Influence of Local Temperature and of Digital Nerve Block on Critical Opening Pressure of Vessels in the Finger

By P. Gaskell, M.D., Ph.D., and A. Diosy, M.D.

Local cooling of the finger increased and local warming decreased the critical opening pressure of small vessels supplying the nailfold capillaries. Digital nerve block also decreased the critical closing pressure of these vessels independently of any concomitant change in local temperature.

It is well known that digital nerve block causes dilatation of the digital blood vessels by interruption of the sympathetic vasoconstrictor nerves. It has also been shown that after nerve block the critical closing pressure (CCP) and the critical opening pressure (COP) of the small vessels of the finger are both reduced. This would be expected since the CCP and COP are indices of the force being exerted by the smooth muscle in the walls of the vessels, and this force should be less during vasodilation. When the vessels dilate after the nerve block, the increased flow of blood brings about a rise in tissue temperature. A rise in the local temperature will itself cause further relaxation of the smooth muscle and more vasodilation. The question arises as to how much of the reduction in COP observed after blocking the digital nerves could have been brought about by the increase in local temperature. How important is it to control the local temperature when measuring the COP in studies of factors modifying the force exerted by vascular smooth muscle? This paper reports experiments performed to answer these questions.

METHODS

The COP of the small vessels supplying the nailfold capillaries was estimated in the manner previously described with one modification. Previously the digital systolic blood pressure was estimated by auscultation. Observation of the nailfold capillaries through the microscope to determine when blood first passed under the blood pressure cuff was substituted for the auscultatory end point. No changes in the preparation of the finger or in apparatus were required for this modification. These 2 methods of measuring the digital systolic blood pressure give very similar results. All the values for COP given in this paper are the means of 6 estimations except where stated otherwise.

In order to change or control the local temperature of the finger a coil of 5 to 7 loops of thin-walled polyethylene tubing was applied around the middle phalanx so that water of suitable temperature could be run through the tubing to cool or warm the finger. The distance between the most distal loop and the nailfold was approximately half an inch. The afferent and efferent limbs of the coil were led in and out of the transparent chamber, into which the 2 distal phalanges were sealed, through rubber tubes and an air-tight seal obtained by pulling each rubber tube tightly about its polyethylene tube with a silk tie (fig. 1). A copper-constantan thermojunction was applied to the tip of the finger to measure the skin temperature. The leads for this were led through a single rubber tube into the chamber and surgical forceps applied to the tube effectively sealed it against any air leak. The skin temperature was recorded every half minute by a Leeds-Northrup Recording Potentiometer.

The skin temperature recorded at the tip of the finger represents fairly closely the temperature of the nailfold area under the circumstance of the experiments. It was shown in separate experiments that the difference in temperature between these 2 areas was not more than 1 C. in 3 of 9 experiments after the temperature of the finger had been changed rapidly through 10 to 20 C. In one experiment the nailfold area was...
2 C. warmer than the tip of the finger when
the finger was warmed to about 36 C. In each
of these experiments the nailfold area was the
warmer area after heating the finger and the
cooler after cooling the finger.

Digital nerve block was accomplished by in-
jecting 1 ml. of 1 per cent xylocaine, without
epinephrine, into each side of the base of the
finger. The block was shown to be successful by
testing the response to pinprick at the tip of
the finger, with a pin introduced through a
special opening in the plihysmograph not indi-
cated in figure 1, and also by a rise in the skin
temperature at the tip if circumstances allowed.

During the experiments the subjects, who were
student nurses, wore their usual clothes and were
covered with a sheet and a blanket so that they
were just comfortably warm. The room tempera-
ture was controlled at 21 ± 1 C. The finger
under investigation was supported just above the
heart level in a comfortable position.

RESULTS

Effect of Rapid Cooling of the Finger on
COP. In 6 experiments the second and fourth
fingers of the same hand were prepared for
measurement of the COP as outlined. One of
the fingers served as a control and the skin
temperature of the tip of this finger was kept
fairly constant by a flow of warm water
through the coil around the middle phalanx.
The other, or test finger, was subjected to
changes in local temperature and the effect
of this on the COP was determined.
The temperature of the tip of the control
finger was kept about 28 C. and that of the
tip of the test finger was adjusted so that it
was somewhere between 35 and 42 C. The
COP was measured in each finger. Subse-
quently, the test finger was rapidly cooled by
circulating cold water through the poly-
ethylene coil. When the temperature of the
tip of the finger was about 18 to 22 C. the
COP was again measured in each finger. It
was found that the COP of the vessels in
the control finger was relatively stable
throughout the experiment while that of
vessels in the test finger was lower than the
COP in the control finger when the test finger
was warmed locally and higher when it was
cooled. In these experiments and others de-
scribed later, it was assumed that the control
finger as well as the test finger would reflect
changes in general vasomotor state so that
the differences in COP between the 2 fingers
could be ascribed to the effect of the differ-
ences in their local temperatures (fig. 2,
table 1).

Effect of Gradual Cooling of the Finger on
COP. Five experiments were carried out
which were similar to those described in the
previous section except that the cooling of
the test finger was gradual and single esti-
mations of the COP were made at intervals
in the test finger during the cooling period.
The COP was estimated in the control about
three times before cooling of the test finger
and about three times at the end of the
cooling period. Figure 3 shows a typical experi-
ment and table 2 summarizes the results in
all the experiments, but only the COP of the
vessels in each finger just before the test
finger was cooled and at the end of the
cooling period are listed. The COP shown is the mean of 2 to 4 estimations. It can be seen from figure 3 that the COP of the vessels in the test finger increased gradually as the temperature fell while the COP in the control finger was usually about the same after cooling the test finger as it was before.

Influence of Digital Nerve Block on COP. In 5 experiments both the ring and the index finger of the same hand were prepared and the COP of vessels in both fingers was measured. Following this, the temperature of the water cooling the ring finger was decreased and the digital nerves of this finger were blocked. The control finger was injected with a similar volume of normal saline. Block of the digital nerves resulted in some increase of the skin temperature in some of the experiments despite the more vigorous cooling of the finger. In these experiments the skin temperature of the control finger was allowed to rise by reducing the cooling of that finger to keep its temperature similar to that of the anesthetized finger. After the anesthetization was shown to be effective by testing with pinprick, the COP of the vessels in each finger was measured again (table 3). In each experiment the skin temperature of the 2 fingers was similar before anesthetization of the test finger, and there was little difference between the COP of the vessels in the 2 fingers. The mean difference in all the experiments was less than 0.5 mm Hg. After the injections were made the COP of the vessels in the anesthetized finger was much less than that in the control finger even though the skin temperature of the 2 fingers was similar. The mean of the differences in all experiments after the injection was 14.0 mm Hg. This shows, as expected, that digital nerve block reduces the COP of the vessels supplying the nailfold capillaries independently of any change brought about by the resulting increase in local temperature. Under the circumstances of the experiments the COP was reduced by more than 50 per cent when the digital nerves were blocked.

The ability of local cold to increase the COP of vessels in the finger after digital nerve block was investigated. Freeman found that local cooling changed the blood flow in hands only slightly 10 days after sympa-
TABLE 1.—Effect of Rapid Cooling on the COP of Digital Blood Vessels

<table>
<thead>
<tr>
<th>COP during warming Skin temp. (°C)</th>
<th>COP during cooling Skin temp. (°C)</th>
<th>COP during cooling (mm. Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Test</td>
<td>Control</td>
</tr>
<tr>
<td>B.A.</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>L.F.</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>B.A.</td>
<td>27</td>
<td>39</td>
</tr>
<tr>
<td>D.B.</td>
<td>27</td>
<td>36</td>
</tr>
<tr>
<td>N.G.</td>
<td>28</td>
<td>39</td>
</tr>
<tr>
<td>B.A.</td>
<td>28</td>
<td>37</td>
</tr>
<tr>
<td>Mean</td>
<td>18.7</td>
<td>8.7</td>
</tr>
</tbody>
</table>

The results of these experiments also indicate that blocking the digital nerves can reduce the COP independently of a rise in local temperature, although the results were not as well controlled from this point of view as those in table 3. It will be seen in table 4 that the temperature of the control finger in each of the experiments is of the order of 34°C. These high temperatures reflect curtailment of heat loss from the finger by the insulation of the chamber. Blocking the digital nerves of these fingers produced little change in their temperature, but markedly reduced the COP of their vessels.

**DISCUSSION**

A marked influence of the local temperature upon the COP of digital vessels was found. The results of those experiments in which the COP was measured in the test finger as it was cooled slowly indicated that the COP increased gradually with decreasing local temperature. If we assume, on this basis, that the change in COP for each degree change in local temperature is uniform over the range of approximately 20 to 36°C, then the COP was increased by the order of 1 to 2 mm. Hg for each reduction of one degree in temperature. These observations...
TABLE 3.—Effect of Digital Nerve Block on the COP of Digital Blood Vessels

<table>
<thead>
<tr>
<th>Subject</th>
<th>Skin temp. (°C)</th>
<th>COP (mm Hg)</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before anesthesia</td>
<td>Test</td>
<td>Control</td>
</tr>
<tr>
<td>R.O.</td>
<td>14 21 20</td>
<td>14 21 20</td>
<td>35 33 30</td>
</tr>
<tr>
<td>E.T.</td>
<td>25 24 23</td>
<td>25 24 23</td>
<td>24 22 19</td>
</tr>
<tr>
<td>B.A.</td>
<td>23 24 24</td>
<td>23 24 24</td>
<td>31 29 26</td>
</tr>
<tr>
<td>R.L.</td>
<td>24 25 26</td>
<td>24 25 25</td>
<td>22 20 17</td>
</tr>
<tr>
<td>R.O.</td>
<td>20 21 20</td>
<td>20 21 20</td>
<td>29 27 24</td>
</tr>
</tbody>
</table>

TABLE 4.—Effect of Local Cooling on the COP of Digital Blood Vessels after Digital Nerve Block

<table>
<thead>
<tr>
<th>Subject</th>
<th>Skin temp. (°C)</th>
<th>COP (mm Hg)</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before cooling and anesthetization</td>
<td>After cooling and anesthetization of both fingers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Skin temp. (°C)</td>
<td>COP (mm Hg)</td>
<td>Skin temp. (°C)</td>
</tr>
<tr>
<td>G.M.</td>
<td>35 32 33</td>
<td>16 13 16</td>
<td>36 33 33</td>
</tr>
<tr>
<td>B.A.</td>
<td>33 36 34</td>
<td>16 13 16</td>
<td>34 33 33</td>
</tr>
<tr>
<td>G.M.</td>
<td>32 32 32</td>
<td>18 18 18</td>
<td>33 25 25</td>
</tr>
<tr>
<td>S.G.</td>
<td>31 31 31</td>
<td>17 17 17</td>
<td>32 25 25</td>
</tr>
<tr>
<td>R.S.</td>
<td>34 34 35</td>
<td>16 15 16</td>
<td>35 28 28</td>
</tr>
<tr>
<td>R.S.</td>
<td>33 33 33</td>
<td>18 16 16</td>
<td>34 28 28</td>
</tr>
<tr>
<td>Mean</td>
<td>16.3 16.1</td>
<td>6.6 6.0</td>
<td>6.6 6.0</td>
</tr>
</tbody>
</table>

The possibility has been raised that the rate of change of temperature is more potent in bringing about alteration in smooth muscle tone than is absolute change in temperature. In the experiments reported here, no difference in the magnitude of change in the COP of the digital vessels was observed whether the cooling was rapid or slow. If it is assumed that there was a uniform increase in COP per degree of local temperature reduction, the increase in COP in the test finger with each reduction of 1°C in local temperature when the finger was cooled rapidly was 1.5, 1.9, 0.7, 1.5, 1.0 and 1.0 mm Hg in experiments 1 to 6, respectively (Table 1), and 1.2, 1.7, 1.9, 5.0 and 1.8 mm Hg when the test finger was cooled slowly in experiments 1 to 5 respectively (Table 2). These 2 series are not significantly different from one another (p > 0.1). This suggests that the COP of the vessels was not altered to a greater extent by relatively rapid than by gradual local cooling. However, the rapid cooling in these experiments was still much slower than the rate of cooling obtained by Perkins et al. and the results reported here should not be compared to theirs.

Digital nerve block reduces the COP of the small vessels of the finger and the results of experiments summarized in Table 3 show that removal of the nervous influence reduces the COP and, therefore, the tone of the vascular smooth muscle independently of the usual concomitant rise in local temperature. Where a rise in local temperature occurs because of some inhibition of sympathetic vasoconstrictor impulses, the final COP will be the result of both factors.

Summary

The effect of local temperature and of anesthetization of the digital nerves on the critical opening pressure (COP) of the small vessels supplying the nailfold capillaries was investigated in apparently healthy subjects. The COP was estimated with a microscopic technic as the difference between the digital systolic blood pressure and the air pressure which, when applied on the distal phalanges...
of the finger, will just allow blood flow in the nailfold capillaries as the air pressure is reduced from above systolic pressure. Local cooling or heating of the finger was accomplished by circulating cold or warm water through the thin-walled polyethylene tube coiled around a more proximal part of the finger.

Local cooling increased the COP of the small vessels and local heating reduced it. When the local temperatures of an anesthetized finger and a control finger were controlled, digital nerve block markedly reduced the COP of vessels in the anesthetized finger independently of any change in local temperature. Reduction of smooth muscle tension by inhibition of neurogenic vasoconstrictor influence brings about an increase in flow of warm blood and a rise in local temperature which further relaxes the smooth muscle.

**Summary in Interlingua**

Le effecto exercite per le temperatura local e per le anesthetisation del nervos digital super le tension critic de apertura (TCA) in le micre vasos alimentante le capillares del plicas subungual esseva investigate in apparentemente normal subjectos. Le TCA esseva estimate per medio de un technica microscopico como le differentia inter le tension de sanguine systolic digital e le pressiou de aere le qual—quando applicate al phalanges distal del digito—es recognoscite como le maximo que permitte ancora le fluxo de sanguine in le capillares del plicas subungual. Iste maximo esseva observe for le reduction gradual del pression de aere ab un nivello initial de plus que le tension systolic. Frigidation e calefaction local del digitos esseva effectuate per le circulation de aqua frigide o calide in un tubo a tenue parietes de polyethyleno que esseva spirala circum un segmento plus proximal del digito.

**References**

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