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Research Article

PHYSIOLOGICAL AND ANATOMICAL CHANGES OF PREGNANCY IMPLICATIONS FOR ANAESTHESIA – A RANDOMIZED CONTROLLED TRIAL

SARMISTHA PANIGRAHI[1], SANDHYA PEETHANI[2]*

[1]Department of Anaesthesiology, Apollo Hospital, Kakinada, Andhra Pradesh, India. [2]Department of Obstetrician and Gynaecologist, Apollo Hospital, Kakinada, Andhra Pradesh, India. Email: sarmistha.luckyfeb@gmail.com

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ABSTRACT

Objectives: The article aims at gaining in-depth knowledge of physiological and anatomical changes in pregnancy.

Methods: A randomized controlled trial was done among 200 pregnant woman in Department of Obstetrics and Gynecology at Tertiary care institute and hospital for the period of 6 months (November 2021 to April 2022). Random Number table was used for selection of patients who were followed for pregnancy in the department. All demographic details and Pre-Anesthetic checkups were done. Statistical analysis was done using the software Statistical Package for the Social Sciences (SPSS) 22.0 version. This consecutive series of original research papers were reviewed for the reporting of ethics committee approval and patient consent.

Results: Respiratory physiology continues to change throughout pregnancy. Airway resistance decreases 50% due to the effects of progesterone on bronchial smooth muscle. With Minute ventilation, RR, Tidal volume, and Alveolar ventilation are increased. Anatomically, diaphragm elevates with cephalad pressure of the growing gravid uterus, and the chest wall diameter increases in the anteroposterior and transverse diameters. This leads to unchanged Total Lung Capacity, Vital Capacity, and CC, while Expiratory Reserve Volume, Residual volume, and Functional residual capacity seen a decreased in 20% in all patients. Blood volume increases early in gestation (at approximately 12 weeks), continues to increase rapidly during the second trimester and more slowly during the remainder of pregnancy. Cardiac output increases in early pregnancy with changes measurable by 8 weeks gestation.

Conclusion: Minute ventilation, RR, Tidal volume, and Alveolar ventilation are increased. Cardiac output increases in the early pregnancy with changes measurable by 8 weeks gestation. Cardiac output increases most rapidly (to approximately 35% above baseline) during the second trimester, then remains about the same until term. Output increases substantially with labor contractions; each contraction increases cardiac output an additional 10–25%.

Keywords: Anesthesia, Labor analgesia, Obstetrics, Postpartum period, Pregnancy.

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INTRODUCTION

During pregnancy, great changes in a woman's anatomy and physiology occur as a result of altered hormonal activity, increasing metabolic demands of a growing fetus and placenta, and mechanical displacement by an enlarging uterus. Many of the changes are advantageous for the child's development during pregnancy, and for the mother's and child's survival of the birth process [1]. However, some of these changes may have potentially adverse implications for anesthetic administration during childbirth and for no obstetrical surgical procedures performed during pregnancy. This article will review the important maternal anatomic and physiological changes and their clinical implications for anesthetic management of pregnant women in the peripartum period and for non-obstetrical surgery [2]. Pregnancy changes everything; from head to toe, no organ system is left unaffected. Our review of the physiological and anatomic changes of pregnancy begins at the top. General anesthesia was once the primary anesthetic technique used in obstetrics, both for vaginal deliveries and Caesarean section. As the field of obstetric anesthesia has advanced, the use of GA has been largely replaced by neuraxial techniques. Failed tracheal intubation and the risk of aspiration and resulting aspiration pneumonitis have historically been the most dreaded complications of GA [3]. Detailed guidelines for the management of difficult intubation in obstetrics have been developed [4]. However, it remains important to remember that increased care should also be used when dealing with tracheal extubation and postoperative management. During pregnancy, anatomical and physiological changes occur to meet the increased metabolic needs, to permit appropriate development of fetus and to prepare the body for childbirth. The changes begin to occur early in the first trimester, peaking at the term or labor, and revert to pre-pregnancy levels by a few weeks into the postpartum. These changes are well tolerated in healthy females but may aggravate or unmask a pre-existing disease or a pregnancy-related pathophysiology [5]. A thorough understanding of the physiological changes is the key to successful anesthetic management of both obstetric and non-obstetric procedures during pregnancy. This conceptual knowledge will also help the anesthesiologists to tailor the anesthetic technique to accommodate coexisting diseases and to manage critically ill pregnant patients. This study was done to discuss the anatomical and physiological changes during pregnancy and their implications to the practice of anesthesia.

METHODS

A Randomized Controlled Trial was done among 200 pregnant woman in the Department of Obstetrics and Gynecology at Tertiary care institute and hospital for the period of 6 months (November 2021 to April 2022). Random Number table was used for selection of patients who were followed for Pregnancy in the department.

Inclusion criteria

All term singleton pregnancy was included in the study.

Exclusion criteria

Pregnant ladies with any pre-determined cardiac disease, kidney disorders, hemoglobin less than 10, hypertension, hypothyroidism, and

diabetes were excluded from the study. Multiple pregnancies (more than 1) and twin pregnancy.

Methodology
All the organ system with their valid physiological and anatomical changes were seen at time of Anesthesia. This consecutive series of original research papers were reviewed for the reporting of ethics committee approval and patient consent.

Pre-anesthetic checkup and counseling
Whatever the period of gestation, the most important step in all of them is thorough pre-operative evaluation. This whole exercise involves close coordination between the anesthesiologist, the obstetrician and the pediatrician as safety of both mother and fetus is the prime objective. Many of the clinical signs and symptoms such as heart murmur, tachypnea, dyspnea, benign ECG changes, and premature beats present commonly during normal pregnancy and may confuse the attending anesthesiologist with a suspicion of underlying comorbidity. Particular attention was paid to airway examination as this subset of the population invariably has edema of the airway as a result of hormonal impact. Difficulties can be encountered during bag-mask ventilation and laryngoscopy as a result of edema and breast engorgement so it was always be ready as multiple attempts at intubation in lieu of vocal cord edema and increased risk of bleeding. In such cases, preference should be given to a smaller sized endotracheal tube and avoidance of nasal intubation. Pre-oxygenation with 100% oxygen for 3–5 min was given ample time for airway securing under GA, which should preferably be administered with rapid sequence induction and intubation [5,6].

At the time of anesthesia
Analgesics, sedatives, and anesthetics must be used with caution for caesarean delivery as they can have a profound effect on neonatal health and Apgar scores. A few of the drugs, surgical, and anesthetic stress have the propensity to suppress lactation, which may or may not be of transient duration and as such necessitates extreme vigil during conduct of anesthesia.

GA is indicated in a number of conditions such as patient's refusal for regional anesthesia, and coagulation abnormalities, various contraindications of regional anesthesia such as severe active infection at the back, neurological diseases, and deformities of the spine fetal compromise necessitating urgent operative intervention.

Parenteral opioids such as pethidine, fentanyl, tramadol, butorphanol, and remifentanil have been used successfully for labor analgesia, but not a single drug is free from side effects when administered in a little higher doses [5-7]. Somewhat less effective are inhalational agents such as Entonox and the short-acting fluoride anesthetic sevoflurane, but even they are also not devoid of side effects, especially at higher doses [7,8]. It is the technical advancements in regional anesthesia, which has propelled labor analgesia to newer horizons. Epidural and combined spinal epidural analgesia using lower dose regimens of LAs and opioids have been revolutionary in achieving the desired goals of labor analgesia [9].

Statistical analysis
Statistical analysis was done using the software Statistical Package for the Social Sciences (SPSS) 22.0 version. Continuous variables was presented by mean±SD and categorical variables by frequency or percentages. Proportion was presented for all the anatomical and Physiological Changes.

RESULTS

As per Table 1, ventilation begins to increase significantly at approximately 8 weeks of gestation, most likely in response to hormonal (progesterone) sensitization of the respiratory center to carbon dioxide and increased metabolic rate. Increased respiratory drive may lead to breathlessness. Oxygen consumption increases by approximately 20% due to increased maternal metabolism and increased oxygen consumption by the uterus and placenta. Respiratory physiology continues to change throughout pregnancy. Airway resistance decreases 50% due to the effects of progesterone on bronchial smooth muscle. Lung compliance remains unchanged, but chest wall compliance decreases, likely from the additional breast and soft-tissue mass of pregnancy. Therefore, on balance, both the maximum breathing capacity and FEV 1 remain unchanged. With Minute ventilation, RR, Tidal volume, and Alveolar ventilation are increased.

As per Table 2 anatomically, diaphragm elevates with cephalad pressure of the growing gravid uterus, and the chest wall diameter increases in the anteroposterior and transverse diameters. This leads to unchanged Total Lung Capacity, Vital Capacity, and Closing Capacity, while Expiratory Reserve Volume, Residual volume, and Functional residual capacity (FRC) seen a decreased in 20% in all patients.

As per Table 3, blood volume increases early in gestation (at approximately 12 weeks), which continues to increase rapidly during the second trimester and more slowly during the remainder of pregnancy. As total blood volume increases, plasma volume increases disproportionately more than red blood cell (RBC) volume. This relative dilution of RBCs in the greater plasma volume results in what is often called the physiological anemia of pregnancy.

As per Table 4, cardiac output increases in early pregnancy with changes measurable by 8 weeks gestation. Cardiac output increases most rapidly (to approximately 35% above baseline) during the second trimester, then remains about the same until term. Output increases substantially with labor contractions; each contraction increases cardiac output an additional 10–25%. This is caused by the inotropic effects of pain-released endogenous catecholamine and also the autotransfusion to the

Table 1: Physiological changes in the respiratory system at term gestation

Parameter	Changes
Minute ventilation	Increased to 50%
Respiratory rate	Increased to 15%
Tidal volume	Increased to 40%
Anatomic dead space	Unchanged
Alveolar ventilation	Increased to 70%

Table 2: Anatomic changes in the respiratory system at term gestation

Parameter	Changes
Total lung capacity	Unchanged
Vital capacity	Unchanged
Expiratory reserve volume	Decreased to 20%
Residual volume	Decreased to 20%
Functional residual capacity	Decreased to 20%
Closing capacity	Unchanged

Table 3: Blood volume changes at term gestation

Parameters	Changes
Blood volume	Increases by 35%
RBC volume	Increases by 20%
Plasma volume	Increases by 45%

Table 4: Cardiac changes at term gestation

Parameters	Changes
Cardiac Volume	Increases by 35%
Stroke volume	Increases by 30%
Pulse Rate	Increases by 15%

central circulation of blood from the contracted well-perfused uterine muscle walls. Cardiac output increases maximally (80%) just after delivery with autotransfusion of blood from the uterus as it contracts completely. This increase in cardiac output and preload after delivery is so substantial that pregnant women with cardiac problems (such as mitral stenosis) may do well through pregnancy and labor, but fail (congestive heart failure) in the postpartum period.

DISCUSSION

This randomized controlled trial was done to predict the major pregnancy changes at the time of anesthesia. These physiological and anatomic changes have several important clinical implications. First, with-increased alveolar ventilation, a pregnant woman's $PaCO_2$ decreases to 32 mm Hg at term gestation, but her pH remains at 7.40–7.44 due to renal compensation with decreased HCO 3 (22 mEq/L) and other buffer bases [7]. Recognizing the ways, in which normal arterial blood gas values in pregnant women differ from those in non-pregnant women can be clinically essential. Due to increased alveolar ventilation, it is also common for pregnant women breathing room air to have PO2s>100.15 this increase-in dissolved oxygen does not significantly improve oxygen delivery to the fetus. However, what does improve oxygen delivery to the fetus is the shifting of the maternal oxyhemoglobin dissociation curve to the right, with maternal Pso increasing from 26 to 30 mm Hg by term [8]. Fetal ability to extract oxygen from the maternal hemoglobin is augmented in a complimentary fashion by special fetal hemoglobin. This hemoglobin, with its Pso of 18 mm Hg, has a higher oxygen affinity than maternal hemoglobin. Induction of inhalation anesthesia is faster due to decreased FRC and increased alveolar ventilation. This coupled with the fact that MAC is also decreased during pregnancy, means that spontaneous ventilation with inhaled vapor in the unintubated, pregnant patient places the woman at risk for aspiration as protective airway reflexes will be lost more rapidly [9,10].

All pregnant women should routinely undergo a thromboembolic risk assessment in the antenatal period and again on admission to hospital with appropriate thromboprophylaxis prescribed. As low molecular weight heparins (LMWHs) are being used increasingly in the antenatal period, it is essential that the anesthetist is aware of this, and importantly, the time the last dose was administered as regional block should not be performed within 12 h of a prophylactic dose of LMWH [11,12].

Physiological changes occur very early in pregnancy, leading to an overall hyperdynamic circulation. These early hormonal effects lead to the primary event of peripheral vasodilatation which causes a decrease in the systemic vascular resistance. This occurs as early as 8 weeks of gestation [12]. The heart is physiologically dilated and displaced in both cephalad and lateral directions. A normal pregnancy ECG may have 15–208 left axis deviation and T waves may be inverted in lateral leads and lead III mimicking left ventricular hypertrophy and other structural disease [13]. Anatomically, the iliac veins join to form the inferior vena cava at a level corresponding to the L4/5 interspace. Once the uterus is at this level, inferior vena cava compression may occur. By the time enlarging uterus approaches the level of the umbilicus, corresponding to 20 weeks in a singleton pregnancy, the mechanical effects of the enlarging uterus can cause compression of both the inferior vena cava and the descending aorta in the supine position. The combination of these leads to a reduced venous return and decreased CO [14].

CONCLUSION

During Pregnancy Anesthesia implications can be disastrous decreased FRC results in the faster onset of hypoxemia during periods of apnea. The incidence of difficult intubation is increased – intubation difficulty may increase further over the course of labor and delivery. With Minute ventilation, RR, Tidal volume, and Alveolar ventilation are increased. Cardiac output increases in the early pregnancy with changes measurable by 8 weeks gestation. Cardiac output increases most rapidly (to approximately 35% above baseline) during the second trimester, then remains about the same until term. Output increases substantially with labor contractions; each contraction increases cardiac output an additional 10–25%.

AUTHORS' CONTRIBUTIONS

Dr. A has finalized the draft and guarantor, Dr. B has prepared the conceptual framework, designing of draft, and data analysis, Dr. A was involved in data collection and analysis, and Dr. B has done manuscript writing and data collection.

CONFLICTS OF INTEREST

None declared.

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