The Continuous Recording of Central Venous Pressure Changes from an Arm Vein

By Otto H. Gauer, M.D. and Herbert O. Sieker, M.D.

With the subject in the right lateral decubitus position, changes of central venous pressure can be recorded accurately and conveniently from a vein in the antecubital fossa of the dependent arm. Theoretically the hydrostatic pressure transforms the venous bed between the heart and the site of puncture into uninterrupted wide channels with relatively low distensibility. Simultaneous recordings of pressure by the method described and by catheterization of the central veins showed that induced changes of central venous pressure were identically recorded from both sites. The mean pressure gradient between the peripheral and central veins was 35 mm. of water.

The importance of the venous system in maintaining homeostasis in the human circulation has recently been reviewed.1-3 An accurate simple method for measuring small changes in central venous pressure is essential to this type of investigation. The method of Moritz and Tabora4 or one of its modifications for measuring pressure in a peripheral vein is believed to be too variable and unreliable to detect and follow small but significant changes in central venous pressure. This scepticism is based upon the factors which may affect the peripheral venous pressure measurement, including postural changes of the subject, positioning of the arm, alterations in peripheral blood flow and uncertainty of a proper reference level for the manometer readings. Duomarco and Rimini6 have particularly emphasized the uncertainties which arise from a total or partial collapse or compression of the veins in the upper arm and under the clavicle. There is, however, agreement that peripheral venous pressure is a function of central venous pressure when the arm is "well below heart level" in the supine subject.6,7 Taking into account these factors, a procedure was devised which allowed accurate continuous recording from the peripheral vein of changes in central venous pressure. The method involves a well defined position of the body which theoretically insures an unobstructed distended system between the peripheral vein and the right atrium. The purpose of this report is to describe the method and present an evaluation of its accuracy and limitations.

METHOD

The subject was placed in the right lateral decubitus position on a flat table covered with a foam rubber mattress 5 cm. thick (fig. 1). The subject's back was supported by a vertical or slightly inclined board and the head rested comfortably on a cushion of appropriate height. The right arm extended downward through an opening in the bed with the elbow slightly bent and the forearm supported in an adjustable trough with a hand grip. The venous pressure was recorded by means of a 0 to 5 cm. Hg Statham pressure transducer connected by polyethylene tubing to a needle in a vein of the antecubital fossa. The system was filled with a heparin-saline solution to prevent clotting and minute leaks were meticulously avoided. An optical galvanometer system was used to record the venous pressure and pulse pattern.

With the pressure transducer placed on the table top, correction of the pressure reading to the level of the heart was made by deducting from the recorded pressure the hydrostatic pressure of a water column equal to one-half the transverse chest diameter determined at the fourth rib. This correction factor was chosen because the great veins and right atrium lie roughly in the center of the circular cross section of the chest (fig. 1). This reference level has the advantage of always intersecting the region of the right atrium and great veins even with moderate rotations from the true lateral position.
Fig. 1. The right lateral decubitus position used for recording pressure from the vein in the antecubital fossa. M, strain gauge manometer connected with polyethylene tubing to the needle. Long arrow, pressure recorded; short arrow, corrected pressure. Insert, cut through the thorax at the level of the fourth rib. VC = vena cava; MSL = midsternal line. (After Gray's Anatomy.)

Fig. 2. Subject O. G. Radial artery pulse (RAP) and venous pulse (PVP) recorded from dependent right arm.

Subject H. A. Comparison of peripheral venous pressure (PVP) and central venous pressure (CVP) recorded through a no. 7 catheter.

Subject C. R. Comparison of central venous pressure (CVP) recorded through a no. 4 catheter and the peripheral venous pressure (PVP) after release of occluding cuffs at the thighs. The pressures returned simultaneously and within six seconds to the control values without a change in the pressure gradient. Note mean venous pressure values recorded.
TABLE 1.—Relationship of Peripheral Venous Pressure and Central Venous Pressure

<table>
<thead>
<tr>
<th>Subject</th>
<th>PVP*</th>
<th>CVP*</th>
<th>Pressure Gradient*</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.A.</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>J.W.</td>
<td>104</td>
<td>71</td>
<td>33</td>
</tr>
<tr>
<td>C.R.</td>
<td>131</td>
<td>93</td>
<td>38</td>
</tr>
<tr>
<td>E.G.</td>
<td>90</td>
<td>53</td>
<td>37</td>
</tr>
<tr>
<td>T.M.</td>
<td>91</td>
<td>53</td>
<td>38</td>
</tr>
<tr>
<td>K.Z.</td>
<td>90</td>
<td>65</td>
<td>25</td>
</tr>
<tr>
<td>R.H.</td>
<td>131</td>
<td>85</td>
<td>46</td>
</tr>
<tr>
<td>Mean</td>
<td>124</td>
<td>46</td>
<td>34 ± 9.0</td>
</tr>
</tbody>
</table>

* Expressed as mm. H₂O.

FIG. 3. Twelve paired values of central venous pressure (ordinate) and peripheral venous pressure (abscissa) obtained on subject C. R. The regression line and individual points indicate that the magnitude of pressure change is essentially the same in the peripheral and central venous pressure with the various maneuvers used to change central venous pressure. Pressure gradient, 4.0 cm. of water.

In seven normal male subjects, the venous pressure and pulse pattern obtained by this method was compared with the central venous pressure and pulse pattern recorded simultaneously through an intravenous catheter in a vein of the left arm. In three subjects intravenous catheterization using a no. 7 catheter was performed by standard technic. In four subjects a no. 4 catheter was threaded through an intravenous needle. The catheter tip in all cases was located in the vena cava opposite the right atrium. By placing the strain gauge manometers side by side on the table top, the necessary hydrostatic corrections for the two pressures were identical. After the normal resting venous pressure was established by the two methods, it was changed by slow deep respiratory movements, the Valsalva maneuver, or the application of occluding venous cuffs around the thighs. Mean peripheral venous pressure (PVP) and central venous pressure (CVP) were determined by planimetry of simultaneous pressure tracings of 6 to 12 heart cycles. In 8 additional normal subjects, the range of resting peripheral venous pressures to be anticipated with this technique was determined by random measurements made at intervals 4 days to 6 months apart.

RESULTS

Sample records of the venous pressure and pulse pattern obtained by the method described are presented in figure 2. The a, c, and v waves in the venous pulse are clearly visible in the records obtained from the peripheral vein. Table 1 summarizes the results from seven experiments in which the venous pressure was recorded simultaneously from the central and peripheral veins. The pressure gradient varied from 20 to 46 mm. of water with a mean of 34 ± 9 mm. of water. As shown in figure 3, when deep inspirations and venous congestive leg cuffs were used to modify the venous pressure, the amount of change was essentially the same in the peripheral vein and in the central vein. Similar regression lines were plotted for

TABLE 2.—Repeat Measurement of the Peripheral Venous Pressure in Normal Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Date</th>
<th>Peripheral Venous Pressure mm. H₂O</th>
<th>Mean and Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.M.</td>
<td>7/28/53</td>
<td>120</td>
<td>124 ± 5</td>
</tr>
<tr>
<td>T.G.</td>
<td>7/28/53</td>
<td>119</td>
<td>94 ± 10</td>
</tr>
<tr>
<td>W.W.</td>
<td>1/8/53</td>
<td>76</td>
<td>70 ± 14</td>
</tr>
<tr>
<td>R.E.</td>
<td>1/12</td>
<td>87</td>
<td>91 ± 4</td>
</tr>
<tr>
<td>J.H.</td>
<td>12/17/52</td>
<td>70</td>
<td>90 ± 9</td>
</tr>
<tr>
<td>O.G.</td>
<td>12/18/52</td>
<td>65</td>
<td>90 ± 14</td>
</tr>
<tr>
<td>H.S.</td>
<td>12/18/52</td>
<td>43</td>
<td>70 ± 11</td>
</tr>
<tr>
<td>D.S.</td>
<td>1/2/53</td>
<td>35</td>
<td>48 ± 5</td>
</tr>
</tbody>
</table>

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all seven subjects and the average slope was 45 degrees \( \left( \frac{CVP}{PVP} = 1 \right) \).

The venous pressures measured by the technique described ranged from 25 to 131 mm. of water in 15 resting subjects (tables 1 and 2). When the measurement was repeated at intervals of four days to 6 months, the individual subjects showed striking similarity in the value obtained and the maximum standard deviation from the mean pressure in a given subject was 15 mm. of water.

**Discussion**

This study demonstrates a simple method for accurately and reliably recording changes in central venous pressure. The body position described theoretically transforms the venous system between the peripheral needle and the heart into a distended patent tube. The central venous pulse pattern recorded renders a continuous check on the patency of the system. The combination of elastic manometers with slow oscillograph camera speeds of 0.2 mm./sec. permits continuous recording of venous pressure over any desired period of time without disturbing the subject. This arrangement directly records the main trend of the venous pressure during control and experimental situations and eliminates the necessity of constructing it from single points. The effect of variations in body position is minimized and a moderate rotation of the body around its long axis can occur without altering the theoretical reference level. Since the method requires only the puncture of an arm vein the subjects are relaxed and can tolerate long term experiments without discomfort. The disadvantage of a continuous saline drip ordinarily used in intra-venous catheterization or the repeated injections of saline as required by the technique of Moritz and Tabora and its modifications is also eliminated. Lastly the peripheral vein is not temporarily damaged as occurs after catheterization and numerous repeated studies can be done.

The resting venous pressures measured in 15 normal subjects by this method ranged between 25 and 131 mm. of water and are not significantly different from the pressures obtained with the conventional procedures.\(^1\)\(^2\)\(^4\) In contrast to the wide variations of venous pressure which becomes apparent in a group of only 15 subjects, the constancy of venous pressure in a single subject with repeated measurements is remarkable. In normal individuals, the pressure gradient between a vein in the antecubital fossa and the right atrium has been reported to be a mean of 43 ± 18 mm.\(^*\) of water when the peripheral venous pressure was measured by a modified Moritz and Tabora method.\(^10\) Pederson\(^7\) found a pressure gradient of 29 ± 15 mm.\(^†\) of water when care was taken to keep the arm "safely below heart level". These figures were close to our own of 34 ± 9 mm. water. In patients with congestive heart failure the pressure gradient may become extremely small.\(^10\) This is believed to occur in part because of the distension of the veins and a more sluggish blood flow in the veins. While the proposed technique for measuring venous pressure should simulate the condition of congestive failure as far as the dependent arm is concerned, the results of this study show that the pressure gradient could not be abolished.

**Summary**

By placing the subject in the right lateral decubitus position and with the use of an elastic manometer, changes of central venous pressure were recorded continuously from a vein in the antecubital fossa of the dependent arm for one to two hours. A comparative study of the pressures, obtained by this method from an arm vein (PVP) with central venous pressure (CVP) directly and simultaneously recorded by intra-venous catheterization of the central veins, showed that induced changes of central venous pressure were accompanied by identical changes in the peripheral venous pressure. The mean pressure gradient between the peripheral and central veins was 35 ± 9 mm. of water. Peripheral venous pressure measured by the described technique ranged between 25 and 131 mm. of water in 15 normal subjects. Repeat measurements

\(^*\) Standard deviation calculated from the original data.

\(^†\) Calculated from original data, excluding patients with right atrial pressures of more than 150 mm. water.
measurements in a given subject showed little variation.

**SUMMARIO IN INTERLINGUA**

Per placiar le subjecto in le position decubital dextero-lateral e per medio de un manometro elastic, alterationes del pression venose central esseva registrate continuamente ab un vena in le fossa antecubital del bracio dependente pro periodos de inter 1 e 2 horas. Le comparation del pressiones assi obtenite ab un vena del bracio con le pression venose central, que esseva registrate directe- e simultaneamente per catheterisation intravenose del venas central, demonstrava que inducite alterationes del pression venose central esseva accompaniate per alterationes identic in le pression venose peripheric. Le gradiente median de pression inter le venas peripheric e central esseva 35 ± 9 mm H₂O. Le pression venose peripheric, mesurate per le technica describite, variava inter 25 e 131 mm H₂O in 15 subjectos normal. Le repetition del mesuramentos in un subjecto individual monstrava pauc variation.

**REFERENCES**

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