Influence of Emotional and Physical Stimuli on Pressure in the Isolated Vein Segment

By Dan A. Martin, M.D., Kerr L. White, M.D., and Charles R. Vernon, M.D.

Generalized alterations in venous tone may shift large amounts of blood within the vascular system. Both physical and emotional stimuli are capable of affecting venous tone. The present report is a study in healthy males of the effects of certain of these factors on pressure (tone) in a peripheral vein segment isolated by means of specially designed, Plexiglas vein occluders. The emotional stimuli employed were the most effective of the group in increasing venous tone.

Venous tone in isolated peripheral vein segments increases in association with a variety of physical stimuli including the Valsalva and Müller maneuvers, foot-down tilting, exercise, hyperventilation, cold and 5 per cent carbon dioxide inhalation. It is reported also that "apprehension" and certain "mental states" including "thought," "interest," "anger," "fear," and "dozing" affect venous tone. "Dozing" is associated with a decrease, "fear" with an increase or decrease, and all others with an increase in tone.

The present study was designed to determine the effects of certain emotional stimuli on the peripheral venous tone of individuals with normal cardiovascular systems and to compare these effects with specific physical activities. The basic hypothesis states that increases in peripheral venous segment pressure (PVSP) in response to emotional stimuli will be related in height and duration to the intensity of the stimulus as interpreted by the subject and will be as great or greater than increases in response to physical activities of types which may directly or indirectly increase venous pressure.

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contrast to the much lower pressure in the same unobstructed vein was evidence of its isolation. The occluders exerted local external pressure on the vein without uncomfortable immobilization of the arm. Baseline pressure in the isolated venous segment was re-determined each time the occluders were re-applied.

Lead II of the electrocardiogram recorded cardiac rate and rhythm and indicated right arm and left leg motion. The average cardiac rate per minute was calculated at 10 sec. intervals. A Sanborn Model 108 pneumograph and a second Statham 0 to 5 cm. Hg strain gage indicated respiratory rate and pattern. These three variables were recorded on an Offner S channel D-3 electroencephalograph with paper speed at 2.5 mm./sec. The mechanical range of the pen excursion occasionally limited the recording of the maximum venous pressure as noted in the illustrations (figs. 4 and 5).

A remote controlled event marker recorded the onset and cessation of all stimuli on a fourth channel.

General instructions regarding the test procedures were given the subject, the occluders applied to the arm, and baseline recordings established. After the baselines became stable, the following test procedures in the order listed were carried out for 30 sec. each: (1) rapid shallow breathing (panting), (2) simple mental arithmetic, i.e., “3 X 65,” predicted to be a mild but relatively uniform emotional stimulus for university students, (3) difficult mental arithmetic, i.e., “73 X 49,” predicted to be a more intense emotional stimulus for university students; to intensify this stimulus further, the subject was offered additional payment if the correct answer was obtained in 30 sec., (4) constant tensing of right forearm and hand muscles, (5) slow deep breathing, (6) finger motion of the right hand, (7) observation of a Thematic Apperception Test (TAT) card (no. 13 MF), considered to be a variable emotional stimulus. The latter is an ambiguous picture open to various interpretations and designed to evoke responses related to the individual’s underlying emotional conflicts, particularly in regard to sex and aggression.

RESULTS

Following each application of the vein occluders to the distended peripheral vein segment, the baseline pressure was recorded until stable. These individual baseline pressures varied from 200 to 520 mm. of water (table 1), a range similar to that recorded by others. All pressure changes are relative to these high initial pressures occurring under the conditions of the experiments. The reasons for the high baseline PVSP are unknown, but they are probably functions of (a) the amount of blood trapped in the vein segment, (b) the pressure of the occluders, (c) the pressure of surrounding tissue, and (d) emotional tensions relating to the experimental situation.
Table 1—Baseline PVSP, Maximum Increases, Durations, and Areas Above Baselines for Six Subjects during Seven Experimental Procedures

<table>
<thead>
<tr>
<th>EXPERIMENTAL PROCEDURES</th>
<th>Baseline PVSP</th>
<th>Maximum Increase</th>
<th>Durations</th>
<th>Areas Above Baselines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punting</td>
<td>490 ± 35</td>
<td>15</td>
<td>60 ± 12</td>
<td>200 ± 30</td>
</tr>
<tr>
<td>Simple Mental Arithmetic</td>
<td>500 ± 30</td>
<td>24</td>
<td>30 ± 11</td>
<td>120 ± 30</td>
</tr>
<tr>
<td>Difficult Mental Arithmetic</td>
<td>510 ± 30</td>
<td>34</td>
<td>30 ± 11</td>
<td>160 ± 30</td>
</tr>
<tr>
<td>Tensing Muscles</td>
<td>200 ± 35</td>
<td>44</td>
<td>28 ± 7</td>
<td>60 ± 15</td>
</tr>
<tr>
<td>Slow Deep Breathing</td>
<td>320 ± 40</td>
<td>76</td>
<td>30 ± 12</td>
<td>120 ± 30</td>
</tr>
<tr>
<td>Finger Motion</td>
<td>225 ± 40</td>
<td>26</td>
<td>28 ± 7</td>
<td>40 ± 12</td>
</tr>
<tr>
<td>Thematic Apprecation Test Card</td>
<td>290 ± 35</td>
<td>32</td>
<td>28 ± 7</td>
<td>40 ± 12</td>
</tr>
</tbody>
</table>

The mean baseline PVSP for the 6 subjects was 324 (± 61) mm. of water prior to difficult mental arithmetic; the mean maximum PVSP increased 86 (± 31) mm. of water during difficult mental arithmetic (table 1). For the 6 subjects the mean maximum increase in PVSP associated with difficult mental arithmetic was greater than the mean maximum increase associated with any other procedure including simple mental arithmetic (p < .001). There was no significant difference between the mean maximum increases of the other 6 procedures.

Figure 3 represents the mean values for the 6 subjects of the maximum increases in PVSP and the durations of these increases, calculated planimetrically for each of the first 6 procedures. The response to difficult mental arithmetic was again greater than that associated with any other procedure (p < .001) and there was no significant difference between the means of the other 5 procedures.

Figure 4 shows the height and duration of PVSP in one subject (R.S.) during simple mental arithmetic compared with the response 2 min. later during difficult mental arithmetic. Both the height and duration were greater in the latter case. The correct solution to the simple problem was obtained by all subjects in less than 30 sec., but the maximum pressures were maintained for 27 to 74 sec. (mean 52 ± 16) (table 1).

The shapes of each of the 7 PVSP response curves were similar for all subjects. Figure 5 shows response curves for one subject. Respiratory pattern did not appear to change appreciably except in those procedures where it was altered intentionally (curves A and B). Tensing of arm and forearm muscles (curve D) was associated with an abrupt increase.
in pressure and a distinct "square wave" PVSP pattern.

The responses of the 6 subjects to the TAT card were the most variable. Two subjects showed no response; 1 a slow rise and slow fall; 1 a delayed elevation to a sustained higher baseline; and another (fig 5, curve G), an immediate elevation with a delayed fall. One tracing was technically unsatisfactory. In one instance, the subject complained that the 30 sec. test period was not long enough for him to consider the card adequately. Other subjects may have had similar reactions but did not express them.

There was an occasional example of the cumulative effects of successive stimuli and of the rapidity with which repeated stimuli could effectively evoke PVSP response. In figure 5, curve A, the effect of rapid shallow respiration is superimposed on that associated with the entrance of the investigator into the room. In figure 6, PVSP decreases following the stimulus provided by simple mental arithmetic; a deep breath is associated with a similar increase in PVSP.

Following procedures which resulted in PVSP elevations, 12 instances were observed when this pressure fell below the previous baseline for periods of 16 to 120 sec. (mean 57 ± 28) before recovering to the original baseline. Since these experiments were not designed to study this phenomenon, complete data during all procedures are not available.

The maximum 10 sec. heart rate in the 30 sec. period prior to each of the first 6 test procedures was compared with the maximum 10 sec. rate during that test procedure (30 sec.). These differences expressed as heart rate per minute are shown for each of the 6 subjects in table 2. The mean heart rate increase (21 ± 18) associated with difficult mental arithmetic is significantly greater than the mean associated with any other activity except panting.

Fig. 4. PVSP response of one subject to simple and difficult mental arithmetic. The magnitude and duration of the pressure increase as well as the increase in heart rate were greater during the latter stimulus.
TABLE 2.—Differences in Maximum Heart Rates per 10 sec. Occurring in 30 sec. Intervals Immediately Prior to Test Procedures Compared with Maximum Rates per 10 sec. during Test Procedures (30 sec.)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Panting</th>
<th>Simple mental arithmetic</th>
<th>Difficult mental arithmetic</th>
<th>Tensing muscles</th>
<th>Slow deep breathing</th>
<th>Finger motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS</td>
<td>12</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>LF</td>
<td>30</td>
<td>24</td>
<td>48</td>
<td>0</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>HR</td>
<td>6</td>
<td>-12</td>
<td>0</td>
<td>-12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EF</td>
<td>30</td>
<td>24</td>
<td>36</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>FP</td>
<td>18</td>
<td>6</td>
<td>21</td>
<td>-3</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td>±10</td>
<td>±14</td>
<td>±18</td>
<td>±6</td>
<td>±9</td>
<td></td>
</tr>
</tbody>
</table>

\*Level of confidence for difficult mental arithmetic compared with each of the other 5 procedures.

No significant change was noted in the cardiac rhythm in any of the tracings.

**DISCUSSION**

Simple mental arithmetic resulted in PVSP increases similar in magnitude to those seen with the physical stimuli employed. Under the conditions of the study, difficult mental arithmetic was found to be the most effective stimulus in producing an elevation in PVSP. The increase during this procedure is in the range reported by Burch and Murtadha\(^3\) who found isolated PVSP increases averaging 33 per cent during "psychogenic" stimuli of various types. The increases in PVSP observed during difficult mental arithmetic could not be attributed entirely to muscle tensing since the height and duration of PVSP increases and the heart rate increases were quantitatively different in difficult mental arithmetic from those observed during muscle tensing. In addition, the shapes of the response curves were characteristically unique for each of the two stimuli (fig. 5, curves \(D\) and \(F\)). Similarly, the respiratory pattern did not appear to change during difficult mental arithmetic and therefore did not affect PVSP materially. No motion of the arm during the difficult arithmetic procedures was detected in the EKG's or by observation of the subjects. Since the increases in PVSP did not appear to be artifacts or indirect accompaniments of other changes and since they occurred rapidly, they probably primarily represented reflex increases in venous tone in association with emotional stimuli.

The lack of uniformity in the responses to the TAT card was expected. The wide variations in the wave pattern seen in response to this stimulus suggest not only that individuals may differ in the time taken to perceive the card but also that their psychological interpretations of the card may be accompanied by different physiologic reactions.

Although Burch and Murtadha\(^3\) found a decrease in PVSP in normal subjects in association with both "dozing" and syncope, a decrease and subsequent recovery to the baseline following an increase in PVSP has not been reported previously. It is possible that these observed decreases and subsequent recoveries of PVSP do not represent changes in tone, but rather the extrusion of blood under the proximal occluder due to a high PVSP followed by slow additions of blood to the segment, perhaps by way of the vasa vasorum. A completely satisfactory explanation for these changes cannot be derived from the present data.

Increases in heart rate were associated with \(+\) types of activities: slow deep breathing, simple mental arithmetic, panting and difficult mental arithmetic. They were most marked in the latter 2 procedures (table 2). Possible explanations for these rate increases include the effects of one or more of the following: (a) direct sympathetic action on the heart, (b) release of epinephrine and (c) the Bainbridge reflex initiated by an increase in venous return. With respect to the last possibility, venous return may be increased during any of the above activities if the increase in venous tone which occurred in peripheral vein segments were generalized. Venous return also may be augmented by in-
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Fig. 5. Pattern of PVSP response with each of 7 procedures. Curve A shows a response to the entrance of the investigator into the patient's room and also the response to rapid respiration. Curve D shows the typical "square wave" response seen with muscle tensing.

Increasing the respiratory rate such as occurred in panting. At the slow speed (2.5 mm./sec.) employed, the precise beat with which tachycardia is initiated could not be determined from the tracings.

It is estimated that the venous circulation may contain as much as 75 per cent of the blood volume, and therefore small increases in peripheral venous tone, if generalized could contribute to large, rapid shifts of blood toward the heart.

Eckstein and Hamilton have calculated that infused epinephrine and levarterenol can shift as much as 500 ml. of blood from the veins of dependent limbs in a short period of time. If venous tone were to increase reflexly in veins throughout the body in response to emotional stimuli, an appreciable amount of blood could be returned to the central veins and made available for increasing cardiac output. Similarly, generalized, intermittently pulsatile, venous constriction could return substantial volumes of blood to the heart. In a failing cardiovascular system, such peripheral venous constriction might be accompanied by a sustained rise in central venous pressure. Pressure in all peripheral veins would necessarily rise to maintain the venous pressure gradient and fluid might then escape from the vascular compartment as edema. It would be important to this hypothesis to know how rapidly venous constriction could be repeated. In the present study the only information related to this...
The heights and durations of PVSP increases associated with difficult mental arithmetic were significantly greater than those associated with the other 6 activities studied. PVSP responses to the TAT card were variable. Heart rate increased significantly in association with difficult mental arithmetic and rapid, shallow breathing.

Increases in PVSP in response to separate stimuli were observed to occur in rapid succession. Following increases, there were frequently decreases in PVSP below the baseline with subsequent recoveries to the original baseline pressures.

The possible relationship of the observed changes in venous tone to the syndrome of congestive heart failure is discussed briefly.

**ACKNOWLEDGMENT**

The statistical help of Dr. Earl Diamond is gratefully acknowledged.

**SUMMARY**

Peripheral venous segment pressures (PVSP) in forearm veins isolated by Plexiglas occluders, were recorded in six normal males during rapid shallow breathing, simple mental arithmetic, difficult mental arithmetic, hand and forearm muscle tensing, slow deep breathing, finger motion, and observation of a Thematic Apperception Test (TAT) card. Respiration, Lead II of the electrocardiogram and heart rate also were recorded.

The possible relationship is that illustrated by figure 6 showing that separate stimuli may evoke similar changes in venous tone within a period of 37 sec, and figure 5, curve A, illustrating the fact that venous tone may be increased by a second stimulus before the maximum effect of the first stimulus has been reached.

Patients with congestive heart failure have been shown to have venous constriction which decreases with treatment of the failure. Whether their veins are capable of further constriction is not known. The relative importance of changes in venous tone in the maintenance of homeostasis in normal individuals as well as in patients with the syndrome of congestive heart failure has yet to be defined and deserves further investigation.

**SUMMARY IN INTERLINGUA**

Pressiones in venose segmentos peripheric (PVSP) in venas del antebracio isolate per oclusores de Plexiglas esseva registrate in 6 masculos normal sub le conditiones de (1) rapide respiration non profunde, (2) simple arithmetica mental, (3) difficile arithmetica mental, (4) tension muscular de mano e antebracio, (5) lente respiration profunde, (6) movimiento digital, e (7) observation de un carta del Test de Apperception Thematic (TAT). Esseva registrate simultaneamente le respiration, le electrocardiogramma a derivation II, e le frequentia cardiac.

Le grado e le duration del augmentos de PVSP associate con le conditiones del difficile arithmetica mental esseva significativamente plus grande que illos associate con le altre 6 activitates includite in le studio. Le responsas del PVSP al cartas de TAT esseva variabile. Le frequentia cardiac esseva augmentate significativamente in association con difficile arithmetica mental e rapide respiration non profunde.

Esseva constatate que le augmentos del PVSP in responsa a separate stimulus occurreva in succession rapide. Post augmentos il
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habeva frequentemente reductiones del PVSP usque a infra le nivellos de controlo, sequite per le restablimento subsequente del pres-sion normal.

Es presentate un breve discussion del pos-sible relation inter le alterationes observate in le tono venose e le syndrome de congestive disfallimento cardiac.

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