The Spatial Vectorcardiogram and Mean Spatial Ventricular Gradient in Normal Pregnant Women

By G. E. Burch, M.D., J. A. Abildskov, M.D., and J. A. Cronvich, M.S.

The spatial vectorcardiogram and the spatial ventricular gradient of normal subjects in the last trimester of pregnancy and in some of the same subjects following delivery have been studied. It was found that the vectorcardiograms could be divided into two groups on the basis of the form of the QRS sE-loops, as has been previously reported for other normal subjects. In some instances records taken after delivery or records taken during pregnancy with the subject in deep inspiration altered both the orientation and the form of the QRS sE-loop. Since these alterations were most likely due to changes in position of the heart and extracardiac tissues, it is suggested that these are factors determining the configurations of the two types of normal QRS sE-loops.

Because of the importance of cardiac position in determining the form of the electrocardiogram and the vectorcardiogram and because of the difficulty of interpreting the electrocardiogram with a large Q wave in lead III, it was considered worthwhile to investigate the spatial vectorcardiogram and the spatial ventricular gradient in subjects during the eighth and ninth months of pregnancy following delivery.

In a previous study of normal subjects it was found that the spatial vectorcardiogram varied considerably in its spatial orientation and that these variations largely accounted for the marked variations in contour of the plane projections of normal vectorcardiograms. In that study it was not possible to evaluate adequately the effect of cardiac position on the orientation or contour of the vectorcardiogram. The present study was undertaken because it was thought that the changes in the vectorcardiogram which occurred with changes in cardiac position during pregnancy and following delivery might assist in a better understanding of the relation of cardiac position and the vectorcardiogram. It had been observed in the study of normal subjects that normal vectorcardiograms could be divided into two groups on the basis of the configuration of the QRS sE-loops. Since the differences between the two types of QRS sE-loops might be the result of differences in heart position as well as differences in electrical conductivity of the tissues surrounding the heart and differences in the order of depolarization, studies during and after pregnancy might elucidate the role of the first of these three factors in determining the configuration of the spatial vectorcardiogram.

Methods and Materials

Details of the apparatus and methods of recording the spatial vectorcardiogram have been described elsewhere. Recordings included projections of the spatial vectorcardiogram on the four planar surfaces of the equilateral tetrahedron and projections on the planes sagittal to these as viewed from the left, as well as stereoscopic views of the projections on the surfaces of the tetrahedron. Each planar projection and corresponding sagittal projection were recorded simultaneously. The amplification of recordings was varied to obtain greater detail in those deflections located near the isoelectric point.

Electrocardiograms were obtained during each recording period. These included recordings of standard leads, unipolar leads from the points defining the apexes of the equilateral tetrahedron as well as leads V 1 through V 6 . Proper pairs of standard and unipolar limb and back leads were recorded.
simultaneously so that any portion of the electro-cardiogram could be properly oriented temporally with respect to any other portion of any other of these leads.

Recordings were obtained with the patients in the supine position with the head elevated approximately 20 degrees from the horizontal. All were obtained at least two hours postprandially and after approximately 30 minutes of bed rest. There were 75 normal pregnant women studied in this series. All subjects were in the eighth or ninth months of pregnancy and were free of any disease. All were under observation in the maternal clinic and had received an adequate inventory of their state of health. They varied in age from 13 to 40 years and all were Negroes. Twenty-three of the subjects returned for a second study approximately six weeks following delivery.

The vectorcardiograms were studied to determine the general contour and spatial orientation of the loops and were correlated with the electro-cardiograms with particular attention devoted to the \( Q_3 \) pattern.

The \( S_{AQRS} \), \( S_{AT} \) and \( S_G \) vectors were obtained by means of measurements from leads I, \( V_F \) and \( V_B \). Models of the spatial vectors were then constructed for more careful inspection. These spatial vectors were studied in conjunction with their respective vectorcardiograms obtained both prior to and following delivery.

**RESULTS**

The results are summarized in tables 1 through 5 and figures 1 through 8.

A. General Contour and Spatial Orientation of the Loops of the Spatial Vectorcardiogram

In general the spatial loops had variations in configuration and orientation similar to those previously reported for normal nonpregnant subjects.1

1. The QRS sE-Loop. As in normal non-pregnant subjects the records of these subjects could be divided into two groups on the basis of the contour of the QRS sE-loops. Records of the form labeled “type 1” in a previous report had narrow elliptoid configurations with the major axis being three or more times as long as the minor axis and directed away from the isoelectric point (fig. 1). Those with a “type 2” configuration had a more complex form, with the width and length being more nearly equal and with the terminal portion of the loop being located posterior to the isoelectric point (fig. 2).

In general the QRS sE-loops tended to be displaced posteriorly during the eighth and

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**Fig. 1.** Frontal, left sagittal and stereoscopic frontal views of a normal spatial vectorcardiogram with a “type 1” QRS sE-loop. For this and all subsequent stereoscopic views, stereoscopic effects are best obtained by placing a card between the two photographs and viewing from a distance of 5 to 10 inches.

**Fig. 2.** Frontal, left sagittal and stereoscopic views of a normal spatial vectorcardiogram with a “type 2” QRS sE-loop.
ninth months of pregnancy. This was due in part to rotation posteriorly about the transverse axis of the loop, but in many of the "type 1" records varying degrees of posterior elongation of approximately the terminal quarter of the loop were also present. This resulted in configurations of the spatial loops which resembled to a variable extent the pattern previously labeled "type 2," although during deep inspiration and following delivery the loops were definitively of the pattern which has been termed "type 1."

None of the subjects whose QRS sE-loops maintained a "type 2" configuration during deep inspiration returned for study following delivery.

The variations in contour of the plane projections of the QRS sE-loops were marked and were as expected from the spatial orientation of the loops described above. The configurations of the plane projections changed after delivery in accordance with the changes in orientation and configuration of the spatial loops. All changes conformed to those expected from the electrocardiogram.

Figure 3 and table 1 show the location of the termini of the maximal instantaneous vectors of the QRS sE-loops of all subjects studied during pregnancy. The location of the terminus of the mean vector is indicated by the heavy dot. These illustrations show that there is more scatter of these vectors with a greater number directed to the left and posteriorly than was previously reported for the group of normal nonpregnant subjects. Following delivery, the termini tended to cluster more closely with less leftward and posterior deviation (fig. 3 and table 2).

(2) The T sE-Loop. The T sE-loops had two general configurations, the majority being nar-

![Diagram](image-url)

**Fig. 3.** Location of the termini of the maximal QRS vectors in frontal and left sagittal planes during pregnancy and following delivery. In this and subsequent figures mean values are indicated by the heavy dots.

<table>
<thead>
<tr>
<th>Table 1.—Maximal Vectors for Pregnant Subjects during Quiet Respiration</th>
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<tr>
<td><strong>Maximal Vector in Frontal Plane</strong></td>
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<td>QRS</td>
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<td>Maximal</td>
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<td>Average</td>
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<th>Table 2.—Maximal Vectors for Subjects after Delivery</th>
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<tr>
<td><strong>Maximal Vector in Frontal Plane</strong></td>
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<tr>
<td>QRS</td>
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<td>Minimal</td>
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<td>Average</td>
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row and elongated and the remainder tending to be more nearly circular, as reported for normal nonpregnant subjects.1

The spatial orientation of the T vector-loops is summarized in figure 4 and tables 1 and 2, in which are indicated the positions of the maximal vectors in the frontal and left sagittal planes. From figure 4 it is evident that practically all were in the sixth sextant of the triaxial reference system with the mean located at +26 degrees in the frontal plane. The magnitudes of these vectors are shown in the figure. The majority of the maximal vectors in the left sagittal plane were directed anteriorly although a significant number were directed posteriorly. The mean vector was located at +101 degrees. The location of the maximal vector was not changed significantly after delivery.

(3) The P Vector-Loop. The P vector-loops were not studied in detail. In general the contour and orientation of loops of these subjects were similar to those of normal nonpregnant subjects.1

(4) The Effect of Deep Inspiration on the Spatial Vectorcardiogram. Deep inspiration during pregnancy usually resulted in a spatial vectorcardiogram whose orientation resembled that in nonpregnant subjects. The changes in orientation with deep inspiration were more marked during pregnancy than following delivery. There was a vertical rotation of the maximal vectors of the QRS vector-loops about the anteroposterior axis such that the mean vector was displaced to +66 degrees, and in the sagittal plane the maximal vectors became more anteriorly located with the mean at +108 degrees (fig. 5 and table 3).

In some instances there was a change in contour as well as in orientation of the QRS vector-loop during deep inspiration. This change occurred in those instances in which there appeared to be a posterior elongation of the terminal portion of the spatial loop and seemed to consist of a shortening of this segment of the loop during deep inspiration. It was always associated with a change in orientation such that the loop became more vertical around its anteroposterior

### Table 3. Maximal Vectors for Pregnant Subjects during Deep Inspiration

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<tr>
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<th>Maximal Vector in Frontal Plane</th>
<th>Maximal Vector in Sagittal Plane</th>
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<tr>
<td></td>
<td>QRS</td>
<td>T</td>
</tr>
<tr>
<td>Maximal</td>
<td>130°</td>
<td>1.74</td>
</tr>
<tr>
<td>Minimal</td>
<td>21°</td>
<td>0.16</td>
</tr>
<tr>
<td>Average</td>
<td>66°</td>
<td>0.80</td>
</tr>
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axis and was rotated anteriorly about its transverse axis.

B. The SAQRS, SA{T and SG Vectors

In general the projections in the frontal plane of the SAQRS, SA{T and SG vectors were found to be directed downward and to the left of the isoelectric point and to lie in a plane parallel to the frontal plane and passing through the isoelectric point. They tended to cluster about the vertical axis (+90 degrees) in the left sagittal plane with approximately equal distribution anteriorly and posteriorly. It is of interest that these vectors were not directed anteriorly as much as the maximal axes of the QRS and T sE-loops. This difference is a result of the fact that the factor of time is involved in the measurement of SAQRS, SA{T and SG; whereas, the maximal vectors of the QRS and T sE-loops are instantaneous values. Portions of the vectorcardiogram which are made up of small vector quantities but are inscribed slowly exert a considerable influence on SAQRS, SA{T and SG. This illustrates one example of the failure of the vectorcardiogram, as usually recorded, to indicate satisfactorily the factor of time. The orientation of the individual and mean values of SAQRS, SA{T and SG for the subjects studied during the late stages of pregnancy and those studied after delivery are shown in figures 6, 7 and 8 and tables 4 and 5. It is evi-

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
 & \text{Values in Frontal Plane} & & \text{Values in Sagittal Plane} & \\
 & \text{SAQRS} & \text{SA{T} } & \text{SG} & \text{SAQRS} & \text{SA{T} } & \text{SG} & \\
\hline
\text{Angle} & \text{Length mV} & \text{Angle} & \text{Length mV} & \text{Angle} & \text{Length mV} & \text{Angle} & \text{Length mV} \\
\hline
\text{Maximal} & 80° & 67 & 67° & 53 & 61° & 107 & 140° & 71 & 160° & 27 & 150° & 58 \\
\text{Minimal} & 11° & 4 & 0° & 4 & 5° & 8 & 103° & 1 & 90° & 0 & 40° & 2 \\
\text{Average} & 33° & 28 & 21° & 26 & 26° & 65 & 77° & 17 & 91° & 10 & 90° & 25 \\
\hline
\end{tabular}
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Table 5.—Mean Spatial Values after Delivery

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<thead>
<tr>
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<th>Values in Frontal Plane</th>
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<th>Values in Sagittal Plane</th>
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<tbody>
<tr>
<td></td>
<td>( S_A_{QRS} )</td>
<td>( S_A_{\Sigma} )</td>
<td>( S_G )</td>
</tr>
<tr>
<td>Angle</td>
<td>Length (mv.)</td>
<td>Angle (degrees)</td>
<td>Length (mv.)</td>
</tr>
<tr>
<td>Maximal</td>
<td>82°</td>
<td>52</td>
<td>90°</td>
</tr>
<tr>
<td>Minimal</td>
<td>6°</td>
<td>14</td>
<td>0°</td>
</tr>
<tr>
<td>Average</td>
<td>42°</td>
<td>25</td>
<td>25°</td>
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Fig. 9. Mean and extremes of the direction of the initial portion of the QRS sE-loops of subjects with Q waves in lead III in the left sagittal plane.

itent that, following delivery, there is no significant change in magnitude.

C. The "Q3 Pattern" and the QRS sE-Loop

A definite Q wave was present in lead III of the electrocardiogram of 18 subjects (23 per cent) studied during pregnancy. This Q wave remained after delivery but usually decreased in magnitude. In these subjects the direction of the first discernible portion of the QRS sE-loop was usually upward and forward in the sagittal plane. The mean and extremes of the direction of the initial portion of these QRS sE-loops are shown in figure 9. With delivery these mean instantaneous vectors extended less upward and forward. The downward displacement of these vectors in the frontal plane is in accord with the decreased magnitude of the Q wave in lead III of the electrocardiogram.

DISCUSSION

Because some of the QRS sE-loops with a "type 2" configuration during pregnancy changed to a "type 1" during deep inspiration and after delivery, it is evident that cardiac position and the electrical conductivity of extracardiac tissue must be at least partially responsible for the two basic patterns of QRS sE-loops previously described. In any event, if the two fundamental patterns of the QRS sE-loop are due primarily to intracardiac events, extracardiac factors associated with pregnancy may modify these patterns. The relative roles of the factors responsible for the two basic types of QRS sE-loops in the normal subject remain unknown.

In these studies the vectorcardiogram has not been found to modify information already existing from electrocardiography concerning the problem of the Q wave in lead III during pregnancy. These studies have shown that the spatial vectorcardiogram can be altered in both spatial orientation and contour by pregnancy. These changes probably result in part from the changes in cardiac position and possibly in part from hemodynamic alterations associated with pregnancy. However, the relative roles of these two factors could not be assessed in this study. The changes observed with deep inspiration during pregnancy, which were similar to those noted following delivery, suggest that changes in cardiac position accounted for most of the alterations observed with pregnancy. Efforts were made to study anatomic positional variations associated with pregnancy by fluoroscopic methods, but the results were not clearly informative. It has been our experience that the fluoroscopic method is not sufficiently accurate for the determination of detailed variations in the anatomic position of the heart to allow satisfactory correlation between the electrocardiogram or vectorcardiogram and cardiac position. The spatial orientation of the initial portion of the QRS sE-loop in those subjects with a Q wave in lead III of the electrocardio-
gram varied widely. After delivery this portion of the loop did not change significantly. Until an adequate number of spatial vectorcardiograms of patients with posterior myocardial infarction with Q2 patterns has been carefully studied and correlated with these observations on the Q2 pattern during pregnancy, the ultimate practical clinical significance of these observations will not be evident. However, the wide range in spatial orientation of the initial portion of the QRS sE-loop in pregnant patients with large Q waves in lead III makes it unlikely that a satisfactory differentiation between the Q wave associated with rotation of the heart and that due to posterior myocardial infarction will be obtained in all patients.

**Summary**

The spatial vectorcardiograms of 75 normal women in the last trimester of pregnancy and of 23 of these same subjects, post partum, have been studied. As previously reported for other normal subjects two basic variations in the form of the QRS sE-loops were found. These have been tentatively labeled "type 1" and "type 2." In some of the records taken after delivery or with the subject in deep inspiration during pregnancy the QRS sE-loop was altered in both orientation and contour suggesting that the position of the heart and extracardiac tissues are factors determining the configuration of the two types of normal QRS sE-loops.

The values of the $S\hat{A}_{QRS}$, $S\hat{A}_T$ and $S\hat{G}$ vectors were determined from the records of all subjects included in this study and the results were reported.

**Sumario Español**

El vectorcardiograma espacial y la pendiente ventricular espacial de sujetas normales en el último trimestre de gestación y en algunas de las mismas sujetas luego de dar á luz ha sido estudiado. Se encontró que los vectorcardiogramas se pudieron dividir en dos grupos a base de la configuración de las ondas QRS sE como ha sido informado previamente en otros sujetos. En algunas ocasiones trazados obtenidos luego de dar á luz o durante la gestación con el sujeto en inspiración extrema alteró tanto la orientación como la forma de las ondas QRS sE. Como estas alteraciones fueron muy probablemente causadas debido a los cambios en posición del corazón y tejidos extra cardíacos, se sugiere que estos factores determinan la configuración de los dos tipos normales de ondas QRS sE.

**REFERENCES**

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