The Electrocardiogram in Pregnancy

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Abstract

This study set out to assess the change in frontal plane ECG axes during pregnancy in a cross sectional study and to determine if there were any maternal factors that might affect the ECG. In addition, the change in ECG axes immediately before and 48 hours after delivery was also studied. ECGs from 149 women with average age 29.4 ± 6.0 years were analysed. 18 women had an ECG recorded before and after delivery. 50% of women were obese or morbidly obese. Body mass index correlated with QRS axis ($r=-0.32$, $p<0.001$) and T axis ($r=-0.28$, $p<0.004$). The mean QRS and T axes in pregnancy were 14º and 17º superior to the normal values respectively ($p<0.001$). The mean QRS and T axes shifted inferiorly by 5º and 12º respectively after delivery ($p<0.01$). Serial ECG recordings are needed to enhance ECG recording in pregnancy where required.

1. Introduction

Little is known about the characteristics of the 12-lead electrocardiogram (ECG) in pregnancy. Yet, cardiovascular disease ranks as the prime indirect cause of maternal death as well as the most common cause of maternal death overall [1]. Alterations in cardiovascular parameters during pregnancy suggest the likelihood of an altered ECG during pregnancy. There is evidence from previous studies to suggest that some electrocardiographic parameters are, indeed, altered by the pregnant state [2-6] and the known cardiovascular adaptations to pregnancy represent potential mechanisms by which these alterations may arise.

The QRS axis is a measure of the overall direction of depolarisation of the ventricles [7]. An abnormal QRS axis superior to -30º may indicate a change in the position of the heart, left anterior fascicular block or left ventricular hypertrophy [7].

Particular attention has been placed on the QRS axis and its direction of shift (if any) during pregnancy. Studies have produced conflicting results with regards to the direction of this shift [3] and its time course during gestation [2-6]. Despite the mixed nature of the evidence, there is a clear suggestion that pregnancy affects the ECG at some time point and that there is restoration of the normal axis late in pregnancy or following delivery [2-6]. However, the underlying cause and mechanism of a potential shift during pregnancy has not been clearly elucidated.

As far as is known, the basic studies of the ECG during pregnancy were completed before widespread use of automated ECG analysis (AEA). The University of Glasgow ECG core laboratory, based at Glasgow Royal Infirmary (GRI), has developed an interpretive program [8] (the "University of Glasgow Program") that is in use worldwide. A pre-requisite in developing the software was the acquisition of "normal limits" for each ECG parameter. These were obtained in Glasgow in the 1980s by collecting large databases comprising of hundreds of individuals, males and females, of all ages, and representative of the normal healthy population [9]. However, no "normal limits" have been identified based on pregnancy status and therefore, the accuracy of AEA in the obstetric population is essentially unknown.

The obstetric population is a heterogeneous group with varying demographics. A number of maternal factors such as body mass index (BMI), parity and age are known to affect pregnancy outcomes [10, 11], and perhaps these factors also exert independent effects on the ECG. Obesity has detrimental effects on the health outcomes of mothers and their babies [10]. In fact, booking BMI (a surrogate for pre-pregnancy weight) has shown a stronger relationship with adverse health outcomes than gestational weight gain [12]. Managing and assessing the obese pregnant woman is therefore an urgent priority and, in this study, it is hypothesised that booking BMI, as well as other maternal factors, impact on the ECG.

This project, therefore, aimed to study a sizeable cohort of women cross-sectionally in order to characterise the maternal ECG during pregnancy, and a subgroup of these women longitudinally to observe the impact of delivery on the ECG. The study aimed to a) make use of the pre-established Glasgow normal limits as a reliable control representative of the normal healthy population in order to assess how the pregnant ECG differs from the non-pregnant ECG b) assess serial change in ECG components throughout gestation c) evaluate the effect of delivery on the ECG d) identify the effect of maternal characteristics, notably booking BMI, on ECG components.

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2. Methods

Pregnant women, aged 18 to 45, across all stages of gestation were recruited for this cross-sectional study. Only singleton pregnancies were eligible. Women with cardiovascular disease, metabolic disease, hypertension (essential or pregnancy-induced), preeclampsia or any condition likely to affect the cardiovascular system and hence the ECG were specifically excluded. Women were also excluded if they were in labour, in any form of distress, or from non-caucasian backgrounds as race is known to affect the ECG [8].

The study was conducted in the antenatal wards and pre-natal assessment clinics of the Princess Royal Maternity Unit of GRI. Each participant was given an explanation of the study protocol and a patient information sheet before being asked to sign a consent form. These documents were reviewed and approved by the Glasgow West of Scotland Research Ethics Committee 2. For each woman, the name, age, parity, gestation, booking BMI (including height and weight when available), blood pressure, smoking and drinking status and past medical history were recorded. This information was obtained from each patient herself and verified using the patient's case notes.

For a small subset of women, an ECG was recorded prior to and after delivery. For practical reasons, only women preparing for caesarean section were eligible. Each of these women was to undergo a lower uterine segment caesarean section as it is the recommended surgical procedure. An interval of at least 48 hours was kept between the 1st ECG recording, prior to delivery, and the 2nd ECG recording following delivery. For each woman, the same demographic information specified above was recorded. The 1st ECG recording for each woman was also included in the data that was analysed in a cross-sectional manner.

An Atria 6100 was used to record the ECG in the same supine position for each woman, who was allowed to rest on 2 or 3 pillows. The analysis was performed by the Glasgow Program [8] which is integrated into this machine. The P, QRS and T axes were automatically measured by the Atria 6100 as was heart rate. The values were subsequently manually entered into an Excel spreadsheet for statistical manipulation. The frontal plane QRS-T angle was calculated from the available data.

The ECG recordings were transmitted via a telephone line to the central computer in the ECG core laboratory for storage and further analysis on a regular basis throughout the study. These ECGs were stored anonymously and identified using participant codes. Only 4 ECG measures were analysed for this study.

The data was analysed using the statistical software package Minitab 15. In order to assess the data for normality, formal tests of normality were performed as well as preliminary informal analyses using appropriate descriptive statistics and graphical displays. A 2-sample t-test was used to evaluate whether any of the ECG measures significantly differed from the pre-established normal limits for healthy women of the same age range. Any difference was presented with its 95% confidence interval and a p-value <0.05 was regarded as significant.

The data was informally assessed for the presence of any relationships between the ECG measures and the covariates of interest (gestational age (GA), booking BMI, parity and maternal age), and to identify any co-linearity, by the use of matrix plots.

An initial univariate analysis was used to examine the relationship between each of the covariates and each of the ECG measures. The relationships were represented by a Pearson correlation coefficient and corresponding p-value. Subsequently, a general linear model was fitted to the data using gestation, booking BMI and other maternal factors as predictors in the model and the ECG measure of interest (QRS axis, T axis, P axis or QRS-T angle) as the response. For any co-efficient obtained from this multivariate analysis, a p-value <0.05 was regarded as significant.

A paired t-test was performed on the longitudinal data to measure the effect of delivery on each of the ECG measures. Methods of assessing normality similar to those specified above were used. Any difference was presented with its 95% CI and a p-value of <0.05 was regarded as significant.

3. Results

A total of 149 patients were recruited for this study but the analysis was performed on 138 of these patients as some were excluded retrospectively because it was found that they did not satisfy the inclusion criteria. The average age was 29.4± 6.0 years and exactly half of the study group, in whom BMI was available, were overweight or obese (mean BMI=27±6.6kg/m^2). With respect to gestational age, 21, 30 and 87 women were in the first, second and third trimester respectively. of their pregnancy. With respect to parity, 39% were primigravidae. Fifteen were current smokers and 109 consumed some alcohol during their pregnancy.

3.1. Cross-sectional study

The assumption of normality was sustained in all the data. The univariate analysis demonstrated that the QRS axis did not correlate significantly with GA ($p = 0.139$) and the T axis was the only ECG measure found to correlate with GA ($r = -0.34$, $p < 0.001$). The only ECG parameters that demonstrated a relationship with BMI were the T axis and the QRS axis ($r = -0.28$ and -0.32 respectively, $p = 0.004$ and 0.001 respectively). In addition, it was also found that the P axis significantly correlated with maternal age (r = 0.18, p = 0.039).

Subsequent multivariate analyses using general linear models demonstrated that BMI and gestation were the only variables to independently predict the T axis (p=0.023 and <0.001 respectively). However, when both of these variables were fitted into the model together, the correlation between BMI and the T axis was found to be more significant than the relationship described by the univariate analysis. Hence, although BMI and gestation are independently associated with T axis, they also represent dependent predictors of the T axis.

BMI was also seen to predict the QRS axis independently of GA and other maternal factors that were input into the model (parity and maternal age) (coefficient = -1.0012, p = 0.006). It was found that BMI correlated even more significantly (coefficient = -1.053, p = 0.001) with this ECG measure when fitted as a single variable.

Parity and maternal age did not contribute significantly to any of the models specified to predict ECG measures of interest. GA was the only variable seen to correlate significantly with the P axis (coefficient = -0.077, p = 0.012). However, this relationship ceased to be significant once GA was input as an independent predictor of the P axis. The QRS-T angle, on the other hand, did not show a relationship with any of the variables of interest.

Table 1. Mean axes over all subjects in pregnancy v normal limits.
CI = Confidence interval.

	Pregnancy	Normal	Mean Difference (95% CI)	p-value
QRS axis	38º ± 22	55 ± 25	13.5 (8.9-18.0)	< 0.001
T axis	22º ± 16	39 ± 15	16.8 (13.7-19.9)	< 0.001
QRS-T angle	16º ± 22	13 ± 25	3.4 (-7.3 -1.2)	0.149

Table 1 shows the pregnant population means (± SD) for each of the ECG measures, and the corresponding normal limits. The estimated difference between the mean pregnant QRS axis and the normal mean QRS axis was significant suggesting that the QRS axis in pregnancy is more superiorly directed than the QRS axis in the non-pregnant individual. The results for the 1st, 2nd and 3rd trimester (TM) QRS axes demonstrated that the mean for the 1TM did not differ significantly from the normal mean QRS axis (p = 0.069). The mean QRS axis for the 2TM appeared very similar to that for the 1TM. A large difference was observed between the mean QRS axis in the 2TM (43º) and 3TM (35º) of pregnancy, however. The results for the T axis suggest a more superiorly directed T axis during pregnancy compared to normal. Again, the 1TM (30º). and 3TM (19º) values differed considerably. The QRS-T angle, however, did not vary significantly from the pre-established normal limits (p = 0.149) presumably since both QRS and T axes moved superiorly during pregnancy.

3.2. Longitudinal study

18 women had an ECG recorded before and after delivery. The QRS, T and P axes were more inferiorly directed following delivery (p = 0.009, <0.001, 0.017 respectively) compared to pre-delivery values, i.e. there was a move back to the normal orientation. However, the magnitude of the changes (Table 2) did not correlate significantly with birth-weight. The QRS-T angle also differed significantly after delivery, but in the opposite direction to the other ECG measures (p = 0.006).

Table 2. Estimation of mean difference in ECG measures before and after delivery. CI = Confidence interval.

	Before delivery	After delivery	Mean Difference (95% CI)	p-value
QRS axis	29.94º	35.22	5.28 (1.52 – 9.04)	0.009
T axis	13.06º	25.06	12.00 (8.34-15.66)	< 0.001
P axis	31.83º	42.67	10.83 (2.17-19.49)	0.017
QRS-T angle	16.89º	10.17	-6.72 (-11.24-2.20)	0.006

4. Discussion

The study demonstrated that certain ECG measures are altered by the physiological state of pregnancy as well as subsequent delivery and that in addition, many of these changes are affected by maternal characteristics, notably booking BMI.

The results suggest that GA correlates negatively with the T axis, i.e. the T axis rotates superiorly with advancing gestation. However, GA was not seen to impact on any other ECG measure. It is surprising that the QRS axis was not significantly affected by GA, as previous studies have reported important changes in the QRS axis during gestation [2-6]. In this study, no correlation between the QRS axis and gestation was identified but after grouping the cohort of women into their respective trimesters, it seemed apparent that the 3TM cohort differed considerably from the 1TM cohort and the normal limits, in terms of mean QRS axis. Therefore, although this study was not able to detect a progressive shift in the QRS axis during gestation, there was still evidence to suggest the initiation of an upward shift probably in the later stages of pregnancy, which is in keeping with results from previous studies [5, 6].

Moreover, a statistically significant difference was observed between the sample mean for the QRS axis and the normal mean QRS axis in non-pregnant women of the same age. However, it is possible that the skewed distribution of GA in this study, which has led to an over-representation of 3TM pregnancies in the study cohort, has given rise to the observed difference which again, emphasises the fact that GA is probably an important predictor of the QRS axis in the later stages of pregnancy.

It is therefore not possible to clearly elucidate the exact physiological mechanisms that underlie the results obtained from this study. However, assessing the difference in ECG measures before and after delivery represents a means of evaluating the role of the physiological load of pregnancy in modifying the ECG.

The return of the QRS axis to its original "pre-pregnancy" direction, thought to occur in late pregnancy [6], or after delivery [5], is thought to be a consequence of "lightening" – the process whereby the uterus assumes a lower position, thereby releasing the pressure it exerted earlier in the pregnancy on the diaphragm [4]. The longitudinal study, in the small subset of women, demonstrated that delivery had a significant impact on the ECG characteristics. The QRS, T and P axes were more inferiorly directed following delivery, which could possibly be explained by the "lightening" phenomenon. In order to specifically identify at which point in time this return to pre-pregnancy levels is initiated, a longitudinal study with monthly ECG measurements would be a more sensitive approach as it would provide more information about serial ECG changes during the actual gestational period as well.

This study has also demonstrated that booking BMI exerts an independent effect on the ECG in pregnancy. With increasing BMI, the QRS and T axes become more inferiorly directed. The burden of obesity is manifesting itself by its increasing prevalence in all age groups and socioeconomic classes and by its adverse effects on health. In fact, exactly half of the study group in whom BMI was available were overweight or obese. Moreover, the univariate analysis demonstrated that the P axis was significantly associated with maternal age. Recognising that maternal factors that have such an important bearing on pregnancy health outcomes [10] affect ECG measures could potentially lead to improvements in future ECG diagnostic software and enhance ECG interpretation in pregnancy.

An important limitation was the over-representation of 3TM pregnancies in our study cohort and the very few numbers of early pregnancies (i.e <10 weeks) in our cohort. This is in fact a difficult limitation to circumvent as many women may not even be aware of their pregnancy before 10 weeks into the gestation.

This study has provided important results relating to the characteristics of the ECG in pregnancy. However, the differences observed between the mean ECG measures of the pregnant population and those of the normal population are not clinically significant. In fact, it was reassuring to find that no participant demonstrated a QRS axis outside of the normal range of -30º to 90º [7]. It is therefore possible to surmise that criteria in use at present can be used in pregnant women without any need for change. Of more importance would be to study longitudinal change in the ECG throughout gestation.

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