A COMPARISON OF JUGULAR AND CENTRAL VENOUS PRESSURE MEASUREMENTS DURING ANAESTHESIA

C. E. BRISCOE

SUMMARY

Simultaneous measurements of the jugular and right atrial venous pressures were made in 16 patients undergoing cardiac and vascular surgery to see whether the jugular veins were a reliable guide to central venous pressure. It was found that with the chest closed both the external and internal jugular veins on the right side provided a good guide. The vessels on the left side were less consistent but still provided a fair guide. However, when the chest was open all the neck veins became unreliable measures of central venous pressure. Certain practical points in the use of these veins for recording venous pressure are considered.

Although the central venous pressure is best measured by a right atrial catheter, there are many occasions during anaesthesia when the time and effort of inserting a right atrial catheter militate against its use. The possible complications (Adar and Mozes, 1971; Editorial, 1972) are an additional drawback.

It is, however, a reasonably simple procedure to insert into the external or internal jugular vein a short catheter which can easily be attached to a manometer to record the venous pressure at this site. The question then arises as to whether this pressure will provide a working guide to the central venous pressure.

In order to answer this question, simultaneous measurements of internal and external jugular, and right atrial, pressures were made in 16 anaesthetized patients.

METHOD

Fourteen of the patients studied were undergoing cardiac operations and two repair of abdominal aortic aneurysms. After induction of anaesthesia a 16 or 18 gauge catheter (Angiocath; Bard) was inserted into the external or internal jugular veins on each side of the neck. Later, a 16 gauge catheter (E-Z Cath; Abbott) was passed through the left innominate vein into the right atrium under direct vision. Its position was subsequently confirmed by radiography.

All catheters were connected to the same manometer scale and its zero point was taken from the angle of Louis. Any error in zeroing was therefore common to all three readings. Observations were taken every hour and recorded to the nearest 0.5 cm H₂O after flushing the tubing and confirming that a respiratory swing was present. It was noted whether the chest was open or closed at the time. No readings were recorded during cardiac bypass. Additional readings were taken with the head rotated to the left and to the right in four patients and with a steep head-down tilt in two other patients. Otherwise all the patients were supine.

RESULTS

Chest closed (table I)

The values of right jugular, left jugular and external jugular vein pressures were on average significantly higher than the right atrial pressures measured at the same time. There was, however, good correlation between values measured in the neck veins and in the right atrium (figs. 1, 2 and 3). This agreement was greater for readings taken from the veins on the right than from those on the left.

Direct comparison between left and right jugular vein pressures show that, on average, left jugular vein pressures exceeded those on the right but not to a statistically significant degree. Correlation between the two was high.

There were not enough readings to make a valid direct comparison between internal jugular and right atrial pressures. However, the differences between simultaneously measured pressures in the external and internal jugular veins were, on average, small and non-significant. Any difference due to the sides of the recordings in this last observation was eliminated by taking half the readings from the left external and right internal jugular veins, and the other


Present address: Research Department of Anaesthetics, Royal College of Surgeons of England, Lincoln's Inn Fields, London. WC2A 3PN.
Fig. 1. Comparison of right atrial and right jugular venous pressures with the chest closed.

Fig. 2. Comparison of right atrial and left jugular venous pressures with the chest closed.

Fig. 3. Comparison of right atrial and external jugular venous pressures with the chest closed.

Fig. 4. Comparison of right atrial and left jugular venous pressures with the chest open.
JUGULAR AND CENTRAL VENOUS PRESSURE MEASUREMENTS

**Table I.** Comparison of right atrial (RA) and jugular venous pressures with chest closed.

<table>
<thead>
<tr>
<th>Veins</th>
<th>No. of patients</th>
<th>No. of readings</th>
<th>Range of pressures recorded (cm H₂O)</th>
<th>Correlation coefficient*</th>
<th>Difference in means (cm H₂O)</th>
<th>Standard deviation of difference in means (cm H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right jugulars (int. and ext.) v. RA</td>
<td>11</td>
<td>18</td>
<td>2-20</td>
<td>0.98</td>
<td>1.0(P&lt;0.001)</td>
<td>1.0</td>
</tr>
<tr>
<td>Left jugulars (int. and ext.) v. RA</td>
<td>11</td>
<td>17</td>
<td>2-20</td>
<td>0.90</td>
<td>2.0(P&lt;0.01)</td>
<td>2.1</td>
</tr>
<tr>
<td>External jugulars v. RA</td>
<td>11</td>
<td>22</td>
<td>2-20</td>
<td>0.95</td>
<td>1.3(P&lt;0.001)</td>
<td>1.6</td>
</tr>
<tr>
<td>Left v. right jugular</td>
<td>12</td>
<td>21</td>
<td>4.5-20</td>
<td>0.92</td>
<td>0.6(n.s.)</td>
<td>1.6</td>
</tr>
<tr>
<td>External v. internal jugulars</td>
<td>10</td>
<td>18</td>
<td>6.5-18.5</td>
<td>0.91</td>
<td>0.03(n.s.)</td>
<td>1.6</td>
</tr>
</tbody>
</table>

* 1.0=perfect correlation 0=no correlation

**Table II.** Comparison of right atrial and jugular venous pressures with chest open.

<table>
<thead>
<tr>
<th>Veins</th>
<th>No. of patients</th>
<th>No. of readings</th>
<th>Range of pressures recorded (cm H₂O)</th>
<th>Correlation coefficient</th>
<th>Difference in means (cm H₂O)</th>
<th>Standard deviation of difference in means (cm H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right jugulars (int. and ext.) v. RA</td>
<td>11</td>
<td>22</td>
<td>2-19</td>
<td>0.77</td>
<td>3.1(P&lt;0.001)</td>
<td>3.2</td>
</tr>
<tr>
<td>Left jugulars (int. and ext.) v. RA</td>
<td>13</td>
<td>26</td>
<td>2-23</td>
<td>0.53</td>
<td>5.9(P&lt;0.001)</td>
<td>4.6</td>
</tr>
<tr>
<td>External jugulars v. RA</td>
<td>12</td>
<td>26</td>
<td>2-20</td>
<td>0.73</td>
<td>4.5(P&lt;0.001)</td>
<td>3.4</td>
</tr>
<tr>
<td>Left v. right jugular</td>
<td>11</td>
<td>22</td>
<td>3-23</td>
<td>0.80</td>
<td>3.3(P&lt;0.001)</td>
<td>3.3</td>
</tr>
<tr>
<td>External v. internal jugulars</td>
<td>9</td>
<td>18</td>
<td>3-23</td>
<td>0.59</td>
<td>0.2(n.s.)</td>
<td>5.0</td>
</tr>
</tbody>
</table>

half from the right external and left internal jugular veins. It was not practical to record from the external and internal jugular veins on the same side of the neck.

In four patients the head was rotated to the extreme left and then to the extreme right. In one of these cases the left internal jugular pressure rose by 4 cm H₂O following rotation to the left, and in another the external jugular pressure rose by 2 cm H₂O. In neither case did the respiratory swing disappear. No changes were produced by turning the head to the right.

Two patients were put into a steep head-down tilt but the external jugular and right arterial pressures were unaltered by this manoeuvre.

A fairly comprehensive range of venous pressures is covered by these readings. Several of the patients were in cardiac failure and had very high venous pressures.

**Chest open (table II).**

Pressures measured in the right and left jugular and the external jugular veins were again significantly higher than the corresponding right atrial values. However, in contrast to the closed chest results correlation between the values for the neck veins and right atrium was poor. The scatter was particularly wide on the left side (fig. 4), for example at a right atrial pressure of 8 cm H₂O the corresponding left jugular vein pressures ranged from 9 to 23 cm H₂O.

Direct comparison between the left and right jugular pressures shows that pressures on the left were significantly higher than those on the right and that correlation between the two was poor.

This difference, due to the side from which the readings were taken, greatly influenced comparison of the external and internal jugular veins. The vessel on the left nearly always gave higher readings than the one on the right, whether it was an external or an internal jugular vein. As these were always measured from opposite sides of the neck a poor degree of correlation resulted. However, an equal number of readings was taken with the left external and right internal as with the right external and left internal jugular veins, and after averaging the results no significant difference emerged between the pressures in the external and internal jugular veins.

**DISCUSSION**

A review of the literature suggests that the question whether jugular venous pressure is a true guide to central venous pressure is a contentious one. On the one hand, some research workers monitor the jugular venous pressure and call this central venous pressure. Thus Maclean and associates (1965), in a paper on shock, recorded pressures from the external jugular veins and refer to this as central venous pressure, and Eustace (1970) in a paper comparing central venous pressure with peripheral venous pressure...
in the arm veins also uses the external jugular veins to record central venous pressure.

On the other hand, authorities such as Sykes (1963), Hardaway (1968) and Wilson and associates (1962) state that central venous pressure must be recorded from vessels inside the chest because only these are truly representative of right atrial pressure.

Although none of these authors actually compared jugular and right atrial pressures it is clear from first principles that there must be a pressure difference between the neck veins and the right atrium or blood would not flow towards the heart. If this difference is small enough and consistent enough, however, it would be practical to utilize these vessels to record central venous pressure.

Before drawing any conclusions about this, it is interesting to consider on a theoretical basis the factors which are responsible for this pressure difference and its alterations and then to see how these theoretical considerations compare with the observed results. For this purpose the veins must be considered as pipes with a laminar flow of fluid passing through them. Poiseuille's formula then shows that the pressure difference (P) between two points varies directly as the length (L) between the points, the rate of flow (F) and the viscosity of the fluid (μ), and inversely as the fourth power of the radius (r)

\[ P = \frac{8L\mu F}{\pi r^4} \]

In considering these various factors one can first eliminate the viscosity of the blood, as this will not vary significantly. The flow of blood from the head and neck will vary somewhat and may be responsible for some small changes in the pressure difference. The length of the vessels connecting the neck to the right atrium will not alter much from patient to patient but will be slightly greater from the left side than from the right side of the neck.

Any changes in the radius of the vessels will, however, cause quite large changes in the pressure difference, and factors affecting the radii of the vessels must therefore be considered further.

Vessel size. As one moves peripherally, the radii of the veins decrease and the pressure difference between them and the heart increases. Indeed it has been shown (Jones, 1965) that during anaesthesia the wrist vein has a pressure about 7 cm H2O above the right atrial pressure whereas the jugular venous pressure is only 1–2 cm H2O higher. Normal values of venous pressure at other sites have been measured by Winsor and Burch (1946) in resting patients.

**Distensibility.** Veins between the neck and the heart are distensible and it might be expected that the higher the venous pressure, the larger the radii of the vessels and the smaller would be the difference in pressure.

**External pressures.** The radius of a vein will clearly be affected by external pressures. Muscular movements are the commonest factor producing these, and the movement of the diaphragm is, of course, responsible for the changing pressure in the chest and hence the respiratory swing. Movements of the voluntary muscles would not, however, be expected to occur during anaesthesia and so would not interfere with blood flow in the neck. Similarly, external objects are not normally allowed to press on the neck, and so would not cause venous obstruction at this site.

Opening the chest, however, will cause serious distortion of the anatomy. Not only will large veins be stretched by the act of opening the chest but retractor and swabs may compress them as well. Positional changes of the neck can also theoretically produce stretching and compression of the neck and innominate veins.

**Other factors.** Points which have led other workers (Shapiro and Bailey, 1968) to dismiss the use of peripheral veins for measuring central venous pressure are the presence of valves, phlebitis and tortuosity. These factors, however, should not be important sources of venous obstruction between the neck and the heart. Veins in this region are not tortuous and are not subject to phlebitis except in rare instances when passage of any form of superior vena caval catheter would be contraindicated. Valves are found at the proximal end of the external and internal jugular veins, especially on the right (Quain, 1899) but these valves should be open during anaesthesia and would in any case not themselves affect the pressure. The factor causing them to close (usually muscular contraction) raises the pressure, rather than the valve closure per se.

It is now necessary to see how these theoretical considerations are borne out by the actual results obtained.

The most dramatic effects were produced by opening the chest. In these cases this was done by a sternal split and clearly led to a distortion of the anatomy. The jugular venous pressures started to rise above the right atrial pressures as soon as the chest was open, and subsequently became a quite unreliable guide to the right atrial pressures. The left side nearly always gave higher readings than the
right and it appeared that this was caused by stretching of the left innominate vein. In this connection it is interesting that in one patient with a left-sided superior vena cava readings were higher on the right.

With the chest closed, jugular venous pressure was a much more reliable guide to right atrial pressure. This was so in spite of the fact that most of the readings taken with the chest closed were taken at the end of the operations. The chest had therefore been opened and the anatomical distortions referred to above had taken place. Even closer agreement might be found in patients whose chests had not been opened. Nevertheless, the readings from the right side of the neck show a correlation factor of 0.98 with the right atrial pressures. The results from the left side are, however, rather less consistent and tend to be higher than the right—probably due both to these distortions and to the longer distance from the left side of the neck. There is a significant pressure difference of 1–2 cm H₂O when the pressures from these vessels are compared with the right atrial pressures and this must be remembered when using them for central venous pressure recording.

The external jugular veins have a smaller radius than the internal and might therefore be expected to give higher readings but this may be compensated for by the lower flow through them. In the event, the external jugulars show good correlation with both the right atrial and the internal jugular pressures.

The possibility of pressure changes in the jugular veins being brought about by rotating the head was confirmed. Extreme rotation of the head to the left will in some patients produce a rise in pressure in both the external and internal jugular veins on that side.

There is also some evidence to support the theoretical expectation that the pressure difference becomes smaller when the pressures are high and the veins distended. In six of the nine series the regression coefficients indicated that this was the case, while in the remaining three the difference was nearly the same at high and low pressures.

Finally, it is interesting to consider what happens when the patient is tilted head down. In this situation the pressure in the jugular veins will rise above the pressure in the right atrium by the number of centimetres that it lies below the right atrium. This extra pressure will be required to drive the blood uphill to the heart. However, as the heart is used as the zero point this effect is eliminated in the actual reading and there is no increase in the pressure difference between the jugular and right atrial pressure recordings.

ACKNOWLEDGEMENTS
I gratefully acknowledge Dr Wylie's helpful criticism of this paper, Dr Mathias's assistance with the statistics, and Miss Davenport's secretarial help.

REFERENCES

UNE COMPARAISON DE LA PRESSION JUGULAIRE ET VEINEUSE CENTRALE DURANT L'ANESTHESIE

SOMMAIRE
Des mesures de la pression jugulaire et de la pression veineuse auriculaire droite ont été faites chez seize patients, subissant une intervention chirurgicale cardiaque et vasculaire, dans le but de déterminer si la veine jugulaire peut servir comme norme sure de la pression veineuse centrale. On a trouvé qu'à thorax fermé les veines jugulaires droites, interne et externe, étaient moins des normes consistentes mais encore modérément bonnes. Mais lorsque le thorax était ouvert, toutes les veines du cou devenaient inadéquates pour mesurer la pression veineuse centrale. Certains points pratiques au sujet de l'emploi de ces veines pour l'enregistrement de la pression veineuse sont prises en considération.
EIN VERGLEICH DER MESSUNG DES VENENDRUCKES DER JUGULARIS UND DER ZENTRALEN VENEN WÄHREND DER NARKOSE

ZUSAMMENFASSUNG


COMPARACION DE LAS MEDICIONES DE LA PRESION VENOSA YUGULAR Y CENTRAL DURANTE LA ANESTESIA

RESUMEN

Fueron efectuadas mediciones simultáneas de las presiones venosas yugular y auricular derecha en dieciséis pacientes sometidos a cirugía cardiaca y vascular para observar si las venas yugulares podían constituir una indicación confiable de la presión venosa central. Se encontró que con el tórax cerrado las venas yugulares externa e interna del lado derecho proveían una orientación buena. Los vasos del lado izquierdo no daban resultados tan constantes, pero constituían una orientación aceptable. Sin embargo, cuando el tórax estaba abierto todas las venas del cuello eran guías inseguras para la presión venosa central. Son considerados ciertos puntos prácticos para el uso de estas venas para el registro de la presión venosa central.

THE AMERICAN ASSOCIATION OF GYNECOLOGICAL LAPAROSCOPISTS

will have its

INTERNATIONAL CONGRESS OF GYNECOLOGICAL LAPAROSCOPY

Fairmont Roosevelt Hotel, New Orleans, Louisiana
November 17, 18, 19, 20, 1973

For further information, please contact: JORDAN M. PHILLIPS, M.D.,
11239 South Lakewood Boulevard, Downey, California 90241.