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PRACA POGLĄDOWA
REVIEW

Electrocardiographic changes in pregnancy and postpartum period

Zmiany elektrokardiograficzne u kobiet ciężarnych i w okresie połogu

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ABSTRACT

Pregnancy and labor, though a physiological and natural time in a woman's life, are associated with many changes to the woman's body. The overall blood volume, cardiac output and heart rate of a pregnant woman differ significantly from pre-pregnancy time. This again has a significant effect on the electrical activity of the heart. Abnormal electric activity of the heart might be confused with an ongoing or commencing heart disease. Moreover, pregnancy, labour and especially the post partum period are also known to increase the risk of cardiac events including arrhythmia, myocardial infarction or even sudden cardiac death, especially in women with a present cardiac disease like LQTS (Long QT Syndrome). In order to reduce the occurrence of adverse cardiac events and enable their early detection and diagnosis, there is a need for a more thorough understanding of electrocardiographic changes occurring during pregnancy. Unfortunately, data regarding changes of the electric activity of the heart during pregnancy are scarce. The aim of this work is to give an outline on the electric activity changes of the heart of a pregnant woman. The available data confirm that intense changes in the cardiovascular system caused by pregnancy strongly affect the electrical activity of the heart.

KEY WORDS
pregnancy, postpartum, ECG, repolarization

STRESZCZENIE

Ciąża i poród, choć należą do fizjologicznego i naturalnego czasu w życiu kobiety, wiążą się z wieloma zmianami w jej organizmie. Całkowita objętość krwi, rzut serca i tętno u kobiet w ciąży znacznie odbiegają od wartości przedciążowych. Zmiany te mają znaczący wpływ na aktywność elektryczną serca. Zmieniona aktywność elektryczna serca może być mylona z trwającą lub nowo powstałą chorobą serca. Ponadto w okresie ciąży, porodu, a również połogu w sposób istotny zwiększa się ryzyko zdarzeń sercowych, w tym zaburzeń rytmu, zawału serca lub nawet nagłej śmierci sercowej, zwłaszcza u kobiet z chorobą serca w wywiadzie, takich jak LQTS (zespół wydłużonego odcinka QT). W celu zmniejszenia występowania niepożądanych zdarzeń sercowych oraz umożliwienia ich wcześniejszego

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wykrywania i diagnostyki istnieje potrzeba bardziej dogłębnego zrozumienia zmian elektrokardiograficznych zachodzących w okresie ciąży. Niestety, dane dotyczące zmian elektrokardiograficznych w ciąży są nieliczne. Celem naszej pracy poglądowej jest przedstawienie zarysu zmian elektrycznej aktywności serca u kobiety ciężarnej. Dostępne wyniki badań dowodzą, że intensywne zmiany w układzie krążenia spowodowane ciążą silnie wpływają na aktywność elektryczną serca.

SŁOWA KLUCZOWE
ciąża, połóg, EKG, repolaryzacja

INTRODUCTION

Pregnancy and labor, though a physiological and natural time in a woman's life, are associated with many changes to the woman's body. The cardiovascular system undergoes possibly the most intensive changes of all human systems. The overall blood volume, cardiac output and heart rate of a pregnant woman differ significantly from pre-pregnancy time. This again has a significant effect on the electrical activity of the heart. Abnormal electric activity of the heart might be confused with an ongoing or commencing heart disease. Moreover, pregnancy, labour and especially the post partum period are also known to increase the risk of cardiac events including arrhythmia, myocardial infarction or even sudden cardiac death, especially in women with a present cardiac disease like LQTS (Long QT Syndrome) [1,2]. A better understanding of pregnancy electrocardiographic changes can possibly lead to improvement of diagnostics, successful prevention of cardiac events and a reduction of sudden cardiac death in women during pregnancy. The aim of this work is to give an outline of the electric activity changes of the heart of a pregnant woman.

PREGNANCY CHANGES

Most of the changes to the cardiovascular system are connected with a rising overall Blood Volume (BV). During pregnancy BV is increased by a mean of 30–50% depending on the BMI of the woman, ranging between 20% for slim patients and reaching a 100% increase in BV in obese patients. The plasma volume rise is about 1250 ml, a little under 50% of the average non-pregnant volume of white European women which normally is about 2600 ml. The red cell mass increases by relatively much less, a rise of about 250 ml (some 18% of the non-pregnant volume) in women who take no supplemental iron, and between 400 and 450 ml when iron supplements are taken [3]. These changes take an almost linear form starting in the first trimester and reaching the highest volume between the 32nd and 34th week of gestation with a slow decline of BV towards the end of pregnancy [4]. Cardiac output increases by 45% and the heart rate by 13% when compared to pre-pregnancy time (see Table I) [5].

Heart hypertrophy combined with changes in the heart axis significantly affect electrocardiographic readings. The rapid increase in BV, volume overload as well as an increased stretch and force demand combined with an increase in hormone and sympathetic modulation is responsible for hypertrophy of the heart myocardium changing the electrical properties [6,7]. However, these are not the only changes affecting the electrical field of the heart. We have to also consider spatial changes to the inner organs. During pregnancy enlargement of the uterus causes a changed spatial position of the chest organs. The fundus of the uterus reaches the costal arch in the 36 week of gestation, which is the highest position of the uterus during pregnancy. The high position of the uterus and the pressure on the diaphragm results in pushing the heart to the left side of the chest and changing the position to a more horizontal one. This is again connected with electrical heart field changes [8].

Table I. Hemodynamic Changes of Pregnancy
Tabela I. Zmiany hemodynamiczne zachodzące w ciąży

Parameter	Nonpregnant	Trimester 1	Trimester 2	Trimester 3
Heart rate (beats/min)	70	78	82	85
Systolic blood pressure (mmHg)	115	112	112	114
Diastolic blood pressure (mmHg)	70	60	63	70
Cardiac output (l/min)	4.5	4.5	6	6
Central venous pressure (mmHg)	9.0	7.5	4.0	3.8
Blood volume (ml)	4000	4200	5000	5600
Hematocrit without iron (%)	40	36	33	34
Hematocrit with iron (%)	40	36	34	36
White blood cell (cell/mm^3)	7200	9100	9700	9800

Table II. Comparison of QRS axis (degrees) between three groups [9]
Tabela II. Porównanie osi QRS pomiędzy trzema grupami (w stopniach) [9]

Variables		Controls [A]	2nd TM [B]	3rd TM [C]	Difference between groups		
					F value	A–B	A–C
QRS axis (in degrees)	Mean + SD	64.10 ± 6.8	53.0 ± 16.7	45.9 ± 22.1	F -15.31 p < 0.001 HS	p < 0.01 S	p < 0.01 S
	Range	48–82	(-3) -82	(-3) -80			

HS – highly significant, S – significant, NS – non-significant

Table III. Comparison of T-wave abnormalities in lead III between three groups [9]
Tabela III. Porównanie zmian fali T w odprowadzeniu III pomiędzy trzema grupami [9]

Control (A)			2nd Trimester (B)			3rd Trimester			Difference between groups	
Flat n (%)	Inverted n (%)	Total n (%)	Flat n (%)	Inverted n (%)	Total n (%)	Flat n (%)	Inverted n (%)	Total n (%)	A–B	A–C
5 (10)	20 (40)	25 (50)	12 (24)	23 (46)	36 (70)	13 (26)	27 (54)	40 (80)	4.17 p < 0.05	9.89 p < 0.01

QRS axis

All the above mentioned changes to the woman's body throughout pregnancy have an effect on the electrical activity of the heart and electrocardiographic (ECG) recordings. First of all, the QRS axis, which is a measure of the depolarization of the ventricles, is changed. Sunitha et al. observed a significant amplitude decrease and a left QRS axis deviation in the pregnant group when compared to the controls. The grade of the deviation was increased along with pregnancy progress (see Table II) [9].
Another research group lead by Misra J. reported a left axis shift starting in early pregnancy. In their study it was explained with an increased left ventricle load due to rising blood volume in early pregnancy and diaphragm elevation in the late term of pregnancy [10]. Another research group also observed a shift towards the left axis of the heart during pregnancy [11]. Singh et al. stated that an electrical axis of $+60^{o}$ corresponding to the semivertical heart position was commonest in pregnant women starting in the first two trimesters. The change corresponded to the rising of the diaphragm during pregnancy and a more horizontal plane of the heart [8,12]. This data is confirmed by other studies where most pregnant women still present a frontal-plane QRS axis [8,13].

Q wave

According to Sunitha et al., there is a significant increase in the incidence of prominent Q waves in lead II in pregnant women in the 2nd trimester and in leads II, III, avF in pregnant women in the 3rd trimester. These ECG changes may either be the result of an increase in circulating vasopressor agents or may reflect diaphragmatic changes [9]. Nevertheless, Veille et al. found that subjects "late" in pregnancy had significantly fewer Q waves in leads II, III, and aVF than the nonpregnant group did [14]. Consent on this matter is to be achieved. Misra J et al. reported a Q wave of less than one quarter of the length of the R wave in lead III in 40% of the cases studied and a prominent Q wave was noted in 6.66% of the cases. It was concluded that although the presence of a Q wave in lead III has been widely accepted, its etiology still remains obscure [10].

T wave

The incidence of T-wave abnormalities like flat T-waves and inverted T-waves in lead III is significantly more frequent in pregnant women than in the nonpregnant. Moreover a significant increase in the incidence of T-wave abnormalities in leads V2–V3 is observed in the 2nd trimester and in leads V1–V3 in the 3rd trimester in pregnant women compared to nonpregnant women (Table III.) [9].
T-wave inversion in V2 was more frequent in the pregnant than the nonpregnant subjects [14]. Misra J and his colleagues in their study observed a negative T-wave in lead III in 70% subjects of normal pregnancy. The T-wave abnormalities in the normal pregnant women in their study was detected in almost all the chest leads [9]. Veille JC et al. observed T-wave inversion in V2 which was more frequent in the pregnant than in the nonpregnant patients. Two cases in their study had marked T-wave peaking and one had a biphasic T-wave in V2 out of the total cases studied [14]. Akinwusi et al. report that a T-wave inversion in lead III and also in other leads was commoner in the pregnant group than the controls (23.2 vs 10%). By contrast, tall and broad T waves in V2–V6 occurred more commonly in the control group than the pregnant group. T-wave inversion in lead III ± any other lead was commoner in the pregnant group than the controls (23.2 vs 10%) (Table IV) [13].

Table IV. ECG findings during pregnancy [13]
Tabela IV. Zmiany w EKG w czasie ciąży [13]

Parameter	Pregnant (n = 69)	Non-pregnant (n = 70)	p-value
Mean pulse rate	84 ± 11.05	75.27 ± 8.51	0.043
DBP < 60 mmHg	64.7% (45)	24.3% (17)	< 0.005
SBP (90–120 mmHg)	80.9% (56)	78.6% (55)	0.704
Cardiac findings	41.2% (29)	12.9% (9)	< 0.0005
Mean ECG heart rate	88.34 ± 11.46	75.16 ± 12.22	0.0215
LVH (RI > 12 mm)	10.2%(7)	0	0.0189
All LVH criteria	18.8% (13)	7.1% (5)	0.0399
Rsr' (mostly lead III)	5.8% (4)	14.3% (10)	0.0964
Rsr' in avF	20.3% (14)	5.1% (4)	0.0105
ST segment – isoelectric line (J junction on isoelectric line)	97.1% (67)	75.7% (53)	< 0.0005
Mild ST elevation (Negroid-pattern ST segment)	2.9% (2)	24.3% (17)	< 0.0005
T-wave inversion – lead III ± any other lead	23.2% (16)	10.0% (7)	0.0364
Tall and broad T waves in V_2– V_6	5.8% (4)	18.6% (13)	0.0215
Prolonged QTc	4.3% (3)	8.6% (6)	0.505

Percentage of distribution (absolute number of patients). DBP = diastolic blood pressure; SBP = systolic blood pressure.

In another study, it is shown that out of the 100 normal pregnant women, 14% of the subjects showed ST changes affecting both limb and chest leads. In another 28% of the subjects there were changes of similar character but limited to one or more limb leads. The type of change noted was sagging of the ST segment, which was depressed to a depth of 0.5 to 1.0 mm, the T-wave in the same lead usually being of low voltage. The leads affected were mainly those from the left side of the precordium, V3 to V6 in most instances, the limb leads involved were according to cardiac position [15]. According to Akinwusi et al. in a Nigerian pregnant women study group, a mild ST-segment elevation (J junction of the ST segment arising from within 1 mm of the isoelectric line, otherwise known as one of the 'normal variants' or the 'normal Negroid pattern') was found in 2.9% of the pregnant patients, against 24.3% in the control group. An isoelectric ST segment was also commoner in the pregnant subjects than the controls (97.1 vs 75.7%) [15]. Perrotta et al. during labor ECG observed a T inversion (59% of patients) and ST shift < or = 0.5 mm (30% of patients) in precordial and inferior leads. These ST-changes were related to the drop in plasmatic K, hyperventilation, hormonal changes, uterine contractions, O_2-consumption and pain. They were not ischemic and disappeared after delivery [16].

QT interval

The QT interval reflects the complex and interrelated aspects of cardiac electrophysiology, cardiac geometry, torso shape, tissue impedance, and biological signal processing [17]. The QT interval and also the more frequently used and a more precise measurement known as corrected QT (QTc) adjusted to the patient's heart rate with Bazett's formula are significantly prolonged during pregnancy. The QTc dispersion time is the difference between the longest and the shortest QT value measured in each of the 12 ECG leads. A longer QTc dispersion time is connected with a higher risk of arrhythmias and cardiac events posing greater risk to patients with a cardiac disease history or latent cardiac disease [18,19].

A study by Lehmanova et al. reports changes in A–V conductance (PQ interval) and ventricular activity time (QT interval). Both shorter PQ and QT intervals could be related to the increased heart rate. However, the QT interval normalized for the heart rate (QTc) was prolonged, suggesting the prolonged relative duration of ventricular electrical activity [7].

Lehmanova et al. reported in their study a shorter QT interval of 323 ms in late pregnancy and an increase in QTc in late pregnancy to a mean of 442 ms. Moreover the QT and QTc dispersions were longer. The difference is possibly connected with the rising heart rate during pregnancy [20]. Another research group confirms that QT and QT dispersion time are prolonged in pregnancy, but showed that maternal age did not affect the heterogeneity of ventricular repolarization or propensity of ventricular arrhythmias in pregnancy [21]. In a study by Rahsba et al., a great increase in arrhythmic events in LQTS patients is shown during the postpartum period. This may be related to a decrease in heart rate and an associated increase in the QT interval, which results in an increased QTc interval [1] (Table V).

Table V. Statistically significant differences in electrocardiographic parameters, QT and QTc dispersion ($p < 0.05$) [20]
Tabela V. Istotne statystycznie różnice w parametrach elektrokardiograficznych, QT i dyspersji QTc [20]

Electrokkardiographic parameters	Control group (n = 18)		Late pregnancy (n = 37)		After delivery (n = 37)
Heart rate (1/min)	75.2	(11.5)	102.1	(18.2)	97.2
QT interval (ms)	365.2	(30.5)	323.7	(29.3)	334.3
QTc interval (ms)	405.3	(20.7)	442.3	(28.9)	418.5
QT dispersion (ms)	34	(12)	73	(18)	64
QTc dispersion (ms)	36	(13)	79	(21)	62
T wave f axis (deg)	27.6	(14.8)	18.8	(9.1)	16.0

Numbers are mean values ± S.D., f – frontal plane

We have not found any data relating to new indicators of ventricular repolarization like QTpTe (QT- peak T-end) in normal pregnancy. Reports show QTpTe as a reliable indicator of ventricular repolarization and good predictor of dangerous arrhythmias and cardiac death [22]. The only available data come from Guillon et al. who report an increase in QTc and QTpTe interval time associated with the usage of drugs during pregnancy and labor like oxytocine and bupivacaine (spinal and local anesthesia) [23].

CONCLUSION

Data regarding pregnancy changes to the electric activity of the heart are scarce. We have found very little data regarding labour and no data concerning postpartum ECG changes. However, the available data provide enough evidence to state that pregnancy significantly changes the electrical activity of the heart. The summary of the most prominent ECG changes is shown in Table VI.

First of all, the electrical axis of the heart is shifted towards the left side. There is also consent among researchers that Q waves are more prominent. There are many changes to the ST repolarization period, where the data are sometimes contradictory. Most researchers agree that T-wave abnormalities including inversion and flattening are more common among pregnant women. Moreover, the QT, QTc intervals and QTc dispersion times are prolonged, which is potentially proarrhythmic. There is little data regarding new indicators of ventricular repolarization and arrhythmia predictors like the QTpTe index. Still many aspects of the electric activity of the heart during pregnancy are undetermined, most of them relate to QT repolarization time. It is widely known to be the most critical time regarding arrhythmogenic potential and cardiac events. Respectively, further research into this matter is required to improve screening and prediction of arrhythmogenic heart activity during pregnancy.

Table VI. Summary of most prominent ECG changes during pregnancy
Tabela VI. Podsumowanie najbardziej ewidentnych zmian w EKG w trakcie ciąży

Most prominent ECG changes during pregnancy
Left shift of heart axis
Changes in Q wave in lead II/III
T-wave abnormalities
Shortened PQ and QT interval
Prolonged QTc, QTp-Te, QTc dispersion time

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