

Original article:

Lung function tests in different trimesters of pregnancy

DR. Y.SHAILAJA, DR.S.SRIKANTH*

Name of the Institute/college:

Department of Physiology, Dr.Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinnavutapalli , Andhra Pradesh , India

*Corresponding author : Email id : physiologypsims@gmail.com

ABSTRACT:

Introduction: Pregnancy is associated with physiological changes in the control of breathing, in lung volumes, in the mechanics of respiration and in acid base balance. The static lung volume changes that occur during pregnancy rapidly normalize after delivery with decompression of the diaphragm and lungs. Our objective was to study the Lung Volume changes which occur in different trimesters of pregnancy using spirometry.

Materials & Methods: The study consists of recording the Pulmonary Function Tests of 4 groups of female subjects including pregnant women of various phases of gestational period i.e., 12 weeks (I trimester), 24 weeks (II trimester) , 36 weeks (III trimester) and control group of non pregnant women. The different static lung function parameters measured in this study were Expiratory Reserve Volume (ERV), Tidal Volume (TV), Vital Capacity (VC), Residual Volume (RV) & Minute Volume (MV).

Results: We observed a statistically significant decrease in Expiratory Reserve Volume, Residual Volume and a significant increase in Tidal Volume, Vital Capacity & Minute Volume in different trimesters' of pregnancy.

Conclusion: From the results of our study, it can be concluded that significant changes in pulmonary physiology occur during pregnancy which are necessary to meet the increased metabolic demands of the mother and fetus.

Keywords: Expiratory Reserve Volume , Tidal Volume , Vital Capacity

INTRODUCTION: Pregnancy is characterized by sequence of dynamic physiological changes that impact on multiple organ system functions and is associated with various changes in pulmonary anatomy and physiology. Three important changes in the configuration of the thorax that occur during pregnancy were an increase in the circumference of the lower chest wall (with increases in antero-posterior and the transverse diameters); elevation of the diaphragm (a cephalad displacement of approximately 4 cm to 5 cm) and a 50% widening of the costal angle⁽¹⁻³⁾. These changes peak around the 37th week of pregnancy and normalize within 6 months after delivery. Pulmonary function is affected by

changes of the airway, thoracic cage, and respiratory drive.

Additionally, capillary engorgement throughout the respiratory tract results in mucosal edema and hyperemia^(4,5). Multiple biochemical alterations like increase in progesterone, estrogen, prostaglandins, corticosteroid and cyclic nucleotide levels occur concomitantly during the course of pregnancy.

The thoracic circumference increases about 6cm but not sufficiently to present a marked reduction in the Residual Volume of air in the lungs controlled by the elevated diaphragm. Diaphragmatic excursion is actually greater during pregnancy than during non pregnant state. At any stage of normal pregnancy, the

amount of oxygen delivered into the lungs, by the increase in Tidal Volume clearly exceeds the oxygen need imposed by pregnancy. Moreover the amount of hemoglobin in circulation increases as a consequence of the maternal arterio-venous oxygen difference.

Pregnancy is associated with physiological changes in the control of breathing, in lung volumes, in the mechanics of respiration and in acid base balance. Maternal respiratory alterations in turn affect the metabolism and well-being of the fetus through their influence on placental gas exchange.

The most striking alteration in lung function is an increase in Minute Ventilation which increases by 36% by the eighth week of pregnancy ultimately reaching levels which are 50% above the non-pregnant need. This adjustment is required to satisfy the increase in oxygen consumption of 30-35% by the growing fetus. However the timing and magnitude of the increase in Minute Ventilation is in excess of the oxygen requirement for fetal development which may be due to the stimulatory effect of progesterone on the respiratory center. This expansion in Minute Ventilation leads to a slight decrease in alveolar PCO_2 and lower $PaCO_2$ from 38 torr to approximately 30 torr at term. The kidney compensates metabolically by an increase in the excretion of bicarbonate partially affecting changes in the blood pH. Mild respiratory alkalosis occurs and the pH rises from 7.35 to 7.4 near term. The increase in ventilation occurs without an increase in respiratory rate and this is accomplished mainly by a rise in Tidal Volume from 500ml to 700 ml and this explains the frequent sighing observed in pregnant women.

The physiological changes induced by pregnancy have been summarized by de Swiet⁽⁶⁾: Vital Capacity

may be increased by about 100 to 200ml ; Inspiratory Capacity increases by about 300ml by late pregnancy; Expiratory Reserve Volume decreases from a total of 1300ml to 100ml ; Residual Volume decreases from a total of 1500ml to 1200ml ; Functional Residual Capacity (FRC), the sum of Expiratory Reserve Volume (ERV) and Residual Volume (RV), is reduced by about 500ml; Total Volume increases considerably from about 500-700ml ; Minute Ventilation increases by 40%., from 7.5 L/min to a total of 10.5L/minute; this is primarily due to increase in Tidal Volume (TV) because the respiratory rate remains unchanged. These changes are induced to help the increased supply of oxygen as basal oxygen consumption increase incrementally by 20-40 ml/minute every month in the second half of pregnancy. As a result, arterial PO_2 falls very slightly, PCO_2 averages 28 mm Hg, plasma pH is slightly alkaline at 7.45 and bicarbonate decreases to about 20 meq/L.

MATERIAL & METHODS:

The study consists of recording the Pulmonary Function Tests in four groups of female subjects including pregnant women of various phases of gestational period 12 weeks, 24 weeks, 36 weeks and control group of non pregnant women of the child bearing age (20-40) , mainly lady doctors, nurses and lady medical students. The subjects considered for this study are with Hemoglobin more than 10 gm%. The study was approved by the Institutional Ethical Committee. Informed consent was taken from the subjects.

All the subjects were called for spirometric tracings in the afternoon between 3 to 5pm. (3 to 4 hrs after meal) in the post absorption stage in order to keep uniform conditions for recording the tests. All the subjects were given instructions and demonstration

with regard to performance of the tests. The tracings in the spirograph were taken after being fully satisfied. Two to three tracings were taken out of which the best is taken as final reading. The female subjects who are nonsmokers and are free from cardiovascular and respiratory disorders were grouped into five groups as:

Group 1 - Female normal subjects aged 20-25 years;

Group 2 - Pregnant subjects of first trimester gestational period aged 20-25 years; Group 3 -

Pregnant subjects of second trimester gestational period aged 20-25 years ; Group 4 - Pregnant subjects of third trimester gestational period of age 20-25 years .

The different lung function parameters measured in this study include ERV, IRV,TV, VC,RV and MV.

Statistical Analysis was done using Graph pad prism 6 Software. Unpaired t test was used to compare the mean value's.

RESULTS:

	CONTROL MEAN ± SD	1ST trimester MEAN ± SD	2ND trimester MEAN ± SD	3RD trimester MEAN ± SD
ERV in Litres	0.7620 ± 0.008660	0.7336 ± 0.003964	0.7062 ± 0.004381	0.6858 ± 0.004661
TV in Litres	0.3232 ± 0.003450	0.3546 ± 0.003535	0.3885 ± 0.004890	0.4267 ± 0.01372
VC L/min	3.011 ± 0.02022	3.116 ± 0.03434	3.122 ± 0.03923	3.207 ± 0.03687
RV in Litres	1.120 ± 0.009420	0.9624 ± 0.01882	0.9495 ± 0.008944	0.8468 ± 0.007921
MV Litres/min	6.224 ± 0.03842	6.345 ± 0.05149	6.558 ± 0.08005	6.824 ± 0.04522

Table 1 : Mean Value's of ERV, TV,VC, RV & MV in different trimester's of pregnancy.

	CONTROL MEAN±SD	1ST TRIMESTER MEAN ± SD	P-VALUE
ERV	0.7620 ± 0.008660	0.7336 ± 0.003964	0.0045 **
TV	0.3232 ± 0.003450	0.3546 ± 0.003535	< 0.0001 ****
VC	3.011 ± 0.02022	3.116 ± 0.03434	0.0116 *
RV	1.120 ± 0.009420	0.9624 ± 0.01882	< 0.0001 ****
MV	6.224 ± 0.03842	6.345 ± 0.05149	0.0653 NS

Table 2 : Comparison of Mean value's of different lung function parameters between control and I trimester pregnant women .

	CONTROL MEAN±SD	IIND TRIMESTER MEAN ± SD	P-VALUE
ERV	0.7620 ± 0.008660	0.7062 ± 0.004381	< 0.0001 ****
TV	0.3232 ± 0.003450	0.3885 ± 0.004890	< 0.0001 ****
VC	3.011 ± 0.02022	3.122 ± 0.03923	0.0155 *
RV	1.120 ± 0.009420	0.9495 ± 0.008944	< 0.0001 ****
MV	6.224 ± 0.03842	6.558 ± 0.08005	0.0005 ***

Table 3 : Comparison of Mean value's of different lung function parameters between control and II trimester pregnant women .

	CONTROL MEAN±SD	IIIRD TRIMESTER MEAN ± SD	P-VALUE
ERV	0.7620 ± 0.008660	0.6858 ± 0.004661	< 0.0001 ****
TV	0.3232 ± 0.003450	0.4267 ± 0.01372	< 0.0001 ****
VC	3.011 ± 0.02022	3.207 ± 0.03687	< 0.0001 ****
RV	1.120 ± 0.009420	0.8468 ± 0.007921	< 0.0001 ****
MV	6.224 ± 0.03842	6.824 ± 0.04522	< 0.0001 ****

Table 3. Comparison of Mean value's of different lung function parameters between control and III trimester pregnant women .

When the mean Expiratory Reserve Volume (ERV) of control subjects is compared with mean Expiratory Reserve Volume (ERV) of the subjects in the I trimester pregnancy, a non significant decrease of 3.67% is observed in subjects of I trimester subjects (p value = 0.045). In the same way, the mean Expiratory Reserve Volume (ERV) in the II trimester subjects has shown a statistically significant decrease of 7.35% when compared with that of the control

subjects (p value < 0.0001). The mean Expiratory Reserve Volume (ERV) in the III trimester subjects also has shown a statistically significant decrease of 9.97 % as compared to the mean Expiratory Reserve (ERV) of the control subjects (p value < 0.0001). Thus there is a gradual decrease in the mean Expiratory Reserve Volume (ERV) in the pregnant subjects (as compared with the controls) as the pregnancy advances reaching its maximum decrease

by the end of III trimester. The mean Tidal volume of I trimester pregnant subjects showed statistically significant increase of 9.72 % when compared with the mean Tidal Volume of the non pregnant subjects (p value < 0.0001). Similar results were obtained when the mean tidal volume of the II trimester and III trimester pregnant subjects, when compared with the mean Tidal Volume of the non pregnant controls showing an statistically significant increase of 20.21 % and 32.51% respectively ($p < 0.0001$). Hence, the mean Tidal Volume progressively increased as pregnancy advances reaching its maximum value at term which is statistically significant.

The mean Residual Volume (RV) of the I trimester pregnant women showed a statistically significant decrease of 21.4% when compared to the mean Residual Volume (RV) of the controls ($p < 0.0001$). The mean residual Volume (RV) in II trimester pregnant subjects showed a statistically significant decrease of 15.27% when compared with that of the control non pregnant women ($p < 0.0001$). The mean Residual Volume (RV) of the III trimester pregnant subjects showed a statistically significant decrease of 24.375 % when compared with the mean Residual Volume (RV) of control non pregnant subjects ($p < 0.0001$). Thus there is a gradual decrease in the mean residual Volume (RV) in the pregnant subjects from the I to the III trimesters which is statistically significant.

An non significant increase of 1.944 % in the mean Minute Volume (MV) is noticed in the I trimester pregnant subjects as compared with the mean Minute Volume (MV) of the control non-pregnant subjects ($p = 0.0653$). Likewise, the mean Minute Volume (MV) of the II and the III trimester subjects has shown a statistically significant increase of 5.35 % and 9.64 % respectively, when

compared with the mean Minute Volume (MV) of the control subjects ($p = 0.0005$ & $p < 0.0001$). Thus there is a gradual increase in the mean Minute Volume (MV) of the pregnant subjects as they proceed to term when compared with the controls. The mean Vital Capacity (VC) of the subjects in the I trimester pregnancy showed a non significant increase of 3.48 % when compared with the mean Vital Capacity (VC) of the control subjects (p value = 0.0116). The same parameter relating to the subjects in the II and III trimester pregnancy showed a statistically significant increase of 3.68 % and 8.60% respectively as compared with the mean Vital Capacity (VC) of the control subjects (p value < 0.0001).

DISCUSSION: Our observation that there is an increase in Tidal Volume and a decrease in Expiratory Reserve Volume (ERV) is in agreement with the results of Chhabra S, Nangia V, Ingley KM et al ⁽⁷⁾. An increase in tidal volume and minute ventilation which occurs in pregnancy was observed in many studies [Rees GB, Pipkin FB, Symonds EM ⁽⁸⁾; Nelson Piercy C ⁽⁹⁾]. Minute ventilation increases during pregnancy because of increases in tidal volume; the respiratory rate does not change. The increase in minute ventilation is greater than the increase in oxygen consumption and this results in both hyperventilation and an increased ventilatory equivalent for oxygen. Subjective awareness of increased ventilation is one explanation for the sensation of dyspnoea in pregnant women without cardiopulmonary limitation. Rowe AW, Gallivan DE, Mathews H, Anthony AJ et al ⁽¹⁰⁾ observed that the Minute Volume of respiration increases progressively as term is approached, principally through an increase in the Tidal Volume, although the respiratory rate also increases slightly.

Some studies (Milne JA⁽¹¹⁾) showed significant rise in Forced Vital Capacity (FVC) while other studies [Puranik BM⁽¹²⁾; Mokkaipatti R⁽¹³⁾; Monga U⁽¹⁴⁾] showed decrease in FVC. Root FR and Root HK⁽¹⁵⁾ observed a slight but definite rise in the vital capacity curve during pregnancy from the third to the eighth month. Also observed a marked increase in the Vital Capacity during the last month of pregnancy. Landt CK, Widlund G and Benjamin PR⁽¹⁶⁾ found an increase in Vital Capacity during pregnancy. Root, Cohen, Landt and others concluded that the Vital Capacity of the lung is increased during pregnancy and the increase in VC observed in our study was in accordance with this study. Rubin et al noticed that there is decrease in Vital Capacity while Cugell⁽¹⁷⁾ felt that Vital Capacity remained unchanged during pregnancy. Howard G Knuttgen and Kendall E⁽¹⁸⁾ studied the physiological changes during normal pregnancy. Pulmonary hyperventilation developed early in pregnancy and persisted at rest which was due to increment in Tidal Volume.

Other significant changes observed in lung volumes during pregnancy were increase in Vital Capacity and Inspiratory Capacity, decrease in Expiratory Reserve Volume and Functional Residual Capacity but no change in total Lung Capacity. The present observation that there is an increase of Tidal Volume, and Inspiratory Capacity and a decrease in Expiratory Reserve Volume is consistent with this study. Plass Ed and Obersdt DW⁽¹⁹⁾ observed a slight increase in Tidal Volume throughout pregnancy. The increase of Tidal Volume among the pregnant subjects observed in our study is in agreement with this study.

Bernard J, Gee L, Bernard S Packer et al⁽²⁰⁾ studied about the Pulmonary Mechanics during Pregnancy.

They observed that during late pregnancy, there is a 25% reduction in FRC and about 40% reduction in ERV. Slight and statistically insignificant reductions in total lung capacity and VC were also found in their study. VC is maintained by the increase in inspiratory capacity. Decrease in ERV in our study correlates with this study but increase in VC did not correlate with this study.

The work done by Berry MJ, Mc Murray RG, Kartz VL et al⁽²¹⁾ showed an increase in Minute Volume (MV) and tidal volume during pregnancy and this observation is in agreement with the results of our study. Also the decrease in Expiratory Reserve Volume (ERV) observed in our study correlate with their findings.

The study of Skandan KP, Mehta YB, Shah V, Parikh SR et al⁽²²⁾ showed a rise in Tidal Volume (TV) together with a decrease in Expiratory Reserve Volume (ERV) and Vital Capacity during pregnancy. Gazioglu K, Kaltreider NL, Lehmann V and Fabel H⁽²³⁾ found that during pregnancy the Inspiratory Capacity increases and the expiratory capacity is decreases. Also observed that the Minute Volume and the tidal Volume increase with no change in the respiratory frequency, and the Functional Residual capacity, the residual volume decrease with no change or a decrease in the Total Lung Capacity.

Pande Y, Guleria JS, Hingorani V et al⁽²⁴⁾ observed an inconsistent decrease in vital capacity during pregnancy & the ERV showed a significant decrease which was most pronounced in the last trimester of pregnancy. The Functional residual Capacity, the Residual Volume decreased progressively as pregnancy advanced. The Minute Ventilation rose markedly, mainly due to an increase in Tidal Volume. The decrease in RV observed in our study might be due to relative decrease in the negativity of

the intrapleural pressure, brought about by an upward displacement of the diaphragm by the enlarging uterus.

Knox AJ, Petkova S et al ⁽²⁵⁾ **observed** a number of physiological changes which occurred during pregnancy. At the end of the first trimester, Ventilation increased by 20-25% and was sustained throughout pregnancy. A decrease in the Residual Volume (RV) and Functional Residual Capacity (FRC) was observed. Also, Diaphragmatic excursion, Vital Capacity and Total Lung Capacity remained unchanged.. Respiratory rate (RR) does not change also during pregnancy and tachypnea with greater than 20 breaths per minute should be considered abnormal in the pregnant woman [Wise RA, Polito AJ, Krishnan V⁽²⁶⁾; Bobrowski RA⁽²⁷⁾].

CONCLUSION: Conflicting results could be due to observations on different subjects from different socio-economic status at different periods of gestation. Hormone determined changes in smooth

muscle tone and possibly connective tissue elastance might occur during pregnancy which probably alter the mechanical properties of the respiratory system. The decrease in ERV is due to reduction in power of the muscles of expiration due to the stretching of the abdominal wall with the progress of pregnancy. Rise in TV could be due to the smooth muscle relaxation, altered thoracic configuration and a direct effect of progesterone increasing the sensitivity of respiratory centre to carbondioxide.

Limitations of the study: We did not consider the parity and also the study is cross sectional. Longitudinal studies may reveal better results. Also the sample size in our study is small. Future studies need to done with large sample size and longitudinal studies taking parity into consideration. PFT should be a part of routine antenatal checkup to prevent any possible respiratory complication.

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