resumed playing soccer pain free.

In two separate case reports found in the literature, iodine iontophoresis was used to break down adhesions and scar tissues. Langley<sup>48</sup> reported using iodine iontophoresis for a 29-year-old music teacher after surgery for repair of the extensor digitorum tendon. The patient received treatment on three



consecutive days after which the patient's total active motion had increased from 235° to 260°. The patient had previously been performing active and resistive exercises for four weeks with no results. In a similar study presented by Tannebaum,<sup>49</sup> a patient was treated with iodine iontophoresis after a bunionectomy of her right great toe. Passive flexion and extension at the MTP joint was initially five degrees and after five treatments had improved to normal motion in both flexion and extension.

### **Anesthetic Use (Iontophoresis)**

#### Human Studies

The successful use of iontophoresis to deliver anesthesia has been shown extensively in the literature.<sup>50</sup> Lidocaine is the most commonly used anesthetic used in practice by physical therapists. It produces a dilation of the blood vessels and a profound anesthetic affect.

Russo and associates<sup>51</sup> compared the use of iontophoresis with lidocaine as opposed to swabbing or injection. Twenty-seven subjects took part in the study. To test for the duration of the anesthesia, a placebo or the lidocaine was administered by iontophoresis, injection, or swabbing to three points on the forearm of each of the subjects. Sensation was tested by the use of a needle prick. The results showed using iontophoresis produced a longer duration of anesthesia than swabbing, but was not as effective as was injection.

In a separate study, Gangarosa<sup>52</sup> reported on anesthesia by using lidocaine separately and with epinephrine with iontophoresis and applying lidocaine and epinephrine topically on the skin. He found lidocaine in combination with epinephrine to be very effective in producing anesthesia. Epinephrine is a vasoconstrictor which enhances the effect of the lidocaine and keeps it from being displaced systemically.

In a dermatological study conducted by Bezzant et al,<sup>53</sup> the effectiveness of iontophoresis on lidocaine and lidocaine with epinephrine was explored. Fourteen subjects who were to receive cauterization of spider veins in the forearms were tested. The average duration of the anesthesia using lidocaine alone was 14 minutes with good results in eliminating pain. Lidocaine and epinephrine supplied anesthesia for 56 minutes with excellent pain free results.

### **Anesthetic Use (Phonophoresis)**

#### Human Studies

Moll<sup>54</sup> compared the effects of phonophoresis of Decadron and lidocaine with ultrasound alone in a group of patients with trigger point pain. The results showed that 88% of the patients obtained relief from phonophoresis compared to 56% of patients with the ultrasound alone.

#### Animal Studies

Using the quadriceps muscle of rabbits, Novak<sup>55</sup> studied the effect of ultrasound on the absorption of lidocaine. He used no control group in the study. The frequency and mode of ultrasound were not reported. He showed excellent results with anesthesia found cutaneously and into the fatty tissues.

## CHAPTER III

### CONCLUSION

Both phonophoresis and iontophoresis are used extensively in clinical practice by physical therapists. Most of the research has shown that there are effective modalities in use with topically applied drugs. However, many of the studies lacked strong scientific techniques and thus their credibility may be questioned.

The most extensive research that is present on iontophoresis is in the area of inflammation and pain control. Most of the studies presented under this topic were well controlled studies with strong statistical findings. It can be concluded that iontophoresis is effective when used with dexamethasone/lidocaine. This is recommended for use with 4 to 5 mA for 10 minutes duration.<sup>5</sup> There is little scientific research that supports the efficacy of iontophoresis in other treatment protocols. However, there are strong indications that iontophoresis is effective in the treatment of burns, wound care, anesthetic use, scar tissues, and calcium deposits. It is recommended that the physical therapist have a strong understanding of the indications and contraindications of the drug of choice before applying iontophoresis.

Research is currently being done on the use of iontophoresis for larger molecular weight substances, such as insulin, for systemic use.<sup>34,35,56</sup> The potential of iontophoresis for use with these peptide and protein drugs is very interesting. Miniaturized, unit-dose iontophoretic systems may become available for the long-term administration of medically effective drugs.<sup>5</sup> Anti-inflammatory

drugs were used most often in the studies done on phonophoresis. The studies using corticosteroids demonstrated positive results in the clinical setting. Benzadamine has questionable value in the treatment of inflammation by phonophoresis. The diffusion of analgesics such as lidocaine and papain appear to be enhanced by the use of ultrasound.

Physical therapists can contribute to the body of knowledge on iontophoresis and phonophoresis by carrying out controlled, scientific research. Much more research is needed when it comes to the application of these modalities in the clinical setting.

## APPENDIX A

Table 1.—Applications for the Use of Iontophoresis

COMMON CONDITIONS	DRUGS
calcium deposits	acetic acid
hyperhidrosis	atropine sulfate
spasm	calcium
scar tissue	iodine
athlete's foot	copper
burns	penicillin, gentamicin sulfate
inflammatory conditions	dexamethasone
local anesthesia	lidocaine/epinephrine
open wounds	histamine, zinc oxide
	idoxiurdine

Table 2.—Applications for the Use of Phonophoresis

CONDITIONS	DRUGS
inflammatory conditions	hydrocortisone/dexamethasone benzydamine
open wounds	papain, DMSO amphotericin B
anesthesia	lidocaine
pain	salicylates

Table 3.—Techniques to Maximize Phonophoresis Effectiveness<sup>2</sup>

- 
- Select only topical agents that transmit ultrasound
  - Check skin for moisture and hydration
  - Pretreat skin with US, heating, or shaving
  - Position the patient to maximize circulation to area being treated
  - Use an intensity in the thermal range (1.5 w/cm<sup>2</sup> or higher)
  - Use pulsating US with an intensity of 0.5 to 1.0 w/cm<sup>2</sup> when treating open wound
  - Leave the drug on the skin with an occlusive dressing after treatment
-



Table 4.—Techniques for Use of Iontophoresis

- 
- Current: 4-5 mA
  - Duration: 10-20 minutes
  - Start current low and raise slowly (also lower current slowly when finished)
  - Use low concentration of solution for best results
  - Cleanse skin thoroughly with alcohol before application
  - Ensure even contact between electrodes and skin to prevent burns
  - Use a direct constant current
  - Position patient so his weight is not directly on the electrodes
-

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