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Thermographic Evaluation of the Painful Shoulder in the Hemiplegic Patient

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In this study, we investigated the applicability of thermography as a technique for evaluating the painful postcerebrovascular accident (CVA) shoulder in hemiplegic patients. A thermographic series was taken of the upper extremities and upper trunk of 27 female subjects. The four groups we evaluated were nonhemiplegic subjects (n = 9), post-CVA subjects with recovered function (n = 6), hemiplegic subjects with upper extremity motor impairment (n = 6), and hemiplegic subjects with both motor impairment and ipsilateral shoulder pain (n = 6). The data revealed a normal thermographic series in 8 of the 9 nonhemiplegic subjects, but only in 1 of the 18 post-CVA subjects. The majority of the abnormal thermographic series of post-CVA subjects showed a 1° to 5°C coolness on the involved side. No consistent thermographic patterns emerged that could be related to the location of pain. Further studies are needed to evaluate the efficacy of thermography as a means of determining the relationship between ipsilateral post-CVA coolness and hemiplegic shoulder pain.

Key Words: Hemiplegia, Pain, Shoulder, Thermography.

Physical therapists have had limited success reducing chronic shoulder pain in hemiplegic patients. Assessment of the specific location or cause of shoulder pain in the hemiplegic patient is difficult, and treatment may be inappropriate without an accurate evaluation.

In hemiplegic patients, as in patients with primary musculoskeletal problems, shoulder pain can be caused by a variety of conditions. These conditions include rotator-cuff injury, arthritis, bursitis, tendinitis, capsular adhesions, and cervical dysfunction. The normal process of aging may be accelerated by changes in the shoulder girdle biomechanics that can result from a cerebrovascular accident (CVA). Also, hemiplegic patients often lose the normal supported position of the humeral head in the glenoid fossa as a result of abnormal function of the shoulder girdle musculature, the downwardly rotated resting position of the scapula, and lateral trunk flexion. The subluxation that may result from this abnormal positioning is theorized to be one cause of shoulder pain. If spasticity develops, painful shoulder dysfunction is postulated to result from excessive tone, abnormal scapulohumeral rhythm, or irritation of both spastic muscles and "trigger points." Abnormal posture may lead to spasm of the anterior scalene muscles, with resultant neck and upper extremity pain. In addition, some hemiplegic patients develop shoulder-hand syndrome or reflex sympathetic dystrophy. The painful shoulder appears to result from a variety of disorders rather than from hemiplegia only, as implied in the common clinical term "painful hemiplegic shoulder."

Tests such as active, resistive, and passive motion commonly used by physical therapists to evaluate a painful shoulder often are inappropriate in the presence of abnormal tone and sensation after a CVA. Although physicians can use arthrography and local anesthetic infiltration in an attempt to locate the site of the pain, these invasive techniques are used rarely. A noninvasive, but accurate, test is needed to evaluate adequately the pain in the involved shoulder of the hemiplegic patient.

With the tremendous advances in medical technology over the past several decades, a variety of newly developed techniques may be useful in the evaluation of a painful shoulder in the hemiplegic patient. Thermography is one such technique that is well established in its use for the evaluation of the painful back and neck and more recently has been used in the evaluation of the shoulder. The purpose of this study was to investigate the applicability of thermography as a technique for evaluating the painful post-CVA hemiplegic shoulder. The hypotheses of the research were as follows:
1. The thermographic series of hemiplegic subjects would differ from those of nonhemiplegic subjects.

2. The thermographic series of hemiplegic subjects with subjective complaints of shoulder pain would differ from those of hemiplegic subjects without subjective complaints of shoulder pain.

3. A variety of abnormal patterns in the thermographic series of hemiplegic subjects with shoulder pain would exist.

4. The amount of abnormality in the thermographic series would be in proportion to the level of subluxation and edema.

5. A spot tender to palpation would be visible on a thermogram.

TERMINELOGY

The thermographic terminology used in this study is new to most physical therapists and, thus, is defined in this section.

Infrared thermograph. An infrared thermograph is a sophisticated machine using an infrared camera to measure minute temperature variations on the skin surface (Fig. 1). This information is converted electronically into a multi-colored video image.

Thermogram. A thermogram is a permanently recorded image, usually a photograph, that is obtained from the thermograph’s video monitor (Figs. 2,3). Because thermograms must be interpreted by a comparison of the right and left sides for each subject, the thermogram either must show both sides of the body on one thermogram or be paired with a thermogram of the same body area on the contralateral side.

Thermographic series. The group of thermograms needed to cover the entire body region under study constitute a thermographic series. The thermographic series in this study was limited to the upper trunk and upper extremities.

Normal thermographic series. A thermographic series is considered normal if the series of thermograms shows a high degree of bilateral symmetry. 18

Abnormal thermographic series. A thermographic series is considered abnormal if the series of thermograms shows a trend, rather than an isolated area, of asymmetry.

Thermographic temperature scale. Displayed under the thermographic image is the six-color thermographic temperature scale (Figs. 2,3). Rather than representing a specific temperature, the colors in the thermographic temperature scale represent an incremental temperature change. In this study, each of the six colors represents a 1°C change relative to the adjacent color. This scale must be adjusted between the hand and trunk thermograms 19 because of the normal temperature variation between these body regions. To ensure, however, an accurate comparison of the relative temperature on the two sides of the body, the scale is never adjusted between the right- and left-paired thermograms.

Focal emission spot. A discrete spot on a thermogram that is warmer than the surrounding area is referred to as a focal emission spot.

Thermographer. A thermographer is a physician who has been trained to evaluate a patient’s thermographic series. Thermographers are trained by experienced thermographic researchers and thermographers and by the American Academy of Thermology. Specific national and international standards do not exist yet but are evolving in this developing profession.

METHOD

Subjects

Nine subjects with no history of a CVA and 18 post-CVA subjects (range of time since the CVA was 2 to 72 months) participated voluntarily in this study. All subjects were right-handed women between 56 and 85 years of age. Exclusionary criteria for all subjects were a history of upper extremity surgery, long-term upper extremity bursitis or arthritis, diabetes, or any skin disorders that might affect the skin temperature. Additional exclusionary criteria for the hemiplegic subjects were pain in their uninvolved shoulder, the inability to sit unsupported on a stool for one hour, and the inability to follow verbal directions. This information was obtained from a questionnaire answered by prospective subjects.

The subjects were divided into four groups. Group A consisted of nine nonhemiplegic subjects without subjective reports of shoulder pain. Group B consisted of six subjects who had recovered essentially normal function after a CVA and reported no shoulder pain. Group C consisted of six hemiplegic subjects with remaining motor involvement of the upper extremity who had reported either no shoulder pain in...
the involved shoulder or minimal pain for less than one hour a day. Group D consisted of six hemiplegic subjects with remaining motor involvement of the upper extremity who reported pain in their involved shoulder more than one hour a day or who wore a sling to minimize shoulder pain. All Group B subjects had previous left-sided involvement. Groups C and D each included five left hemiplegic subjects and one right hemiplegic subject. The median age and the time since the CVA of all groups are recorded in the Table.

**TABLE**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Description</th>
<th>Median Age (yr)</th>
<th>Side of Involvement (n)</th>
<th>Median Time Since CVA (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>nonhemiplegic subject with no shoulder pain (n = 9)</td>
<td>66</td>
<td>left (6)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>post-CVA subject with recovered motor function and no shoulder pain (n = 6)</td>
<td>69</td>
<td>right (0)</td>
<td>17</td>
</tr>
<tr>
<td>C</td>
<td>hemiplegic subject with motor involvement and no shoulder pain (n = 6)</td>
<td>73</td>
<td>left (5)</td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td>hemiplegic subject with motor involvement and shoulder pain (n = 6)</td>
<td>72</td>
<td>right (1)</td>
<td>13</td>
</tr>
</tbody>
</table>

**Procedure**

Informed consent was obtained from all subjects based on the protocols approved by the committee for the protection of human rights. The subjects attended two sessions, which were scheduled one to seven days apart. During the first session, the subjects responded verbally to a short questionnaire, which elicited demographic data and information about their CVA and shoulder pain. The questionnaire was followed by a brief physical therapy examination, which consisted of a gross passive range-of-motion examination and three assessments commonly used in the clinic to document any difference between the right and left upper extremities. The three assessments were

1. Subluxation: A comparison of the bilateral measurements of the distance between the acromion and the superior margin of the head of the humerus on the lateral aspect of the shoulder.
2. Hand edema: A comparison of the bilateral measurements of the circumference at the middle of the proximal phalanx of the index finger.
3. Tenderness to palpation: A subject’s report of tenderness on palpation and, if tenderness was present, the side of the most tenderness. The following points were palpated bilaterally: the center of the belly of the upper trapezius muscle, the greater tubercle of the humerus, the lesser tubercle of the humerus, the deltoid tuberosity, the center of the belly of the pectoralis major muscle, and the area between the posterior axilla and the lateral border of the scapula. Measurements for Assessments 1 and 2 were made with a fiberglass tape measure and recorded in centimeters. Reliability of the distance measurements was established in a pilot study to be virtually 100% with a standard deviation of 1 mm.

Fig. 2. Drawing of a normal thermogram (posterior view) of a nonhemiplegic subject without shoulder pain.

Fig. 3. Drawing of abnormal paired thermograms (right and left lateral views of the shoulder and upper arm) of a left hemiplegic subject with involved shoulder pain showing a 2° to 4°C relative coolness on left body areas 5, 6, and 7.

**THERMOGRAPHIC SCALE**

(cold) aqua green blue pink red yellow (hot)
RESEARCH

in a total of 28 measurements of three people. All data were collected by the primary investigator (N.M.T.).

At the end of the initial session, the scheduled thermographic examination was described to and discussed with the subjects. Also, they were instructed to refrain from the following in preparation for the thermographic examination: 1) applying lotion, deodorant, or perfume on the day of the examination; 2) smoking for six hours before the examination; and 3) drinking or touching anything hot or cold, showering, or wearing jewelry for two hours before the examination.

The second session was a thermographic examination of the upper body with an electronic infrared thermograph* (Fig. 1). In accordance with standard thermographic protocol, this examination was performed as follows:

1. The thermograms were taken in a draft-free room, with minimal variation in temperature or humidity.
2. The subjects sat in the testing room for at least 15 minutes before the examination. They wore no blouse and removed the shoulder straps of their brassieres, which allowed the subjects' skin temperature to stabilize, free of the effects of clothing.
3. A series of 12 thermograms was taken of the upper trunk and upper extremities. A 30- × 50-cm cardboard rectangle was placed between the upper extremities and the trunk in the anterior and lateral views to give a clear outline of the heat patterns on the upper extremity and to prevent heat transfer between the upper extremity and trunk. In the lateral and posterior-oblique views, where both the right and left sides could not be viewed simultaneously, a thermogram of the uninvolved side was taken first, immediately followed by a thermogram of the involved side. For nonhemiplegic subjects, a thermogram of the right side was taken first. To allow for accurate comparisons, no thermographic scale adjustments were made between the right and left paired thermograms of the same body area.
4. After 15 to 20 minutes, the series was repeated to ensure that the temperature pattern was stable.

Data Analysis

Because the temperature pattern was stable between the two thermographic series of each subject, the second series was chosen arbitrarily for use in the data analysis. Eight thermograms from the second thermographic series were analyzed and constitute the thermographic series for this study. Because examination of the thermographic data from the lateral view of the neck and the posterior-oblique view indicated the same data found in the remaining thermograms, these two views were omitted from the analysis. The views thus included in the analysis were 1 posterior, 1 anterior, and 3 sets of lateral paired thermograms.

Because the exact temperature pattern will vary between individuals, a thermographic series is interpreted by a comparison of the relative temperature differences between the same location on the right and left sides of the body, rather than by a comparison to a norm. Our consulting thermographer's protocol for evaluating thermographic data involved dividing the body into standard, discrete bilateral body areas. For this study, we used the nine standard body areas of the upper trunk and upper extremities (Fig. 4). Recordings were made of the relative temperature differences between the right and left sides within each of these nine areas. A temperature difference between the right and left sides of at least 1°C in more than 25% of a specific body area was classified and recorded as asymmetrical. Any series with three or more contiguous body areas of asymmetry was defined in this study as an abnormal thermographic series (Fig. 3). Any series with a high degree of symmetry was defined as a normal thermographic series (Fig. 2).

All of the thermographic data were collected by the primary investigator. The thermographic images were analyzed by the primary investigator and verified by the consulting thermographer.

A chi-square analysis was performed to determine the association between the degree of abnormality on the hemiplegic subject's thermographic series and the following two variables: the level of subluxation and the level of edema. The statistical relationship between the spots of tenderness to palpation and the corresponding thermographic spots of relative warmth or coolness could not be analyzed because the number of subjects with tender spots was too small for statistical accuracy.

RESULTS

One of the nine subjects in Group A had an abnormal thermographic series as reflected by a 1°C relative coolness in

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Two subjects in Group D were 1°C cooler on their involved (left) side than on their uninvolved side. The remaining 4 subjects (3 left hemiplegic subjects and 1 right hemiplegic subject) were 1° to 4°C cooler on their involved side than on their uninvolved side (Fig. 3). Group D subjects had asymmetry in three to nine contiguous body areas (Fig. 5). The posterior neck (body area 1) had an asymmetrical temperature pattern in only five subjects, four of which were Group D subjects.

The subjects differed in their levels of subluxation and edema. Increased levels of subluxation (0.8 mm or greater) were present in 2 Group B subjects (0.9 mm each), 3 Group C subjects (1.3 mm, 1.2 mm, and 1.2 mm), and 3 Group D subjects (1.1 mm, 0.9 mm, and 0.9 mm). Increased levels of edema (0.9 mm or greater) were present in one Group C subject (1.1 mm) and one Group D subject (0.9 mm). No increased level of subluxation or edema was found in any Group A subject, nor was an increased level of edema found in any Group B subject. The chi-square analysis indicated no significant association between the amount of thermographic abnormality and subluxation or edema ($x^2 = .075, df = 1$).

Two subjects from Group A and two subjects from Group B had some unilateral tenderness to palpation. Five Group C and all six Group D subjects had some unilateral tenderness to palpation. No association could be found between the spots that were painful to palpation and the temperature differential of the corresponding spots on the thermograms.

Verbal descriptions of the mild, transient pain from Group C subjects included, "feels like it is out of joint," "short heavy pain," and "ache." The latter description was the only remark of transient pain by one of the three Group C subjects with increased levels of subluxation. Verbal descriptions of the shoulder pain from Group D subjects included, "disjointed," "deep soreness," "pressure and pulling," "deep hurt," "ache," and "deep, dull, with a little burning." The latter three descriptions were from subjects with an increased level of subluxation. No association could be found between the verbal complaints of pain and the thermographic or physical findings. The various subject ages and elapsed time since the CVA were different from the thermographic series of nonhemiplegic subjects. A variety of abnormal patterns could be seen in the thermographic series of hemiplegic subjects with shoulder pain. The other three hypotheses were not supported by our data.

The lack of a conclusive difference between the thermographic series of subjects in Groups C and D suggests either that shoulder pain is not reflected in a thermographic series or that a subjective report of shoulder pain is not specific enough to distinguish between the two groups. The lack of a thermographic reflection of the level of subluxation, the level of edema, or the presence of tender spots suggests either that the effect of the CVA on skin temperature masked the subtle temperature changes resulting from these variables or that these variables do not affect skin temperature.

**DISCUSSION**

The data revealed that two of the five hypotheses were supported. The thermographic series of hemiplegic subjects was different from the thermographic series of nonhemiplegic subjects. A variety of abnormal patterns could be seen in the thermographic series of hemiplegic subjects with shoulder pain. The other three hypotheses were not supported by our data.
The thermographic results confirmed that the involved upper extremity of a hemiplegic subject with residual motor impairment was relatively cooler after the CVA. Relative coolness, however, was unexpected on the previously involved side of subjects who had recovered essentially normal function after a CVA. These results appear to discount the common clinical assumption that the relative coolness results from the limited use of a flaccid or spastic upper extremity. The diffuse pattern of coolness suggests abnormal activity of the sympathetic nervous system (SNS), resulting in vasoconstriction of the blood vessels in the involved upper extremity. The CVA may have damaged the central SNS. Previous research has implicated SNS damage as a contributing cause of acute post-CVA electrocardiogram abnormalities such as ventricular fibrillation and ventricular tachycardia. The presence and extent of SNS damage after a CVA and the implications for rehabilitation are not yet clear.

Middleditch and Jarman reported “hot spots” (focal emission spots) in the thermographic series of nonhemiplegic subjects with shoulder pain. Our study found few focal emission spots in the thermographic series of hemiplegic subjects with shoulder pain.

This study revealed thermal abnormalities on the involved side of post-CVA subjects. The subject sample was small, however, and the results varied too much to assess the usefulness of thermography as an evaluation technique for a painful shoulder in hemiplegic patients. The category differentiation by verbal description of shoulder pain proved to be so general that no conclusions could be drawn about the relationship between the amount of pain and the degree of thermal abnormality.

As a result of this study, we believe that infrared thermography currently has limited clinical relevance. The equipment is expensive and not readily available to clinicians. This study was preliminary research concerning the use of thermography to augment the evaluation and, thus, treatment of hemiplegic patients with chronic and intense post-CVA shoulder pain. Variables within the hemiplegic subject population, including the effect of the side of hemiplegia, the amount of motor and sensory involvement, and the length of time since the CVA, each may affect the thermographic data. Therefore, additional studies by both physical therapists and thermographers are needed to establish a normative database for effective thermography of hemiplegic subjects. Equipment developed recently to enable computerized analysis of the data will be useful in standardizing the thermographic evaluation and, thus, will aid in these normative studies. Future studies of thermography should be expanded to include a larger sample size and an extensive physical evaluation designed to divide the subjects into discrete categories relative to the motor and sensory involvement and shoulder pain.

CONCLUSIONS

Based on infrared thermographic analysis of the upper trunk and upper extremity, we found that nonhemiplegic subjects generally had highly symmetrical temperature patterns. All hemiplegic subjects were abnormally cooler on their involved side than on their involved side. Even subjects who had recovered essentially normal function after their CVA were abnormally cooler generally on their previously involved side. No consistent thermographic patterns emerged that could be related to the location or severity of pain as described verbally by the subjects. No relationship was seen between the amount of thermographic abnormality and the measurements of shoulder subluxation, hand edema, or tender spots among the subjects. Further studies are needed to establish a normative thermographic database for hemiplegic subjects and to determine the cause of the ipsilateral coolness in post-CVA subjects and its effect on shoulder pain.

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