

Physiological Changes in Cardiovascular System during Normal Pregnancy: A Review

Madhuri Taranikanti¹

¹Department of Physiology, ESIC Medical College, Hyderabad, Telangana, India

Address for correspondence Madhuri Taranikanti, MD, Professor and Head of Department, Department of Physiology, ESIC Medical College, Sanathnagar, Hyderabad 500038, Telangana, India (e-mail: madhuri.taranikanti@gmail.com; dr.taranikanti.madhuri@esic.in).

Indian J Cardiovasc Dis Women-WINCARS 2018;3:62–67

Abstract

Pregnancy is a complex biological process associated with changes in physiologic functions of the body. Dramatic changes take place in the cardiovascular physiology leading to gradual adaptation of these changes by the body of the pregnant woman. Cardiac output increases during pregnancy to 30 to 50% above the prepregnant levels. The increase in cardiac output occurs due to increase in stroke volume initially during gestation and later by increase in heart rate. These changes in cardiac output are attributed to either neurohumoral factors such as estrogen and progesterone or placental factors. Maternal body position affects cardiac output with highest in kneel-chest and left lateral positions. Along with these changes, variations in heart rate, blood pressure, and blood volume are observed following a specific pattern of change during pregnancy. Hence, it is necessary to understand the cardiovascular changes during pregnancy to interpret, predict, and diagnose any cardiac disease efficiently.

Keywords

- ▶ cardiac output
- ▶ cardiovascular adaptations
- ▶ neuro humoral factors
- ▶ pregnancy

Introduction

The term *pregnancy* is derived from the Latin words *pre*- meaning before and *-gnatus* meaning birth. It is the period from the time of fertilization to birth. It is a complex biological process that utilizes several resources of the mother as a result leading to widespread effects on the body of the pregnant woman. Pregnancy is a special physiologic condition that enables study of various bodily adaptations in normal individuals. Immediately after conception, growth of the fetus occurs tremendously by each week with changes in several systems to cause adaptation of the maternal body to the growing fetus.¹ Changes occur in anatomical and physiologic parameters to protect the mother and support the growing fetus only to return to the prepregnant levels after the birth of the baby. One of the systems that changes remarkably during pregnancy is the cardiovascular system. These changes are necessary for a successful pregnancy outcome. To meet the increased metabolic needs of the tissues of the mother and the increasing demands of the growing fetus, blood flow to various organs increases. Metabolic shifts serve largely to support fetal demands and maximize maternal efficiency.^{2–5} Increasing blood flow is kept

intact by the uninterrupted cardiac contractions to provide the required nutrients and oxygen. Hence, the metabolic needs of the heart rise and depend on continuous energy supply.⁶ Observations by Lindhard in 1915 that cardiac output (CO) increases during pregnancy formed the basis for subsequent work in circulatory physiology in pregnant woman. Structural changes occur in the heart with lateral and upward shift of cardiac apex to fourth intercostal space. Increased volume and shift of the heart provide more dullness over precordial region. Such alterations often lead to presence of systolic flow-type murmur commonly seen in pregnancy. Risk assessment for estimation of maternal and offspring risk is necessary and may be done through prepregnancy counseling and stratified as per the principles of modified World Health Organization (WHO) classification of maternal cardiovascular risk.⁷

Cardiovascular Physiology of the Heart

Cardiac Output during Pregnancy

Dramatic changes occur in CO early during pregnancy, starting in the first trimester and reaching peak by fifth month of gestation and continuing till delivery.⁸ Literature suggests an

increase of 30 to 35% in CO over and above the nonpregnant levels. An increase in CO was demonstrated as early as 1949, but the cause for the increase was not clearly established whether it was due to increase in contractility of the heart or due to increased stroke volume (SV) caused by increased end diastolic volume.⁹ It is also not clear as per literature the precise time of peaking of CO during gestation. However, studies have shown that CO shows a peak anytime between 25 and 30 weeks.¹⁰ Several studies have shown that it is necessary to maintain a stable CO from the second trimester of pregnancy, which is achieved by increase in heart rate (HR) and decrease in SV¹⁰⁻¹⁶ (► Fig. 1). A steady CO is seen from 24 weeks of gestation with a small decrease closer to term.¹⁵ Increased CO during the last trimester has not been projected sufficiently as a variety of studies are available showing a decrease, no change, or an increase, and have been mostly attributed to subjective adaptations of the mother during pregnancy along with interference by anthropometric variables of the mother and positioning of the body.^{13,16-26} Studies have also shown that this increased CO is likely to be enhanced in subsequent pregnancies.²⁷ The changes in CO are attributed to either neurohumoral factors such as estrogen and progesterone or placental factors.²⁸ Placenta behaving as a functional arterio-venous (AV) fistula leads to an increase in maternal HR too. As early as eighth week of gestation, the CO rises by 20%, the possible mechanism associated being peripheral vasodilatation. Factors mediating this vasodilatation are synthesis of nitric oxide by endothelium and prostaglandins, leading to a fall in systemic vascular resistance and further increase in CO to almost 40%.¹⁶ An increase in SV and an increase in HR are the main contributors for this mechanism. Relaxin produced by corpus luteum is found to have an effect in reducing the total peripheral resistance, thereby increasing CO and systemic arterial compliance.²⁸⁻³⁰ Though the proportion of CO to various organs remains similar to the prepregnant levels in the first trimester, due to the absolute increase in CO with advancing pregnancy, blood flow to all organs such as the

uterus, breasts, kidneys, skin, brain, and heart increases by 50%. There is a combination of increased preload, increased contractility and reduced afterload due to fall in systemic vascular resistance, all contributing to increased CO to nearly 50%, thereby increasing the efficiency of the heart.¹⁹ There is an increase in coronary blood flow as coronary arteries become sensitive to stress-induced vasodilation. Venous return increases dramatically during pregnancy. Mean circulatory pressure that is an important determinant of venous return increases during pregnancy and resistance to venous return decreases.

Maternal Body Position and Cardiac Output

Studies on normal pregnant women have shown the CO to be highest in knee-chest and left lateral positions and less in standing and supine positions. The fall in supine position is attributed to the compression of the enlarged uterus on the inferior vena cava reducing the venous return, sometimes completely occluding it toward term and is more common after 24 weeks of gestation and earlier in twin pregnancies. However, a small percentage of women only experience the symptoms associated with supine hypotension during pregnancy. Understanding the benefits of posture-related effects of blood pressure on the body would help if a pregnant woman suffers from cardiac arrest requiring successful resuscitation.^{20,21,31}

Heart Rate Variations during Pregnancy

Heart rate is found to increase progressively till the end of pregnancy reaching its peak in the third trimester (► Figs. 2, 3). About 25% change in heart from the baseline values has been noted.^{25,27,32} There is an increase in sympathetic activity during pregnancy that explains the increase in HR.³² A possible explanation for sympathetic overactivity is that it occurs as a compensatory mechanism to peripheral vasodilatation, increased secretion of estradiol-stimulating nitric oxide synthesis leading to β -adrenergic-mediated vasodilatation.³³ The

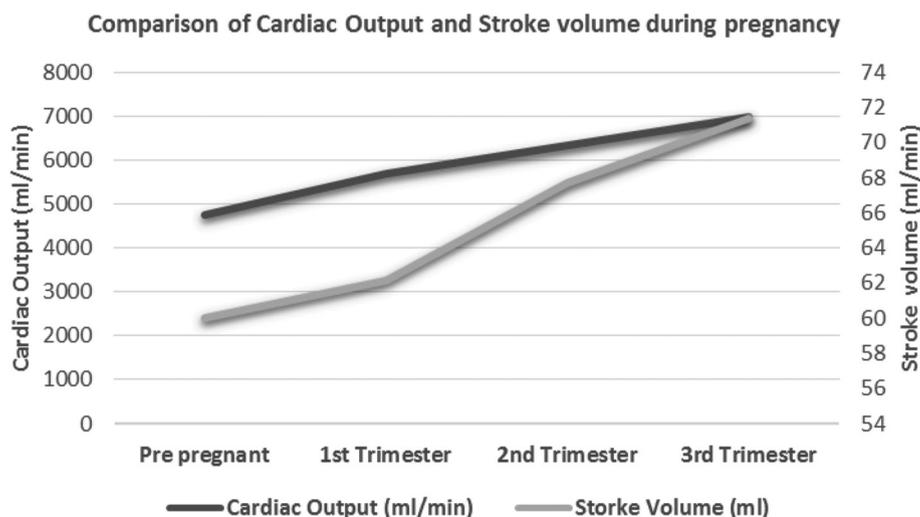


Fig. 1 Comparison of cardiac output and stroke volume in different trimesters of pregnancy.

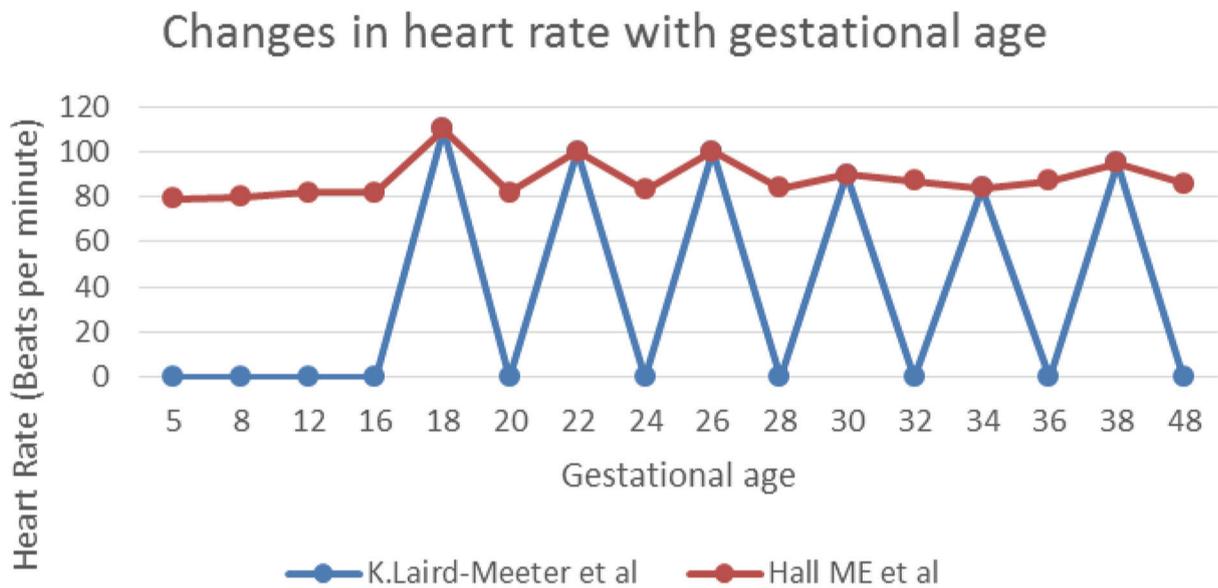


Fig. 2 Heart rate changes with gestational age.

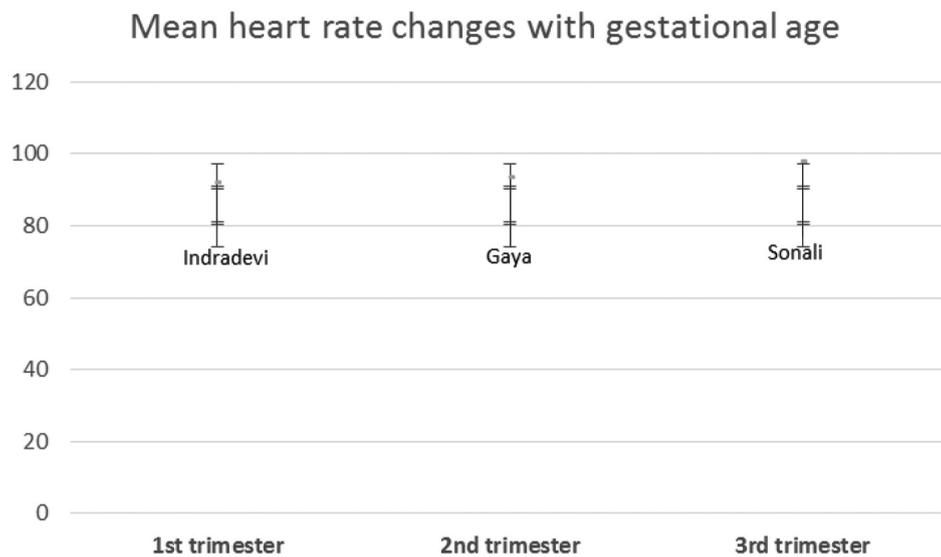


Fig. 3 Changes in mean heart rate with gestational age.

heart adjusts to higher fluid load by increasing the HR rather than increasing the end-diastolic volume, thereby increasing the CO. Echocardiography could not document any increase in end diastolic volume with increasing gestational age.³⁴ However, there is an increase in left ventricular wall thickness and left ventricular mass during pregnancy, causing a concentric left ventricular remodeling due to additional circulatory needs during pregnancy.³⁵ Commonly, a physiologic third heart sound and a cervical venous hum may be heard during pregnancy and need to be interpreted with caution being signs of systolic heart failure and patent ductus arteriosus, respectively.

Changes in Blood Pressure during Pregnancy

With fall in vascular resistance caused by progesterone-mediated smooth muscle relaxation, blood pressure also falls up to midterm and then gradually rises.^{36,37} The combination of increased CO with fall in blood pressure is associated with reduced systemic vascular resistance.^{38,39} Overall vascular resistance is lower than prepregnant levels. Because nitric oxide is the main mediator for smooth muscle relaxation and fall in resistance, parallelly, there appears to be reduced response of vessels to vasoconstrictor agents as well.⁴⁰ Overall, there is a fall in blood pressure by 5 to 10 mm Hg, with most of the fall occurring in the early part of pregnancy.^{39,41,42}

Hence, the hemodynamic changes occurring during pregnancy should be compared with prepregnant values rather than early pregnancy period as many changes would have already taken place. The fall in blood pressure is seen in both systolic and diastolic blood pressures with the fall more prominent in diastolic blood pressure (►Figs. 4, 5). Some recent studies have shown that there is a progressive increase in blood pressure with gestation and that the increase is related to their body mass index.⁴³ Obese and overweight women are seen to have higher blood pressure when compared with normal-weight women during early pregnancy, and this difference sustains throughout pregnancy.⁴⁴ Variations in systolic and diastolic blood pressures and mean arterial pressure are observed in women across continents probably due to a subjective variation in other factors such as nutrition and anthropometric data.^{31,45-47}

Changes in Blood Volume during Pregnancy

One of the hallmarks of pregnancy is a significant expansion of the blood volume, particularly in the first trimester and progressively later on.⁴⁸⁻⁵⁰ On an average, the plasma volume increases by 40% along with an increase in erythropoiesis. Placental lactogen plays an important role in enhancing

erythropoiesis by stimulating the production of erythropoietin. A condition of hemodilution occurs leading to physiologic anemia due to slight increase in plasma volume above the red cell mass. Though blood volume and SV increase, pulmonary capillary wedge pressure does not increase. Along with a fall in systemic vascular resistance, there is also a decline in the pulmonary vascular resistance.⁵¹ The combined effect of reduced colloid osmotic pressure with no significant increase in pulmonary capillary wedge pressure makes a pregnant woman susceptible to pulmonary edema. Hence, caution should be exercised while giving fluids to a pregnant woman to prevent any increase in preload that would precipitate pulmonary edema.⁵²

Changes in Electrocardiogram during Pregnancy

Alteration in structure and function of the heart often leads to occurrence of systolic murmur during pregnancy. However, to label a pregnant woman with a diagnosis of heart disease, it is necessary to look for ECG changes that exceed normal variations during pregnancy.⁵² Changes occur in arrangement of chest organs, sympathohormonal changes, left ventricular dimension alteration based on hemodynamic requirements during pregnancy, all of which bring about changes in ECG. Left-axis deviation, occurrence of Q-wave, and T-wave abnormalities are common findings in ECG recordings during pregnancy. However, interpretation of these changes needs to be done with caution, though several times, these changes are seen as minor and temporary.

Understanding the physiologic changes during pregnancy is necessary to avoid any misinterpretation of these changes as pathologic processes. A systematic evaluation of hemodynamic changes during pregnancy is necessary. Any electrical changes in the heart should be evaluated cautiously due to large and subjective variations occurring during pregnancy. The cardiovascular changes are by and large temporary and reversible reverting back to the prepregnant levels within few weeks of delivery.

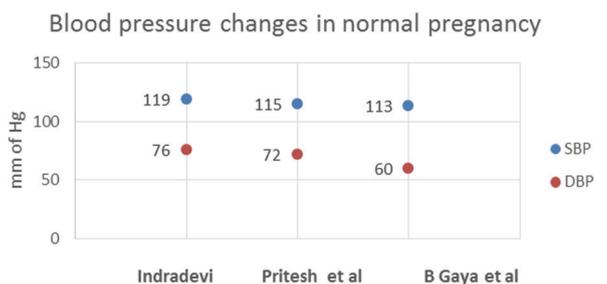


Fig. 4 Mean systolic (SBP) and diastolic blood pressures (DBP) during pregnancy.

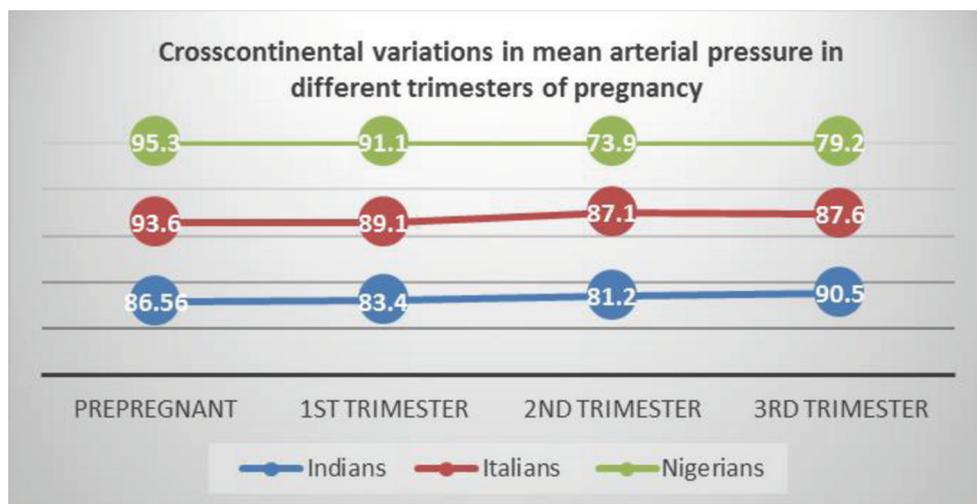


Fig. 5 Changes in mean arterial pressures with gestation.

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