SUMMARY AND CONCLUSION OF THE THESIS ENTITLED

# A DESCRIPTIVE ANALYSIS OF EXPIRATORY AND INSPIRATORY PARAMETERS OF RESPIRATION DURING NORMAL PREGNANCY



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# SUMMARY

Reproductive system is highly influenced by physiological, anatomical and hormonal changes as a consequence of endocrine and uterine functions during pregnancy. Respiratory system shows self-evident change that can be measured by well-known universal strategy – pulmonary function tests – where in the status of pulmons in alliance with intrathoracic and extrathoracic elements are studied.

Objectives of undertaken pulmonary functions were – scarcity of literature during pregnancy, that too on pulmonary functions in normal pregnancy; studies available gave scattered picture of pulmonary functions, meaning one to few parameters were studied at a time; inspiratory lung functions did not have any place in literature, even though being an active process might give information on status of respiratory system; to find the extent of presence of obstructive and restrictive element; to corroborate chronic adaptation during pregnancy due to numerous changes taking place in the body; data obtained may be useful to assess pregnant women status by clinicians and deviation from normalcy as compared to nonpregnant state, as well during gestational period. Changes in cardiopulmonary parameters may prove to be a reasonable

screening technique for unexpected abortion and other complications of pregnancy.

Permission for the study was taken and ambience for the same was created in the Obstetric and Gynecology Department of Shree Sayaji General Hospital, Baroda. The incidental selection of nonpregnant subjects and random selection of pregnant subjects led them in four groups. Nonpregnant subjects were treated as controls and pregnant subjects as experimental group with gestational age divided in three months forming three groups namely first, second and third trimester groups. Every subject upon selection had to complete the proforma and they were given future date and time for doing pulmonary function tests, as it required more time.

Pulmonary function tests were performed taking all necessary precautions on safe, sound and operational equipment. Most of static and dynamic lung volumes, capacities and flow rates (large and small airway function) except few were measured during expiratory and inspiratory phases of respiration namely TV, ERV, IRV, VC, MVV, FEVC, FIVC, $FEV_{0.75}$, $FEV_1$, $FIV_{0.75}$ and $FIV_1$. $f$ was measured by inspection. RMV, RR, BRR, $FEV_{0.75}\%$, $FEV_1$ %, $FIV_{0.75}\%$, $FIV_1\%$, MEFR, MIFR, MMEFR, MMIFR and ratios of inspiratory to expiratory flow rates – FIV/FEV for 0.75 and 1 sec, MIFR/MEFR and MMIFR/MMEFR were computed from the measured volumes. Respiratory efficiency tests as BHT and that on manometer as ET and MET were conducted. Relevant cardiocirculatory parameters as Hb, HR and BP were also studied. The data obtained were statistically analyzed.

Pulmonary functions during pregnancy were reviewed to find out whether present study, gets support or not on account of data as well as to peep into logic given by others. Review had given a scattered study of pulmonary functions from 131 – 201 BC till 2000. Ample work has been done on static lung volumes but sparse literature was found on dynamic lung volumes while negligible literature was available on inspiratory phase of respiration.

Findings of present study are discussed henceforth along with the assumptions and speculations. It was hypothesized that some changes take place during pregnancy and obstructive and restrictive both elements may be present during pregnancy whereas most studies had stated pregnancy being restrictive condition.

The result for various parameters is summarized below. The figures in bracket give mean (for that group), average (for all three trimesters as $\overline{X}$) or % as per requisite.

Respiratory rate (breaths/min) was found to be more by 66% or 9.5 (breaths/min) during pregnancy ($\overline{X}$=24) than nongravid state (14.5). Considerable rise throughout pregnancy was observed. Increase in f is resultant of shallow breathing, biochemical, and gaseous and ionic changes in blood. Increased thyroid function, metabolism and ß adrenergic activity leads to increase in frequency. Progesterone predominately increases sensitivity of respiratory centers lowering their threshold to $pco_2$, this action being facilitated by estrogen.

TV measured in controls (561 ml) was higher by 17% (94 ml) than experimental group ($\bar{X}$=467 ml). Fluctuations were seen during pregnancy with slight rise in mid pregnancy. All the fluctuations and lowered values during pregnancy were statistically significant and are probably caused by upward displacement of diaphragm. Diminished TV is suggestive of shallow breathing.

Calculated RMV (TV x f) was seen to increase significantly throughout pregnancy in all three trimesters and as well as in relation to control subjects. Average increase ($\bar{X}$=11.19 l/m) during pregnancy was by 3.2 l/m or 4 % as compared to nonparturients (7.9 l/m.). Increase in RMV is the contribution of increased f primarily. RMV increases to combat maternal and fetal demands of oxygen and increased $CO_2$. Metabolic, hormonal, mechanical configuration and some local changes lead to hyperventilation.

ERV showed minor statistical changes from nonpregnant vs first but significant changes vs second and third trimester. During pregnancy the fall and slight rise were statistically significant indicating adaptation in later state of pregnancy. Overall decrease of 147 ml or 18.3% seen from nonpregnant (806 ml) state to pregnant ($\bar{X}$=658 ml) state might be caused by upward displacement of diaphragm, reduced strength of expiratory muscles and mechanical effect of growing uterus.

Significant decline in IRV by 413 ml or 27.5% in pregnancy ($\bar{X}$=1089 ml) was noted as compared to control subjects (1052 ml). Trifle changes were seen during pregnancy. The decrease could be due to the major inspiratory muscle diaphragm being displaced to higher level by growing fetus.

IC incorporating IRV displayed identical picture of significant fall of 504 ml i.e. 20.6% in pregnancy ($\bar{X}$=1556 ml) with regard to nongravid (2063 ml) state. Change in prenatal stage of gestation was negligible but later half was considerable.

Both IRV and IC exhibited significant changes in first vs third trimester. Though anteroposterior and lateral diameter increase to compensate reduction in vertical diameter, but humid warm air inspired from spirometer might be precipitating queasiness, restricting optimal performance on part of subjects especially in early pregnancy where significant fall was encountered. Adaptability a key factor is indicated from almost same values of first and second trimester. Maximum decrease was seen at term perhaps due to constrain to expansion of lung tissues that is pressed by growing gravida. Enlarged breast along with tight strapping also contributes to decrease in inspiratory volumes.

VC considerably decreased by 685 ml or 23.9% in parturient state ($\overline{X}$=2178 ml) to nonparturient state (2863 ml). The changes were less significant during pregnancy. It is dependent not only on forceful and maximal effort but also on ERV, IRV, and TV. All these reduced, consequently VC also reduced by more than 50% at term from control or early pregnancy state probably as a result of compressed lung tissue through elevated diaphragm and increased pulmonary blood volume during pregnancy.

MVV showed highly significant decrease by 23.4 l/m or 27.1% throughout pregnancy ($\overline{X}$=62.76) and even when compared to control subjects (86.15). MVV is well correlated with $FEV_1$ and VC. As both these values decreased during pregnancy, MVV was seen to decrease. Strikingly, it was almost 37% - 45% less in late pregnancy from early pregnancy or nonparturient state as optimally growing fetus poses limitation to expansion. Increment in progesterone induces mellowness of smooth muscles lessening efficiency of respiratory muscles especially when maximum efforts are required. Tertiary factors as morning sickness, lack of motivation and resistance to exertion contribute in decreasing MVV.

RR (MVV – RMV) significantly declined by 26.6 l/m or 34% during pregnancy ($\bar{X}$=51.57 l/m) as compared to controls (78.17 l/m). RR decreased in consequence to significant decrease in MVV and increase in RMV throughout pregnancy.

BRR decreased by 11% in proportion to decrease in RR. The ratio obtained for pregnants ($\bar{X}$=80.41) was within normal range suggesting dyspnea even if it occurs, is of mild magnitude leading to inference of pregnancy being an example of adaptation.

Significantly diminishing values of RR and BRR during pregnancy suggest the consumption of reserve during pregnancy for operation of corrective mechanisms so as to adapt to physiological changes.

Flow rates calculated from forced expirogram and inspirogram are important and reliable indices to distinguish between obstructive and restrictive conditions (as mentioned in literature).

Significant difference was observed in FEVC between early and mid pregnancy. Minor changes were found within other groups on comparison. There was overall rise of FEVC by 46.5 ml or 2.55% in pregnancy ($\bar{X}$=1868 ml) when compared with control sample (1822). Fall was due to restrictive effect of enlarging uterus. FEVC was seen to be less than VC though procedure of breathing was same. Writing device may introduce some resistance while recording on smoked paper contributing in lowering FEVC to certain extent.

$FEV_{0.75}$% ($\bar{X}$=58.39) and $FEV_1$% ($\bar{X}$=76.6) both decreased insignificantly throughout pregnancy and a highly significant lowered values were registered as compared to control subjects ($FEV_{0.75}$%=73.68 and $FEV_1$%=90.3). $FEV_{0.75}$% and $FEV_1$% obtained was only 61% to 56% and 78.25% to 74.15% from early to late pregnancy respectively showing insignificant decrease. Decline in both the values on an average was by 14% – 15% during pregnancy. Fall in both the values indicate a restrictive condition developing in mid and late pregnancy. Dynamic maneuver required to expire air to achieve the normal values of flow rates may not be adequate during later half of pregnancy even though airway resistance decreases and cross sectional area is augmented by relaxin and progesterone.

Significant fluctuations, a decrease and an increase value in FIVC were observed during pregnancy. FIVC findings were parallel to FEVC. Drop by 58.3 ml or 4.45% was seen in parturient state ($\bar{X}$=1253 ml) as compared to nonparturient (1311 ml) state. Inspiratory values were less as compared to expiratory due to restrictive effect being more for inspiration than expiration and anticipation of unpleasant feeling by inhaling moist and warm air.

$FIV_{0.75}$% and $FIV_1$% showed parallel changes – an increase from nonpregnant state to mid pregnancy and a fall at term with very minor changes during pregnancy. These values were more in pregnant subjects ($FIV_{0.75}$%, $\bar{X}$=70.65; $FIV_1$%, $\bar{X}$=88.3) as compared to control subjects ($FIV_{0.75}$%=66.13; $FIV_1$%=84.9). $FIV_{0.75}$% showed a rise of 4.52 or 6.84% and $FIV_1$% a rise of 3.53 or 4.16%.

Ratio of inspiratory to expiratory timed vital capacity showed significant gain of 0.49 or 53.8% in experimental group ($\bar{X}$=1.4) as compared to control group (0.9) but the ratio during pregnancy was almost constant (with difference of 0-0.1) through out the pregnancy. This ascertains the chronic adaptability.

The decrease seen in large expiratory airways from control to first trimester might be due to sudden rise of placental and other hormones to which body is not able to adapt immediately or due to traversing of trophoblasts from uterine sinuses to maternal alveoli. Morning sickness and other psychological changes may cause fall in TEVC% from control to first trimester. As the pregnancy advances both remain steady along with gradual decrease in VC which means that there is restrictive ventilation without much obstructive element.

Large inspiratory airways show a rise from control to first trimester as a result of bronchopulmonary dilatation and decrease airway resistance on account of progesterone causing free inflow of air. TIVC shows on an average increase in pregnants possibly because of increased cross sectional area of airways by direct action of progesterone and relaxin. Moreover initial phase of inspiration is faster drawing in more air and end inspiratory value is affected by restrictive element.

MEFR and MIFR exhibited insignificant changes all through pregnancy as well as in control vs all three trimesters. MEFR declined by 16.8 l/m or 16.2% from nonparturient state (103.6 l/m) as compared to parturient state ($\overline{X}$=86.77 l/m). MIFR showed a slight insignificant rise of 3.8 l/m (4.5%) from control (83.91 l/m to parturient state ($\overline{X}$=87.7 l/m).

MEFR > MIFR in control subjects indicating controls can perform forceful expiration effortlessly, as there is no intrathoracic and extrathoracic restriction. MIFR > MEFR in first and second trimester suggesting restrictive component brought about by modified abdominal structure is mild to moderate while in third trimester values of both are same, indicating restricting severity is enhanced by breast enlargement as well.

The ratio of MIFR/MEFR showed insignificant changes within the trimesters while less significant change in experimental group ($\bar{x}$=1.0) when compared with control group (0.88), a rise of 0.2 (23.1%). Ratio was 1 (one) in third trimester as MIFR = MEFR. This could be due to bronchodilatory effect that limits expiratory effort and facilitates inspiratory effort.

MMEFR and MMIFR increased from control to first trimester. MMEFR later decreased during pregnancy with average being 100.5 (-12%). MMIFR fluctuations with average value being 87.87 displayed a slight increase in pregnancy by 13.8%. Overall decrease in MMEFR and increase in MMIFR can be elucidated on the same basis as mentioned above. MMIFR showed insignificant changes through out pregnancy as well when compared to controls.

Almost no change in ratio of MMIFR/MMEFR was seen within the experimental groups ($\bar{X}$=0.95) but when compared to control (0.73) all the three experimental groups gave a significant rise in ratio by 31.1% (0.22).

Ratio of inspiratory to expiratory flow rate continuous declined from early to late pregnancy while inspiratory flow rate showed mild rise in mid pregnancy. Ratios being slightly more in early pregnancy suggest infiltration of obstructive element during early state of pregnancy. The fall in ratio from early to mid and almost steady ratio from mid to late pregnancy gives presence of restrictive element in later half of gestational period.

In breath holding test and 40 mm endurance test, time taken to hold the breath gave a continues decline significantly from controls to third trimester except with insignificant decline from early to mid pregnancy. Breath holding time for control subjects was 35.23 sec while average during gestation is $\bar{X}$=20.1 sec pointing to a decline by 15 sec that is 42.6%. Mean 40-mm ET time in controls was 31.3 sec while during pregnancy average breath holding time was $\bar{X}$=19.2 sec with a decline of 12.1 sec or 38.6%. The time taken to hold the breath with effort (ET) was much less than holding breath without effort (BHT)

Breath holding time in both the above tests in controls was observed to be less than norms given indicating decrease efficiency of respiratory system in controls. During pregnancy breath holding time in both tests could be because increase in molecules of oxygen move from lung to blood at a constant rate. Lung volumes decrease passively increasing fractional concentration of nitrogen and oxygen. This fractional oxygen concentration would be exchanged with carbon dioxide of alveolar blood and increase $pCO_2$, decrease $pO_2$ and decrease pH during pregnancy shorten breath holding time to bring the operation of compensatory mechanism earlier than the normal rate. Decrease lung volumes contribute in declining breath-holding time. Increase in alveolar pCO2 initiates reflexes stimulate respiratory centers that are already sensitized by progesterone. Apart from these factors metabolic activity of active expiratory muscles involved in raising mercury level and constraint caused by abdominal contour are responsible for lowering breath-holding time in 40 mm ET.

Level of mercury raised for expiratory pressure test (MET) decreased all through pregnancy ($\bar{X}$=61.1 mm) with overall decrease of 22 mm Hg or 26.5% as compared to controls (83.2 mm Hg. The significant fall could be attributed to the action of progesterone and relaxin reducing muscular tone.

High pressure developed with middle ear, morning sickness during prenatal stage, mechanical alteration, muscular weakness and anxiety cause discomfort in performing the test where mercury level is to be raised at highest possible level with maximum effort input. These factors also contribute in lowering values of ET and MET.

A significant decrease in Hb was observed in pregnancy, average being 11.6 gm% that is 9.4% less than controls (12.8 gm%) caused by increased circulating plasma volume.

Statistically significant increase heart rate from nonparturient state (87.4) to parturient state ($\bar{X}$=95.6) as well as gradual increase during gestation was noticed. Increased HR within normal range brings slight rise in cardiac output to combat the metabolic and biochemical fetomaternal demands.

A rise in systolic blood pressure was observed while diastolic blood pressure exhibited significant fluctuations in three trimesters. The systolic and diastolic blood pressure (mm Hg) means were 103.8 and 68.3 respectively in controls and 110.4 and 70.2 in enceinte state. The successive growth of fetus puts load over the heart and lungs causing increase in blood pressure that is maintained within normal limits due to compensatory mechanism and adaptation.

Summarizing all the facts it can be said there is decrease in static lung volumes except RMV that increase due to increase in f. dynamic lung volumes as MVV and TEVC shows decrease while TIVC shows increase. Small expiratory airways decline and small inspiratory airways rise during pregnancy. The results obtained for static and dynamic lung volumes exhibit presence of small amount of obstruction along with greater extent of restrictive component. The ratios as BRR and inspiratory to expiratory flow rates are within the normal range as per the norms, imply body becoming suited to pregnancy as all these ratios have direct or inverse relationship with one or the other parameters that vacillate. Various compensatory mechanisms as discussed play an important role in compatibility to pregnancy.

## CONCLUSION

Going through the contents of whole text some consequential and significant conclusions are drawn associated to vice a versa relationship of acculturation towards pregnancy and alteration brought about in studied parameters by restorative mechanisms. Each parameter isolated or in conjunction with other parameter is important to find out lung functioning

Increase in RMV termed as hyperventilation reflected by increased f (+66%) primarily (progesterone sensitizing respiratory centers to lowered threshold to $pCO_2$) and decreased TV secondarily (altered thoracic configuration) is a chronic adaptive change to balance respiration and metabolic functions. Local changes as augmented dead space, unsatisfactory intrapulmonary distribution of gases and altered diffusion across alveolo-capillary membrane also contribute in hyperventilation.



Diminished TV (-17%) , IRV (-27.5%) , ERV (-28.3%) , IC (-24.6%) all share in lowering VC (-23.9%), as VC is an expression of sum of TV, ERV and IRV or ERV and IC.

All the parameters decrease because of adjusted thoracic and abdominal configuration as explained. Latter brings about compression of basal lung tissues and increased angulation of bronchi. Increased pulmonary blood volume might decrease these parameters.

Increased abdominal compression to forceful expiration after deep inspiration causes concern in pregnant subjects as they anticipate complications by dynamic procedure of carrying out the tests at term.

MVV decrease suggests presence of obstructive element and along with decrease in VC suggests restrictive element. This can be justified by not achieving normal MVV values despite the great effort input, as progesterone and relaxin causing smooth muscles relaxation hamper optimal efficiency of respiratory muscle thereby lowering MVV.

Maturing fetus and agitation due to labor input may impose limitations at term causing maximum fall in MVV in third trimester. VC also requires efforts and shows parallel decrease as of MVV – justifying presence of restrictive component.

RR is used by respiratory system in emergency. Bodily demands during pregnancy increase and hence it is this reserve that is used up to compensate dyspnea and combat other alterations. This is evident from decrease in RR and BRR. Decrease in RR with proportionate decrease in MVV results in decreased BRR, the ratio that is maintained within normal limits denoting absence of true dyspnea. Decrease in RR and BRR designate gestation as an adaptive change.

Mid pregnancy decrease in FEVC and FIVC owing to restrictive effect and at term adaptability brings back the values to normal as in controls. Mid pregnancy fall could not be explained physiologically. But values of FIVC in all four groups being lower than FEVC are feasibly due to resistance to inhaling humid warm air through mouth from spirometer and resistance offered by writing device against gravity on recording inspirograms.

TEVC and TIVC show overall decrease and increase respectively in parturient state but their ratio is almost constant during pregnancy specifying it a progressive adaptability

MEFR > MIFR in controls as expiratory efforts are optimal with expiration being a passive process. MIFR > MEFR in initial six months as restrictive elements as intrathoracic decrease in volume from mild to moderate extent and bronchodilatory action facilitates inspiratory efforts rather than expiratory efforts. Extra and intra thoracic restriction for inspiration and abdominal stretching restricting expiratory efforts also lead to same values of MIFR and MEFR with their ratio being one. Changes in MMEFR, MMIFR and their ratios are similar to MEFR and MIFR. Hence explanation given above holds valid for these parameters as well.

Breath-holding time for BHT and 40-mm ET significantly declines during pregnancy, decline being more in ET. Increase $pCO_2$, increase alveolar $pCO_2$, decrease $pO_2$ and decrease pH initiate reflexes stimulating respiratory centers sensitized by progesterone compel subject to breath. This shows the integrity of respiratory system. The level of mercury raised in MET is low in pregnant subjects, is attribution of progesterone and relaxin reducing muscular tone. Discomfort due to pressure developed in middle ear while raising mercury level, morning sickness in early stage of pregnancy, mechanical alterations and muscular weakness lead to decrease in respiratory efficiency. Inspite of the reduced efficiency of respiratory system, the compensatory mechanisms operate to help in adaptation to pregnancy.

Hb decreases reducing oxygen carrying capacity that is compensated by increased HR to increase the cardiac output during pregnancy. This also fulfills the feto-maternal demands. Progressive growth of fetus and bodily demands put load over the heart and lungs causing increased blood pressure. Though increase of blood pressure within the normal range is a corrective strategy.

Glancing at the values of static and dynamic large and small airways and the related ratios of all the parameters, it can be said that restorative mechanisms function for adaptation to pregnancy. There is appearance of obstructive component along with mild restriction during early pregnancy as well as presence of restrictive component of moderate to severe degree from mid to late pregnancy. This proves the formulated hypothesis was legitimate. Thus though pregnant women has apparent handicaps causing restrictive changes in respiratory apparatus the anatomical, physiological, hormonal changes compensate for them causing no discomfort to the pregnant women.

Besides understanding the physiology of lung function during pregnancy the study also provides a control as the background of which any respiratory problem that may appear during pregnancy can be evaluated with great precision.

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