Temperature of the Great Toe as an Indication of the Severity of Shock

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SUMMARY

To establish whether changes in skin temperature would provide objective indication of the presence and severity of shock, hemodynamic and temperature measurements were obtained with the aid of a digital computer. Values obtained 3 hours after admission and 3 hours prior to discharge or death in 100 patients who presented with clinical signs of circulatory shock were analyzed. Temperature was measured with standard thermistor probes at five sites: the digital pad of the third finger, the large toe, the deltoid region of the arm, the lateral portion of the thigh, and the rectum.

A significant correlation was demonstrated between the cardiac output and temperature of the toe \( (r = 0.71) \). Correlations were increased to 0.73 when corrections were made for changes in ambient temperature. A stepwise regression analysis provided no significant improvement in the predictability of cardiac index when the values for temperatures of other skin sites were included. Discriminant function analysis showed that an early measurement of toe temperature correctly predicts patient outcome 67% of the time.

AFTER TRAUMA, or during the course of a severe systemic illness, a critical curtailment of effective blood flow and a consequent curtailment of the function of vital organs is clinically recognized as circulatory shock. Reduction in arterial blood pressure, decline in urinary output, lessened mental alertness, and inadequacy of blood flow in the extremities with reduced or absent peripheral pulsation, constriction of superficial vessels, and loss of warmth in the hands and feet are physical signs on which the clinician bases the diagnosis of shock.

The present study was undertaken to establish whether quantitative changes in skin temperature might provide a more competent indication of the presence and severity of circulatory shock. Such measurements would be objective and yet available without trauma or discomfort to the patient. They would require only a minor investment in instrumentation and technical support, and therefore their potential value for routine monitoring was especially attractive.

The possibility that an index based on multiple measurements of skin temperature and rectal temperature would serve as a competent indication of peripheral blood flow, and hence would quantitate a circulatory defect characteristic of shock, was suggested by the previous work of Burton. Preliminary studies in our unit on patients who had shock in consequence of pancreatitis indicated that increases in the skin temperature, measured in
the ventrum of the great toe, were closely related to increases in systemic blood flow and clinical improvement.2

Data were then gathered on a larger group of patients to document the potential value of changes in skin temperature as an objective measure of the severity of shock. Skin temperature was measured at various sites on the body and changes in temperature were compared to simultaneous changes in other hemodynamic and metabolic parameters.

Methods

Patients

Observations were made on patients admitted to the Shock Research Unit by referral from the medical and surgical service of the Los Angeles County-USC Medical Center. To facilitate statistical analysis, we examined data on 100 patients. A group of 153 patients representing sequential admissions to the Shock Research Unit (SRU no. 654 to SRU no. 807) were reviewed and of these 53 were excluded from the study. Cases were excluded (1) if the period of observation, or of survival, was less than 6 hours and (2) if a complete inventory of measurements was unavailable because of technical or clinical limitations as was the case with patients who had extensive body burns in whom application of thermistors was medically contraindicated. Left for analysis were observations on 54 men and 46 women. Each patient was critically ill and had an acute life-threatening respiratory, circulatory, or metabolic defect. The primary causes of life-threatening illness were myocardial infarction in 17 patients, overwhelming infection in 20, massive loss of blood or fluid in 12, drug overdose in 15, and other causes including pulmonary embolism, central nervous system injury, and mesenteric infarction in 36 patients. The series of measurements were made over periods ranging from 6 to 144 (mean 31, SEM ± 3) hours. Of the 100 patients under observation, 44 died during the period of observation and treatment.

Procedure

Temperatures were measured with the use of standard Yellow Springs Instruments thermistors (Model 401 interchangeable thermistor probes). The thermistors were positioned on the lateral arm at a site corresponding to the central mass of the deltoid muscle, the center of the digital pad of the third finger, the lateral mid-thigh, and the digital pad on the ventrum of the first toe. All thermistors were positioned opposite to the side of the body used for arterial and venous catheterization. General purpose thermistor probes were used in preference to the discs specifically provided for measurement of the skin temperature. The general purpose probes, which are ordinarily used for measurements of esophageal and rectal temperature, proved less fragile than the usual surface probes and were of adequate sensitivity. Their use obviated the high breakage rate of the vinyl-covered wire lead at the junction with the disc of the surface probe.

The application of the thermistors to the skin is illustrated in figure 1. The probes were covered with a three-quarter inch rectangle of polyethylene sheet, which was sealed to the skin with waterproof tape to preclude local loss of heat and to maintain the thermistors in a saturated environment.

In addition to skin temperature, rectal temperature was measured with a probe which was inserted into the rectum for a distance of approximately 8 cm. Ambient (amb) temperature was monitored by means of an additional general purpose probe which was mounted on the bedside console at a position corresponding to the height of the patient’s hip, but approximately 25 cm distant from the skin surface.

The thermistor probes were connected to an 8-channel data-acquisition device which was developed in our unit to replace the YSI telethermistor. From the device, the information was transmitted to an analog-to-digital converter and an IBM 1620 digital computer (fig. 2) for automated measurements according to techniques previously described.8 Each thermistor was separately calibrated with a thermometer having a precision of 0.2 C in a water bath. A computer

![Figure 1](http://circ.ahajournals.org/)

**Figure 1**

Application of thermistor to toe.

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program was adapted for purposes of automated calibration over the range of interest. The computer calibration was based on a least squares fit of three points establishing intercept and slope for each thermistor. A systematic error, not exceeding 0.5 C, over the range of 25 to 45 C, is introduced by this method because the output of the thermistors is logarithmic whereas the calibration procedure assumes linearity over this range.

In addition to measurements of temperature, a series of hemodynamic and metabolic measurements were made according to methods previously described. Cardiac output, appearance time, mean circulation time, and central blood volume were measured by the indicator-dilution technique. Arterial pressure was measured with an indwelling catheter in the femoral or brachial artery; central venous pressure was measured in the superior vena cava or right atrium; heart rate was measured by means of standard electrocardiographic techniques. Urinary flow was monitored by use of a urinometer as previously described. Concentrations of lactate were measured by an enzymatic technique. The arterial resistance was computed from the intra-arterial pressure and cardiac output. The sensors were incorporated into a system which included the analog-to-digital converter and the IBM 1620 computer (IBM 1710 system) which provided both numerical and graphic outputs of data.

Analysis

For each of the 100 patients, two sets of 22 parameters were measured. The temperature values obtained at two stages of the patient’s stay were compared with the 16 other reference measurements which served to indicate the hemodynamic and metabolic status of patients. A set of “early” values was obtained approximately 3 hours after admission, and a set of “late” values was obtained from measurements recorded 3 hours prior to the patient’s discharge or death. The statistical methods for analysis of temperature relationships included a stepwise regression analysis, and a two-sample t test on two groups of patients (patients who survived, patients who died), and a discriminant function analysis.

Burton’s index (B.I.) was computed according to the following formula:

\[ B.I. = \frac{T_{\text{toe}} - T_{\text{amb}}}{T_{\text{rec}} - T_{\text{toe}}} \]

Results

Clinical Observations

Observations on two cases illustrate the relationship of changes in toe and rectal temperature to objective hemodynamic and metabolic measurements during circulatory shock. The first case graphically summarized in figure 3 is that of a 65-year-old woman who was observed after an acute myocardial infarction. Cardiac output and toe temperature were increased from a markedly reduced level in response to administration of isoproterenol. The subsequent course was characterized by a progressive decline in cardiac index, and both clinical and physiological signs of progressive perfusion failure. Hypotension, anuria, lactic acidosis, and a decline in toe
temperature were observed during the terminal course.

Improvement in effective circulation was demonstrated by the case of a 20-year-old woman who had attempted suicide by ingestion of a barbiturate drug and sodium cyanide. Hemodynamic and metabolic changes indicating progressive improvement in clinical status during infusion of 11 L of fluid over a period of 26 hours are graphically summarized in figure 4. Clinical improvement was closely related to gradual increases in cardiac index and arterial pressure to normal levels. The mean transit time of dye from the right atrium to the femoral artery was reduced to normal levels, and reduction in the lactate concentration in blood confirmed that perfusion was restored to levels which were adequate to sustain aerobic metabolism. A progressive increase in toe tempera-

![Table 1](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAABlgAAAXhCAIAAADIR1lYAAABl0lzMwAAAdwAAAh0bT77AAAABl0lZeCM+e2QAAAABl0lZwAAAAASUVORK5CYII=)

**Table 1**

*Correlation Coefficients (r) Between Temperature at Various Body Sites and the Principal Hemodynamic Measurements*

<table>
<thead>
<tr>
<th></th>
<th>Mean arterial pressure</th>
<th>Cardiac index</th>
<th>Appearance time</th>
<th>Mean circulation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe</td>
<td>0.28</td>
<td>0.71</td>
<td>-0.52</td>
<td>-0.54</td>
</tr>
<tr>
<td>Toe — ambient</td>
<td>0.27</td>
<td>0.73</td>
<td>-0.54</td>
<td>-0.55</td>
</tr>
<tr>
<td>Finger</td>
<td>0.15</td>
<td>0.56</td>
<td>-0.37</td>
<td>-0.38</td>
</tr>
<tr>
<td>Rectal</td>
<td>0.25</td>
<td>0.11</td>
<td>-0.03</td>
<td>-0.03</td>
</tr>
<tr>
<td>Burton’s index</td>
<td>0.03</td>
<td>0.62</td>
<td>-0.34</td>
<td>-0.43</td>
</tr>
</tbody>
</table>

**Figure 5**

Correlation between cardiac index and toe temperature (3 hours after admission).

Favorable course of a patient with drug overdose and shock.
and toe temperature: \( r = 0.71 \) \((P < 0.01)\). The correlation coefficient was slightly improved when correction was made for differences in ambient temperature: \( r = 0.73 \) \((P < 0.01)\).

When the effects of rectal temperature were also taken into account by computation of Burton’s ratio, no further improvement in correlation was achieved. To the contrary, \( r \) was reduced to 0.62. The implication that the internal body temperature did not independently affect the predictability was surprising and was contradictory to concepts inherent in the use of Burton’s ratio. For this reason a separate partial correlation analysis was undertaken. The partial correlation between Burton’s index, after the effects of skin and ambient temperatures were excluded, was \( r = 0.12 \), a value which was not statistically significant. This computation confirmed that after changes in toe and ambient temperature had been taken into account, changes in rectal temperature did not independently affect the cardiac index (table 1).

Concerning other hemodynamic parameters, significant correlations were found between toe temperature and mean circulation and appearance times which are measures of the velocity of blood flow. The low correlation with arterial pressure is not surprising since major workers in the field of shock have reaffirmed that flow and pressure are poorly related (table 1).

### Other Sites of Measurements

Of the four sites at which skin temperature was measured, the toe provided the best indication of changes in blood flow. We have investigated the extent to which predictability of blood flow could be improved by including measurements of skin temperatures at additional sites. The results of a stepwise regression analysis reveal no significant improvement in predictability when measurements obtained from the three other sites are included (table 2). Hence, the information of temperature changes in the toe provides the full source of information contained in the

### Table 2

**Stepwise Regression Analysis***

<table>
<thead>
<tr>
<th></th>
<th>( r )</th>
<th>( r^2 ) Increase</th>
<th>( F )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe — ambient</td>
<td>0.7115</td>
<td>0.51</td>
<td>99.42</td>
<td>( P &lt; 0.01 )</td>
</tr>
<tr>
<td>Deltoid — ambient</td>
<td>0.7169</td>
<td>0.51</td>
<td>1.54</td>
<td>NS</td>
</tr>
<tr>
<td>Finger — ambient</td>
<td>0.7277</td>
<td>0.53</td>
<td>0.48</td>
<td>NS</td>
</tr>
<tr>
<td>Rectal — ambient</td>
<td>0.7260</td>
<td>0.53</td>
<td>2.64</td>
<td>NS</td>
</tr>
<tr>
<td>Thigh — ambient</td>
<td>0.7280</td>
<td>0.53</td>
<td>0.07</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Cardiac index is the dependent variable. The temperatures at other sites, corrected from ambient temperature, are independent variables. NS = not significant.

### Table 3

**Temperature (°C) Differences and Significance of Differences Between Means for Survivors and Patients Who Died after Circulatory Shock**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Mean of survivors</th>
<th>Mean of fatal cases</th>
<th>( F )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe — ambient</td>
<td>3.40</td>
<td>0.95</td>
<td>19.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deltoid — ambient</td>
<td>6.62</td>
<td>5.26</td>
<td>9.44</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Finger — ambient</td>
<td>4.22</td>
<td>2.56</td>
<td>4.76</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Rectal — ambient</td>
<td>12.68</td>
<td>11.52</td>
<td>5.79</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>Thigh — ambient</td>
<td>7.04</td>
<td>5.05</td>
<td>13.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Burton’s index</td>
<td>0.69</td>
<td>0.20</td>
<td>6.42</td>
<td>&lt;0.025</td>
</tr>
</tbody>
</table>

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skin temperature measurements. A relatively high correlation between toe and finger temperature was observed ($r = 0.56$). This indicates that much, but not all, of the pertinent information is also contained in the finger temperature.

**Temperature and Prognosis**

A study of the clinical course of this group of patients confirmed that increases in skin temperature, and especially in toe temperature, indicated improvement in the patient’s status. For purposes of assessing the value of measurement of temperature in establishing prognosis, the extent to which an “early” measurement served to indicate the likelihood that the patient would survive was examined. Our population of 100 patients was therefore classified on the basis of survival. Skin temperature measurements were compared in the two groups using a two-sample $t$ test. Toe temperature and toe temperature minus ambient temperature gave the best discrimination between survival and death (table 3). The computation of Burton’s ratio did not give as good a discrimination. The highly significant difference between the mean toe temperature in the two groups (fig. 6) allows to a certain extent a prediction of the prognosis since the temperatures taken into account are the result of the “early” measurement. The prediction was correct in 67% of the cases. When a “late” measurement is considered, the difference between toe temperature in the two groups is of course even greater (fig. 6). A good prognosis was correctly predicted in 40 patients out of 45 on the basis of toe temperature alone. When other temperatures were included in the computation, 44 out of 47 were correctly classified although this is not a statistically significant improvement in predictability.

We also related prognosis to observed changes in temperatures during the course of

![Figure 7](image_url)

**Figure 7**

Changes in toe temperature in survivors and patients who died.

![Figure 8](image_url)

**Figure 8**

Difference between changes in toe minus ambient temperatures in survivors and patients who died.
observation. A rising toe temperature in the
interval between admission and discharge
was a reliable indication of good prognosis
and vice versa (fig. 7). A two-sample t test
showed a highly significant difference in the
changes of toe temperature minus ambient
temperature for the two groups (fig. 8).

Discussion

In assessing the severity of shock, the phy-
sician recognizes the importance of taking in-
to account a combination of parameters. For
instance, changes in blood pressure are inter-
preted in relation to changes in flow of urine,
mental alertness, and both the color and
warmth of the extremities. Increasingly rec-
ognized is the importance of assessing those
changes which indicate alterations in blood
flow. Demands of clinical management, the
restlessness of patients, and congestion at the
bedside preclude use of refined techniques,
such as plethysmography. The patient cannot
cooperate and the essential vigor of medical
and nursing activities at the bedside usually
preclude mechanical stability and a steady
state.

More recently, measurement of cardiac
output has become an established routine in
some clinical research centers. However, this
method for routine use involves major tech-
nical commitment.

On the other hand, measurement of skin
temperature may be achieved with relatively
little commitment of staff, without costly
equipment and supplies, and without signifi-
cant mechanical impediment at the bedside.
Since measurements of toe temperature are
not significantly affected by patient move-
ment, it may be used without reference to
the patient's mental status. Finger tempera-
ture does not provide the same level of
reliability since significant increases are some-
times observed after the patient moves his
upper extremity and especially when he rubs
his finger against the bedding.

Ibsen12, 13 evaluated changes in the skin
temperature of the thumb and the toe when
patients in shock were treated with chlor-
promazine in a temperature controlled en-
vironment. In his description of observations
on 150 patients, the author stated that clinical
improvement was closely related to increases
in skin temperature. As in the present study,
the toe served as a more reliable indicator than
the finger for assessment of severity of the
shock state.

There is no simple relationship between
skin temperature and blood flow.12 When
this relationship is quantified by the use of
plethysmographic techniques, an equation
which corresponds well to experimental data
provided by several workers1, 15, 16 is as fol-

\[
\text{Flow} = K \frac{T_s - T_r}{T_b - T_x}
\]

where 

- \( K = 6.3 \)
- \( T_s = \text{temperature (skin)} \)
- \( T_r = \text{temperature (room)} \) (20.5 C)
- \( T_b = \text{temperature (blood)} \) (foot)
- (33.0 C).

However, such data are based on studies
performed on normal subjects during steady
states. No adequate data are currently avail-
able which would confirm the validity of
temperature measurements for estimates of
quantitative changes in peripheral blood flow
during clinical shock states. On the other hand,
the present data do indicate that toe tempera-
ture is a reliable indicator of cardiac out-
put and indirectly an indicator of systemic
blood flow. It provides particularly compe-
tent directional information with regard to
effective blood flow in terms of tissue per-
fusion.

Conclusions

In addition to aiding in the assessment of
blood flow, toe temperature permits a help-
ful indication of prognosis. If toe temperature,
3 hours after admission, is less than 27 C, or
if the difference between toe and ambient
temperatures is less than 2 C, the likelihood
of death is high (67%). Increases in skin tem-
perature are likely to improve cardiac output
and survival. Since toe temperature provides
objective information on the severity of
shock, with minor investment in instrumenta-
tion, the authors regard it as a valuable addi-
tion for clinical monitoring of patients with shock.

References


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