Alterations of Systolic Time Intervals During Pregnancy

By John R. Burg, M.D., Arthur Dodek, M.D., Frank E. Kloster, M.D., and James Metcalfe, M.D.

SUMMARY

Systolic time interval measurements were made sequentially throughout pregnancy and during the postpartum period. Recordings were made in the supine and lateral positions. Although the greatest deviations from predicted values were present in the third trimester, changes were evident as early as the first trimester. During the first two trimesters the pre-ejection period (PEP) was significantly shortened. The left ventricular ejection time (LVET) remained normal while the PEP/LVET decreased.

The third trimester was characterized by a markedly shortened LVET, a prolonged PEP, and an increased PEP/LVET, all more apparent in the supine than in the lateral position. These findings are consistent with impaired left ventricular performance and are probably due to decreased left ventricular preload resulting from diminished venous return secondary to inferior vena caval obstruction by the gravid uterus.

In the postpartum period, the PEP/LVET remained elevated in both positions; the PEP was prolonged and the LVET shortened in the lateral posture. It is concluded that alterations in systolic time interval measurements occur normally during the course of uncomplicated pregnancy and persist into the postpartum period. Possible mechanisms are discussed.

Additional Indexing Words:
Pre-ejection period  Left ventricular ejection time  Vena cava  Postpartum cardiac changes
Left ventricular function in pregnancy

HEMODYNAMIC ALTERATIONS occurring during pregnancy have been known at least since 1911 when cardiac output was found to be significantly increased.1 Since that time, several investigations,2–5 utilizing various techniques, have demonstrated an increase in cardiac output as early as the first trimester of pregnancy with a peak near the end of the second trimester and a gradual decline in the last trimester. The change in cardiac output may be related to maternal position,6–8 metabolic needs of the fetus,9 and hormonal effects.6,7 Changes in left ventricular performance would be of interest but have heretofore been unavailable due to the hazards of X-ray radiation, the risks of catheterization, and the inability to record serial observations.

The determination of systolic time intervals has proved to be a reliable and innocuous technique for assessment of left ventricular function.8,9 Hemodynamic correlates of these intervals have been established by invasive techniques.8–12

The purposes of this investigation were to 1) define alterations of systolic time intervals in pregnancy, 2) describe the influence of maternal posture, and 3) evaluate the chronology of these changes during pregnancy.

Materials and Methods

Forty-two normotensive pregnant women with no prior history of cardiac disease were evaluated with systolic time intervals during pregnancy and in the postpartum period; their ages ranged from 14 to 31 years (mean 23 years). Primigravid patients numbered 26. Twelve patients were studied sequentially throughout pregnancy and in the postpartum period. None was receiving any medication known to influence cardio-
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vascular dynamics. In addition, systolic time intervals were determined in 21 healthy nonpregnant women under identical conditions to assess the effects of positional change. Their ages ranged from 22 to 42 years (mean 31 years). None had any known cardiovascular disorder and none were taking any medication.

Simultaneous electrocardiogram, phonocardiogram and carotid artery pulse tracing were recorded (fig. 1) at a photographic paper speed of 100 mm/sec using a multichannel physiologic data recorder (Sanborn 550 M). The standard limb lead best delineating the onset of ventricular depolarization was selected. Heart sounds were recorded with a Sanborn microphone with a frequency response of 50–250 Hz. A Statham P23AA strain gauge connected to a small funnel was placed over the carotid artery. Recordings were obtained between 8:00 and 10:00 a.m. in the supine and lateral positions following at least five minutes of rest after any change in position.

Total electromechanical systole (QS₂) was measured from the onset of the ventricular depolarization complex to the first high frequency vibration of the aortic component of the second heart sound. Left ventricular ejection time (LVET) was measured from the rapid upstroke of the carotid pulse to the incisure. The pre-ejection period (PEP) was obtained by subtracting the value for LVET from QS₂. At least 20 cycles were measured. The values were compared to the predicted values, corrected for heart rate (HR), using the regression equations of Weissler et al.:

\[
QS₂ = (-0.0020 \times \text{Heart Rate}) + 0.549
\]

\[
\text{PEP} = (-0.0004 \times \text{Heart Rate}) + 0.133
\]

\[
\text{LVET} = (-0.0016 \times \text{Heart Rate}) + 0.418
\]

Because the standard regression equations derived by Weissler et al. were based on data collected only in the supine position, we measured supine and lateral systolic time intervals in 21 nonpregnant control patients. Differences between the observed and predicted intervals were calculated and the statistical significance of these differences was tested using the unpaired t-test. Comparisons between values obtained in the supine and lateral positions in the control population were made using the paired t-test.

Results

Heart rate did not differ significantly between measurements in the supine and lateral positions in any trimester of pregnancy or in the postpartum period. The mean observed and predicted values for supine and lateral QS₂, LVET, PEP, and PEP/LVET for nonpregnant and pregnant women are given in tables 1 and 2, respectively, and in figure 2.

The values observed in the control population were not significantly different from those predicted, in either the supine or lateral posture. However, direct comparison of the lateral versus supine findings in the control population disclosed significant differences between the two positions with LVET shortened, PEP lengthened, and the PEP/LVET ratio increased in the lateral position (P < 0.001, paired t-test).

Table 1

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Abbreviations: Obs = observed; Pred = predicted values based on regression equations of Weissler et al.; SEM = standard error of the mean; QS₂ = electromechanical systole; LVET = left ventricular ejection time; PEP = pre-ejection period; and n = number of subjects.

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In the first trimester, mean \( Q_S \) and LVET did not differ from values predicted from Weisler's regression equations. However, supine PEP was significantly shorter \((P < 0.02)\) and the PEP/LVET diminished \((P < 0.01)\) when compared to predicted values whereas lateral values for PEP and PEP/LVET were not altered significantly. Similar changes were observed when comparisons were made with values obtained from our normal control population.

During the second trimester, average supine and lateral \( Q_S \) and LVET were within the range predicted either from the regression equation or control values. On the other hand, mean PEP and PEP/LVET showed highly significant decreases in the supine position \((P < 0.001)\) and significant decreases in the lateral position \((P < 0.02)\).

The greatest deviation from predicted values was observed in the third trimester. In the supine position, mean PEP was lengthened \((\text{observed } 108 \text{ msec, predicted } 98 \text{ msec})\) and mean LVET was markedly shortened \((\text{observed } 252 \text{ msec, predicted } 276 \text{ msec})\). This resulted in an insignificant decrease in total electromechanical systole but an elevated PEP/LVET ratio. The changes in LVET, PEP and PEP/LVET were highly significant at the \( P < 0.001 \) level. Systolic time intervals were also determined in the lateral position and compared to standard regression equations (fig. 2). In this position, there was a tendency for mean LVET to return toward predicted values \((\text{observed } 271 \text{ msec, predicted } 284 \text{ msec})\) although the difference continued to be significant at the \( P < 0.005 \) level. The average PEP was 104 msec \((\text{predicted } 100 \text{ msec, } P < 0.05)\). Again \( Q_S \) did not differ from predicted values \((P < 0.20)\) whereas the PEP/LVET ratio was increased \((P < 0.005)\).

Recordings were obtained from 23 women during the postpartum period \((\text{mean } 5.8 \text{ weeks, range } 2-18 \text{ weeks})\). No difference from predicted values were observed in mean \( Q_S \). In the supine position, LVET had returned to predicted levels. A barely significant decrease in lateral LVET was present which paralleled that seen in the normal control women in changing from supine to lateral position. While no significant alteration of PEP was evident in the supine position, PEP was prolonged in the
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lateral position (P < 0.001) when compared to the predicted or normal control population. The PEP/LVET ratio was significantly elevated above predicted for both the supine and lateral positions.

Discussion

Several important hemodynamic alterations occurring during pregnancy have been elucidated in previous studies. Most have shown a gradual rise in cardiac output as pregnancy progresses with peak values at 26 to 34 weeks of gestation. Ueland et al. found that cardiac output and stroke volume reached peak levels as early as 20 to 24 weeks of gestation with a gradual decline in these indices late in pregnancy, whether the patient assumed the supine or lateral position. These investigators also noted a decrease in cardiovascular reserve to the stress of moderate exercise during late pregnancy. However, in none of these studies was left ventricular function assessed.

The technique of systolic time interval analysis now provides a sensitive and safe method for evaluation of left ventricular function. The left ventricular ejection time (LVET) correlates well with stroke volume. The pre-ejection period (PEP) is closely related to true isovolumic contraction time and with left ventricular dp/dt, provided left ventricular end-diastolic pressure remains constant. The PEP/LVET ratio, which tends to remain relatively constant in normal individuals, often magnifies minor changes in either component and bears a significant inverse relationship to LV ejection fraction. Furthermore, the noninvasive nature of this method permits frequent serial observations.

The changes in systolic time intervals which were observed during pregnancy are small, but they were consistent and statistically significant. Evidence for their physiological significance is supplied by their correlation with established adjustments in maternal hemodynamics during normal human pregnancy. The most pronounced alterations in the systolic time intervals were observed in the last trimester, when PEP and PEP/LVET were increased and LVET was shortened. These changes suggest a decrease in stroke volume and left ventricular ejection fraction. Their reversion toward normal in the lateral position points to decreased venous return as the mechanism producing them. Several investigations have demonstrated either a reduction of stroke volume or cardiac output in the last trimester in the supine position. The mechanism proposed for decreased venous return implicates either partial or complete obstruction of the inferior vena cava by the gravid uterus.

In the first and second trimesters the abbreviation of PEP (fig. 2B) and consequent reduction in PEP/LVET (fig. 2D) suggest an enhancement of myocardial performance and an increase in ejection fraction. The effect of the hyperkinetic circulatory state of pregnancy has been likened to that of an arteriovenous fistula due to the placenta and to the presence of a “modified” arteriovenous shunt through the body as a whole. However, the maternal hemodynamic changes are not due entirely to the placenta or the nutritional requirements of the fetus, and effects of steroid hormones on myocardial contractility have been demonstrated. Ueland and Parer have demonstrated that estrogen can induce hemodynamic changes in sheep similar to those seen in pregnancy, and it is possible that the alterations in systolic time intervals observed during the first trimester may be due to the positive inotropic action of estrogen.

Improved left ventricular function could also be due to increased diastolic filling of the ventricle. Significant hypervolemia is present during gestation, and experimental and clinical investigation has confirmed that hypervolemia may be responsible for the significant changes in cardiovascular hemodynamics. Bader et al. demonstrated elevation of right ventricular end-diastolic pressure during the time period from the 25th to 35th week of gestation with a return to normal levels thereafter. If an increased diastolic filling volume and pressure were to occur in the left ventricle, enhanced ventricular performance could be explained by an increased myocardial fiber length (Starling's law of the heart) due to increased ventricular preload. In addition, decreased peripheral vascular resistance secondary to estrogen effect may contribute further to improved emptying.

The cause of PEP prolongation and diminished LVET in the lateral position during the postpartum period is not clear. Although the supine values demonstrated a similar trend, statistical significance was not attained. The PEP/LVET ratio, which accentuates minor differences in either parameter, was elevated in each position and possibly indicates a decreased ejection fraction. Whether these changes represent subclinical abnormalities of left ventricular function, perhaps a forme fruste of peripartum cardiomyopathy, is not known.

Acknowledgments

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