The purpose of this study was to determine the relative transmission of ultrasound by the media commonly used by physical therapists to apply phonophoresis. The relative transmission of ultrasound energy through various phonophoresis media was compared with that of degassed water, which is the ideal standard. Transmission was assessed by placing a thin layer of the test medium on the transducer of a therapeutic ultrasound unit and measuring delivery of ultrasound with an ultrasound power meter. The media evaluated produced two significantly different groups of transmission results: (1) transmission greater than 80% of that of water and (2) transmission less than 40% of that of water. Media that optimize the therapeutic efficacy of phonophoresis in both clinical and experimental settings are discussed. [Cameron MH, Monroe LG. Relative transmission of ultrasound by media customarily used for phonophoresis. Phys Ther. 1992;72:142–148.]

Key Words: Corticosteroid, Phonophoresis, Ultrasound.
A recent study of phonophoresis with rats and guinea pigs showed a fivefold to twentyfold increase in transdermal delivery of D-mannitol, inulin, and phystostigmine within 2 hours following ultrasound application. Radiolabeled solutions of these chemicals were used as the transmission media for this study, and drug penetration was assessed by measuring the output of these chemicals in the urine.

Human studies of transdermal penetration of an anesthetic and a nonsteroidal anti-inflammatory drug failed to demonstrate enhanced penetration with ultrasound. The topical anesthetic was in a cream, and the nonsteroidal anti-inflammatory was a gel documented to have 87% to 139% ultrasound transmission as compared with water. We believe that with such good transmission, the lack of effect found with the nonsteroidal anti-inflammatory must be due to factors other than poor ultrasound transmission. The authors suggest that ultrasound may not affect transdermal penetration because either the drug used is unsuitable for this method of administration or the method used was not sensitive enough to distinguish a treatment effect. All of these studies evaluated only the effects of ultrasound on drug penetration. Other studies of phonophoresis have assessed the therapeutic efficacy of this procedure.

Griffin et al found that 68% of adult patients with a wide variety of musculoskeletal inflammatory conditions who received hydrocortisone phonophoresis had increased range of motion and decreased pain compared with 28% of those who received ultrasound alone (N=102). They used Cortri ointment with either 10% or 0% hydrocortisone as the ultrasound transmission medium. They did not evaluate the effects of topical application of hydrocortisone alone and thus were unable to compare standard application of this drug with application by phonophoresis.

Kleinkort and Wood carried out a retrospective study of 285 patients treated for a variety of common inflammatory conditions and compared the results of treatment using a 1% hydrocortisone preparation and a 10% hydrocortisone preparation. The 1% hydrocortisone medium used was a water-based cream, and the 10% hydrocortisone medium was micronized hydrocortisone powder in petrolatum ointment. They found that, on average, the patients in the 10% hydrocortisone group received two treatments fewer than those in the 1% hydrocortisone group, and thus concluded that 10% hydrocortisone is more effective.

Two published case studies documented improvement in temporomandibular joint dysfunction after treatment with phonophoresis. Wing used 10% micronized hydrocortisone acetate in petrolatum as the transmission medium, and Kahn used 0.5% hydrocortisone ointment covered with mineral oil. Both authors reported complete resolution of symptoms after 5 to 10 treatments.

In summary, some studies indicate that phonophoresis may be an effective treatment modality. Most investigators, however, fail to consider ultrasound transmission through the media they use as a factor in their studies.

Benson and McElney studied the transmission of ultrasound through topical pharmaceutical products available in Europe; however, they did not evaluate the media commonly used in the United States for phonophoresis. Moreover, neither drug concentration nor media components were sufficiently documented to allow direct comparison with other media. They reported a wide range of results, with gels transmitting ultrasound most effectively and several media not transmitting any ultrasound.

The purposes of this study were (1) to identify transmission media commonly used by physical therapists for phonophoresis, (2) to determine the relative transmission of ultrasound by these media and other corticosteroid preparations, and (3) to identify a group of media that transmit ultrasound well.

Method

Determination of Commonly Used Media

A questionnaire regarding the use of phonophoresis was sent to the directors of 125 physical therapy practices in northern California. Directors of practices using phonophoresis were asked to identify the drugs and types of media they used for this procedure. The types of media were categorized on the survey questionnaire as thick white creams, ointments, gels, mixed media, and other media.

Sixty-two percent (77%) of the questionnaires were returned completed. Of the respondents, 77% (59) reported regularly using phonophoresis in patient treatment. Hydrocortisone was the most frequently applied drug, with 81% (48) of the respondents using 10% hydrocortisone and 19% (11) of the respondents using 1% hydrocortisone. Thick white cream (46%) and thick white cream mixed with ultrasound gel (44%) were the most commonly used transmission media. Selection of the media tested for ultrasound transmission in this study was based in part on the responses to this survey.

Analysis of Ultrasound Transmission

The media tested for ultrasound transmission are listed in the Appendix. These include media used by the survey respondents for phonophoresis, media used in prior research on phonophoresis, and some potent corticosteroid gels selected by these researchers. Some nonmedicated media used for therapeutic ultrasound application were also tested.
Ultrasound transmission was determined using an Ohmic UPM-30 ultrasound power meter and a Chattanooga Intelect Model 700 therapeutic ultrasound unit, as shown in Figure 1. The power meter uses the radiation force balance method to measure ultrasound power. It consists of a conical metal target suspended from a precision balance into a rubber-lined tank filled with degassed water. The transducer of the therapeutic ultrasound unit is immersed approximately 1 cm below the surface of the water, directly above the conical target, and the ultrasound is turned on. The sound waves exert a force on the target, pushing it deeper into the water and thus deflecting the balance. The balance measures the exerted force, which is directly proportional to the ultrasound energy reaching the target. The UPM-30 power meter was evaluated by the National Bureau of Standards and the Division of Electronic Products of the Bureau of Radiological Health to be accurate to ±6%, with a reproducibility error of ±5%. The power meter used for this study was calibrated with a 1-g standard weight and then used to calibrate the ultrasound unit with degassed water. The ultrasound unit generates 1-MHz frequency ultrasound with power from 0 to 3 W/cm² and an effective radiating area of 8.5 cm². It does not shut off power with poor ultrasound transmission.

To assess ultrasound transmission by different media, the transducer of the ultrasound unit was covered with a 5-mm-thick layer of test medium. The medium was contained in a plastic cuff, which had been put around the transducer, and the medium was covered with polyethylene wrap. Visible air bubbles were removed from the medium with a syringe and needle. To test ultrasound transmission by the 1-mm-thick Chempad, a single sheet was placed over the transducer head and then covered with polyethylene. The ultrasound transducer, with a layer of test medium, was secured head down 1 cm below the surface of the water in the power meter tank. The transducer head was centered above the conical target. Power was set at 1.5 W/cm² on the ultrasound unit’s power meter for each medium tested, and the reading on the balance was noted after 1 minute. Degassed water was tested first, after every third measurement, and last to verify the consistency of ultrasound output. Ultrasound transmission with just the polyethylene cover was measured to assess its effect on transmission.

Ultrasound transmission relative to water was calculated by dividing gram force exerted through the medium being tested by the average gram force exerted when degassed water alone was used. The transmission by degassed water varied ±2%.

**Results**

The ultrasound transmission relative to degassed water for each medium tested is displayed in the Table. Transmission was not significantly affected by the polyethylene cover. All media tested, except for the Chempad, produced results in one of two transmission groups: (1) good transmission (ie, transmission greater than 80% of that of water) or (2) poor transmission (ie, transmission less than 40% of that of water). Eighty percent was chosen as the lower cutoff for good transmission because most newer therapeutic ultrasound units automatically shut off power when they detect less than 60% to 80% transmission.

The media that transmitted ultrasound well were corticosteroid gels, a methyl salicylate cream, and media specifically made for use with ultrasound.
This study identified a wide variety of ultrasound transmission media used by physical therapists for phonophoresis. Most clinicians surveyed reported using 10% or 1% hydrocortisone in a thick white cream base. However, all thick white corticosteroid creams tested were found to transmit ultrasound poorly, and transmission was not improved by admixture of these media with a gel that transmits well. Ultrasound gel mixed with micronized hydrocortisone acetate powder also yielded a poorly transmitting medium, possibly because of the reflection of ultrasound by drug particles.

Three of the drug-containing media tested—Lidex®, betamethasone gel, and Thera-Gesic® cream—were found to transmit ultrasound well. It is likely that some other topical drug preparations, particularly gels with low drug concentrations, also transmit ultrasound well. Although the ideal ultrasound power for clinical application of phonophoresis is not known, whatever power is used, one must use a medium that transmits effectively to achieve predictable ultrasound transfer. When a poor transmission medium is used, much less ultrasound energy reaches the patient than is shown on the ultrasound unit's power meter. Fortunately, there is a wide selection of media that transmit ultrasound well. These media should be used with the ultrasound power and frequency most appropriate to the pathology being treated.

When applying phonophoresis, it is also important to select the appropriate drug for the pathology. Low- and high-potency corticosteroids, local anesthetics, counterirritants, methyl salicylate, and nonsteroidal anti-inflammatory agents are all available.

**Table. Ultrasound (US) Transmission by Phonophoresis Media**

<table>
<thead>
<tr>
<th>Product</th>
<th>Transmission Relative to Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media that transmit US well</td>
<td></td>
</tr>
<tr>
<td>Lidex® gel, fluocinonide 0.05%*</td>
<td>97</td>
</tr>
<tr>
<td>Thera-Gesic® cream, methyl salicylate 15%*</td>
<td>97</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>97</td>
</tr>
<tr>
<td>US gel</td>
<td>96</td>
</tr>
<tr>
<td>US lotion</td>
<td>90</td>
</tr>
<tr>
<td>Betamethasone 0.05%/in US gel</td>
<td>88</td>
</tr>
<tr>
<td>Media that transmit US poorly</td>
<td></td>
</tr>
<tr>
<td>Diprolene® ointment, betamethasone 0.05%*</td>
<td>36</td>
</tr>
<tr>
<td>Hydrocortisone (HC) powder 1%/in US gel</td>
<td>29</td>
</tr>
<tr>
<td>HC powder 10%/in US gel</td>
<td>7</td>
</tr>
<tr>
<td>Cortril® ointment, HC 1%</td>
<td>0</td>
</tr>
<tr>
<td>Eucern® cream</td>
<td>0</td>
</tr>
<tr>
<td>HC cream 1%</td>
<td>0</td>
</tr>
<tr>
<td>HC cream 10%</td>
<td>0</td>
</tr>
<tr>
<td>HC cream 10%/mixed with equal weight US gel</td>
<td>0</td>
</tr>
<tr>
<td>Myoflex® cream, trolamine salicylate 10%</td>
<td>0</td>
</tr>
<tr>
<td>Triamcinolone acetonide cream 0.1%/</td>
<td>0</td>
</tr>
<tr>
<td>Velva HC cream 10%*</td>
<td>0</td>
</tr>
<tr>
<td>Velva HC cream 10%/with equal weight US gel</td>
<td>0</td>
</tr>
<tr>
<td>White petrolatum</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Chempad-La®</td>
<td>68</td>
</tr>
<tr>
<td>Polyethylene wrap</td>
<td>98</td>
</tr>
</tbody>
</table>

*Syntex Laboratories Inc, 3401 Hillview Ave, PO Box 10850, Palo Alto, CA 94303.
*Mission Pharmacal Co, 1325 E Durango, San Antonio, TX 78210.
*Pennex Corp, Eastern Ave at Pennex Dr, Verona, PA 15147.
*Ultraphonic®, Pharmaceutical Innovations Inc, 897 Frelinghuysen Dr, Newark, NJ 07114.
*Polysonic, Parker Laboratories Inc, 307 Washington St, Orange, NJ 07050.
*Pharmfair Inc, 110 Kennedy Dr, Hauppauge, NY 11788.
*Schering Corp, Galloping Hill Rd, Kenilworth, NJ 07033.
*Purepac Pharmaceutical Co, 200 Elmora Ave, Elizabeth, NJ 07207.
*Pfizer Labs Division, Pfizer Inc, 253 E 42nd St, New York, NY 10017.
*Beiersdorf Inc, PO Box 5529, Norwalk, CT 06856-5529.
*E Fougera & Co, 60 Baylis Rd, Melville, NY 11747.
*Rorer Consumer Pharmaceuticals, Div of Rhône-Poulenc Rorer Pharmaceuticals Inc, 500 Virginia Dr, Fort Washington, PA 19034.
*Universal Cooperatives Inc, 7801 Metro Pkwy, Minneapolis, MN 55420.
*Henley International, 104 Industrial Blvd, Sugar Land, TX 77478.
*Saran Wrap®, Dow Brands Inc, 9550 Zionsville Rd, Indianapolis, IN 46268.

*Syntex Laboratories Inc, 3401 Hillview Ave, PO Box 10850, Palo Alto, CA 94303.
*Mission Pharmacal Co, 1325 E Durango, San Antonio, TX 78210.
in topical preparations. The relative clinical potential of these different drug preparations depends on pharmacologic activity, topical potency, and concentration.24 The corticosteroids in Lidex® and betamethasone gels are highly potent anti-inflammatory drugs that may also produce systemic side effects such as endocrine suppression or the manifestations of Cushing's symptom complex when absorbed in large amounts.25 As phonophoresis may increase drug penetration, it also may increase the clinical benefits and the risks of topical drug application.

Not uncommonly, phonophoresis is administered by putting a poorly transmitting medium on the skin and then placing the area to be treated, and the ultrasound transducer, under water. As water is a good transmitter of ultrasound, this procedure prevents the ultrasound unit from shutting off but also effectively keeps the ultrasound from reaching the intended treatment area. Thus, we do not recommend the application of phonophoresis under water except for areas in which a liquid is needed to keep air from coming between the transducer and an unevenly contoured area of the body. In this circumstance, a medium that transmits ultrasound well should be applied to the skin before the limb and transducer are placed in water.

As many topical drug preparations currently used for phonophoresis transmit ultrasound poorly, we recommend that the clinical physical therapist qualitatively evaluate the ultrasound transmission by any medium using this simple technique. First, form an approximately 1-cm-deep well above the face of the transducer of an ultrasound machine by placing wide gummed tape around the transducer, as shown in Figure 2. Place a layer of the medium to be tested on the transducer surface and fill the remainder of the well with water. Then turn on the ultrasound machine to 1 to 2 W/cm². If the medium transmits ultrasound at all, the water will be agitated, as shown in Figure 3. If the medium transmits ultrasound poorly, the water remains still, as shown in Figure 2.

The depth of the medium and the duration of the test used in this study differ from those used clinically. We used a 5-mm thickness of medium, whereas a layer as thin as 0.5 mm may be used clinically. We do not believe that changes in the thickness of the layer within this range will change transmission through the medium; changes in thickness within this range will not affect how well the medium couples with water in this experimental model or with the body in the clinical setting. When medium depth is less than the diameter of the sound field, any decrease in transmission will be due to losses across boundaries between materials, rather than to losses within the materials themselves.13 The ultrasound applica-
tion time used in this study was shorter than is typically used clinically. This application time was chosen in order to avoid obscuring our results through heating the components of the experimental system.

Conclusions

Phonophoresis is an accepted physical therapy procedure. A variety of media are used to allow the coupling required for transmission of ultrasound to the body. Phonophoresis media that transmit ultrasound well are identified in this study. Many commonly used media were found to be poor transmitters of ultrasound. Prior research using such media concluded that ultrasound enhances drug penetration, with improved relief of symptoms. As little ultrasound was generated in this study, the results were probably not due to the specific effect of ultrasound on penetration of topical medication. Both experimental evaluation and clinical use of phonophoresis in the future should include selection of media that are known to transmit ultrasound well. Such considerations would allow studies of transdermal drug penetration, depth of penetration, and clinical efficacy, which will help to identify the ultrasound characteristics and drugs most appropriate for different clinical applications. The identification of good phonophoresis media and the description of a quick method for qualitative evaluation of other media in this article will enable clinicians to select appropriate phonophoresis media for their clinical treatment of patients.

Acknowledgments

We thank Ohmic Instruments Company for supplying the wattmeter used in this study. Gratitude is also due to Marcia Hendrick, MA, PT, for her support and to John R Cameron, PhD, MD, for photographic and editorial assistance.

References


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