Background and Purpose Vasomotor changes occur in the arm after paralytic stroke. Previous studies have provided conflicting results, with most showing an increase in skin temperature of the hemiplegic arm. However, a number of patients complain of distressing coldness of the hemiplegic arm.

Methods Eleven patients with symptomatic coldness and 10 patients with hemiplegia but no coldness were recruited. The severity of the symptom of coldness was compared by questionnaire with other common symptoms after stroke. A thermographic camera was used to record the finger skin temperature response to cold stress. Blood flow to both hands was also measured simultaneously by means of two plethysmographs. In all patients there were no symptoms in the unaffected arm, and this was used as a control.

Results The symptom of coldness rated highly compared with other symptoms. In the symptomatic group the finger temperature on the hemiplegic side was lower at rest (median difference at rest, 0.65°C; P<.0001) and at all times after cold stress. In the asymptomatic group the fingers on the hemiplegic side were colder at rest and after initial cooling (median temperature difference, 0.2°C) but at no other time. Hand blood flow on the hemiplegic side was also decreased in the symptomatic group by 35%. This was not seen in the asymptomatic group.

Conclusions Coldness of the hand may be a severe and distressing symptom in some patients after hemiplegia. Symptomatic patients have lower finger skin temperatures at rest and after standard cold stress. These symptomatic patients also had reduced blood flow to the hemiplegic hand. (Stroke. 1994;25:1765-1770.)

Key Words • hemiplegia • thermography • vasomotor system

Subjects and Methods Stroke patients were recruited from the clinics and wards at Seacroft and St James’ hospitals and stroke clubs in Leeds. No attempt was made to define a sample frame because we were studying a clinical phenomenon rather than performing an epidemiological survey. Eligible patients were those with unilateral weakness with or without the symptom of coldness in the affected arm. Patients with severe dysphasia or with spasticity resulting in an inability to open the hand fully were excluded.

All patients gave informed consent to participate in the trial, and approval for the trial was obtained from the local ethics committee.

An initial assessment consisted of a questionnaire asking about the presence and severity of symptoms in the arms. A scale of 0 to 5 was used to quantify feelings of coldness as well as heat, pain, pins and needles, and numbness in the arm. The scale ranged from 0 to 5. This rating scale was performed to compare the subjective severity of the symptom of coldness compared with some other common symptoms after stroke. Motor power was assessed in each patient with the motoricity index. This involved power testing of various movements. The upper limb pinch grip, elbow flexion, and shoulder abduction were tested. In the lower limb ankle dorsiflexion, knee extension, and hip flexion were tested. The motoricity index has been validated as a measure of motor function after stroke. The maximum score attainable is 100, and when interpreting the score a higher value represents greater motor power.

We used two methods to measure different aspects of the circulation in the hands. A thermographic camera was used to determine resting skin temperature in the fingers and the response to local cooling and subsequent rewarming. Venous occlusion plethysmography was used to measure the total blood flow to the hands at a neutral temperature and after cooling. We also performed plethysmography on 6 age-matched healthy control subjects who were taking no vasoc-
TABLE 1. Characteristics of Stroke Patients With and Without Cold Hemiplegic Arms

<table>
<thead>
<tr>
<th></th>
<th>Patients With Cold Arm (n=11)</th>
<th>Patients Without Cold Arm (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age,* y</td>
<td>74.9 (67-81)</td>
<td>74.2 (58-89)</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>10/1</td>
<td>5/5</td>
</tr>
<tr>
<td>Hemiplegic side</td>
<td>5 left, 6 right</td>
<td>2 left, 8 right</td>
</tr>
<tr>
<td>Time since stroke,* mo</td>
<td>43.9 (18-96)</td>
<td>61.4 (2-228)</td>
</tr>
<tr>
<td>Motoricity score*</td>
<td>75.6 (57-100)</td>
<td>83.6 (40-100)</td>
</tr>
<tr>
<td>Smokers</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

*Values are mean, with range in parentheses.

tive medication at the time. This was to ascertain whether there is any asymmetry in the blood flow to normal hands in this elderly group.

None of the patients in any of the groups had symptoms in the unaffected hand, and this was used as a control in all cases.

We conducted a cold stress test using the method of Wilkinson et al.12 On entering the laboratory, patients were allowed to acclimatize to indoor temperatures for 30 minutes and were then seated in a constant temperature cabinet at 25 ± 1°C. Images were taken at room temperature with a Starsight Thermographic camera (Insight Vision Systems) with the images recorded directly onto videotape. Latex gloves were placed on the hands, which were then immersed in water at 5°C for 1 minute. To standardize the cold stress, the patients were asked to keep the hands still and not allow them to touch the sides of the container. After removal of the gloves, images were recorded constantly during the rewarming period of 10 minutes. The results were analyzed by a coworker who was unaware of the characteristics of the patients using the THERMOSOFT (EIC, Inc) computer software package. Values for the temperature of the tips and bases of the index, middle, and ring fingers were obtained for each time point in both hands.

Temperature results were obtained in the thermoneutral state and at 0, 3, 5, and 10 minutes after cooling. The median finger temperatures at each time were calculated for both hands.

We used water-filled plethysmographs to measure blood flow in each hand. In healthy subjects there is a large normal

TABLE 2. Mean Symptom Scores for Stroke Patients With and Without Cold Hemiplegic Arms

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No. Complaining of Symptom</th>
<th>Mean Symptom Score*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coldness</td>
<td>Patients With Cold Arm</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>2</td>
</tr>
<tr>
<td>Pain</td>
<td>Patients With Cold Arm</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>2</td>
</tr>
<tr>
<td>Heat</td>
<td>Patients With Cold Arm</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>1</td>
</tr>
<tr>
<td>Numbness</td>
<td>Patients With Cold Arm</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>0</td>
</tr>
<tr>
<td>Pins/needles</td>
<td>Patients With Cold Arm</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>0</td>
</tr>
<tr>
<td>Weakness</td>
<td>Patients With Cold Arm</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>6</td>
</tr>
<tr>
<td>Dependence</td>
<td>Patients With Cold Arm</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Patients Without Cold Arm</td>
<td>6</td>
</tr>
</tbody>
</table>

*Scored on a 5-point scale.

FIG 1. Line graph of the median finger temperature in each hand during cold stress test in patients complaining of cold in the hemiplegic hand. Interquartile ranges quoted are from 25th to 75th percentiles and represent 50% of the values (Wilcoxon test). IQR indicates interquartile range.
Patients were matched for age but not for sex or side of hemiplegia. In addition, the symptomatic group had a lower mean motoricity score (Table 1).

Mean symptom scores were calculated for both patient groups (Table 2). Coldness of the arm was a prominent symptom in our study group (mean symptom score of 2.2 versus 3.4 for weakness).

All 21 patients underwent thermography. In the group of patients complaining of a cold arm, the median resting temperature of all points in the hemiplegic hand was 0.7°C cooler than the unaffected hand ($P<.0001$). In addition, the hand affected by stroke remained significantly cooler than the unaffected hand at all times after cold provocation (Fig 1). Fig 2 shows a typical result in a patient with hemiplegia and symptomatic coldness of the arm.

In the asymptomatic group the temperature of the hand affected by stroke at rest and immediately after cooling was lower than the unaffected hand. The median resting temperature difference was only 0.2°C. During rewarming, the hemiplegic hand was either warmer or no different in temperature than the unaffected hand (Fig 3). A degree of asymmetry between the two hands existed in the symptomatic and asymptomatic groups. Comparing this degree of asymmetry in the two groups, we found a significantly larger difference in temperature between the two hands in the symptomatic group at all time points (Fig 4).

Twenty of the 21 patients underwent plethysmography, 10 with cold arms and 10 subjects without this symptom (Table 3). In the symptomatic group blood flow to the hemiplegic hand was significantly lower than the unaffected hand at all temperatures. At 32°C the median blood flow difference was 1.3 mL • 100 mL$^{-1}$ • min$^{-1}$; at 30°C and 28°C the median differences were 1.1 and 0.8 mL • 100 mL$^{-1}$ • min$^{-1}$, respectively. In those patients not complaining of a cold arm, there was no difference in blood flow between the hands at any temperature. In the small group of healthy age-matched subjects (n=6) there was also no difference in blood flow between the two hands at any temperature (Table 4).

**Discussion**

This study was prompted by the observation that some patients have an unpleasant feeling of coldness in the hemiplegic arm after a stroke. The symptom developed within days in some patients but more commonly took weeks or months to become prominent. The severity of the problem varied considerably, but most of our patients were constantly aware of the symptom and obtained only limited relief from local measures such as gloves or hot water bottles. While our subjective rating system is crude, the comparison with other problems after stroke showed that coldness in the arm was surprisingly prominent in our study group (mean symptom score of 2.2 versus 3.4 for weakness). It is of interest that the group with coldness complained of more symptoms overall.

We investigated skin temperature and blood flow, but another possible mechanism producing the symptom might be abnormal temperature perception due to the stroke. Damage to the parietal lobe might cause altered interpretations of limb temperatures. In general, patients with left-sided paralysis are more likely to have perceptual problems than those with right-sided weak-
FIG 3. Line graph of the median finger temperature in each hand during cold stress test in patients not complaining of cold in the hemiplegic hand. Interquartile ranges quoted are from 25th to 75th percentiles and represent 50% of values (Wilcoxon test). IQR indicates interquartile range.

FIG 4. Bar graph shows median temperature difference between hands during cold stress test. Difference represents temperature of unaffected hand minus temperature of hemiplegic hand. If the hemiplegic hand is colder, the difference will be positive. There is a significant difference between the symptomatic and asymptomatic patients at all time points (Mann-Whitney U test). IQR indicates interquartile range.
ness. In our small series, 6 of 11 symptomatic patients had right-sided weakness, suggesting that altered perception is unlikely to be the major factor in the genesis of this phenomenon. However, sensory impairment or inattention may play a role in deciding who develops symptoms. One patient in the asymptomatic group had a markedly colder hemiplegic hand and reduced hand blood flow. This patient had sensory deficits on examination and a right parietal infarct on cranial computed tomographic scan. Patients with other neurological lesions such as poliomyelitis develop cold limbs, and some work on peripheral circulatory changes has been reported. Although initial success was claimed for sympatheticotomy in cold postpolio limbs. Instead, it is suggested that venous congestion of the limb results in uncontrolled heat loss. Venous congestion is suggested because of the violet hue of extremities in these patients and vascular microscopy showing dilated venules. Our patients did not show any red or purple color change in the affected limb, and there was no evidence of edema on clinical examination.

Infrared thermography provides an accurate measure of skin temperature. Furthermore, it is noninvasive and well tolerated by patients and has been used extensively in the evaluation of vasospastic conditions. There may be a temperature difference of up to 0.25°C between the hands in healthy people. The thermographic results showed that members of our group with symptomatic coldness do indeed have lower resting finger temperatures in the hemiplegic hand, and the variation between the two sides is well in excess of that seen in healthy subjects. Those hemiplegic stroke patients who did not complain of a cold arm had a much smaller difference in temperature between the hands at rest. This difference was only found in the patients complaining of cold arm (Wilcoxon test).

**Table 3. Differences in Median Hand Blood Flow as Measured by Plethysmography**

<table>
<thead>
<tr>
<th>Temperature of Water, °C</th>
<th>Hemiplegic Arm</th>
<th>Unaffected Arm</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>1.5 (1.9)</td>
<td>2.3 (3.3)</td>
<td>.05</td>
</tr>
<tr>
<td>30</td>
<td>2.1 (2.6)</td>
<td>3.2 (5.7)</td>
<td>.05</td>
</tr>
<tr>
<td>32</td>
<td>2.4 (3.9)</td>
<td>3.7 (5.7)</td>
<td>.05</td>
</tr>
</tbody>
</table>

Values in parentheses are interquartile range. Significant differences between the hemiplegic and unaffected hands were only found in the patients complaining of cold arm (Wilcoxon test).

**Table 4. Differences in Median Hand Blood Flow as Measured by Plethysmography in Age-Matched Control Subjects (n=6)**

<table>
<thead>
<tr>
<th>Water Temperature, °C</th>
<th>Left Hand</th>
<th>Right Hand</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>4.4 (3.4)</td>
<td>4.25 (4.5)</td>
<td>.68</td>
</tr>
<tr>
<td>30</td>
<td>6.3 (2.9)</td>
<td>6.45 (3.4)</td>
<td>.89</td>
</tr>
<tr>
<td>32</td>
<td>7.4 (6.0)</td>
<td>6.65 (8.2)</td>
<td>.66</td>
</tr>
</tbody>
</table>

Values in parentheses are interquartile range. No significant differences in flow were detected between the two hands.
ably more important in determining blood flow than local mediators produced by active muscle. Reflex sympathetic dystrophy is another complication of stroke that produces symptoms in the hand, but our patients did not exhibit other recognized features of the condition. Only one symptomatic patient described any pain in the arm. Pain is not always present in the extremity in reflex sympathetic dystrophy, although it is reported to occur in the majority of cases. In addition, none of our patients had a history of a spinal reflex. The hemiplegic hand shown in this study, after use, and none had evidence of swelling of the hand. Skin temperature, particularly in the fingers, largely reflects the state of tone in the skin vasculature. Large numbers of arteriovenous anastomoses are present in the fingers. Constriction in the precapillary sphincters due to various influences causes blood to be diverted away from the skin capillaries via these anastomoses. Constricting influences include α receptor-mediated sympathetic stimulation, circulating norepinephrine, and possibly 5-hydroxytryptamine, although the former mechanism is by far the most important.22

Is it possible that vascular reactivity is altered in the hemiplegic arm after stroke? After deep inspiration or cough, vasoconstriction occurs in the limbs, which is succeeded. We would also like to thank the staff in the financial support, without which the project would not have done to improve this symptom, and future studies might acknowledge the efficacy of vasoconstrictors.

Acknowledgments

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