PREDICTION OF MATERNAL DISORDERS BY SERIAL CARDIAC OUTPUT ESTIMATION DURING PREGNANCY

Jaiswal A, Singam A, Chhabra S*, Namgyal A

*Department of Obstetrics Gynaecology, Mahatma Gandhi Institute of Medical Sciences, Sevagram-442102, Wardha, Maharashtra, India.
E-mail of Corresponding Author: chhabra_s@rediffmail.com

Abstract
In pregnancy there is increased blood volume, heart rate (HR), stroke volume (SV), and cardiac output (CO). Present study was to assess the predictive value of serial measurements of cardiac output between 8 – 32 weeks of pregnancy for prediction of maternal disorders. Cardiac output was measured by thoracic electrical impedance plethysmography at 10 ± 2 weeks, 14 ± 2 weeks, 18 ± 2 weeks, 22 ± 2 weeks, 26 ± 2 weeks and 30 ± 2 weeks of pregnancy. These women were followed till 7 days post-partum. Pregnant women having high cardiac output developed hypertensive disorders and those having low cardiac output developed intrauterine growth restriction and oligohydramnios.

Keywords: Cardiac Disorders, Maternal Disorders, Plethysmography

1. Introduction
Obstetrics is largely a preventive science, a lot of which is achieved by appropriate ante, intra and postnatal care. The Utopian objective of maternal care is that “Every pregnancy culminates in a healthy mother and a healthy baby; undamaged mentally and physically.” For this there are extensive physiologic, biochemical and anatomic changes that occur during pregnancy which are local as well as systemic and are responsible for maintaining a healthy environment for the growing fetus and preserving the mother’s health. Early cardiovascular adaptations are central to circulation to growing pregnancy and its outcome. Successful maternal cardiovascular adaptations are also a diagnostic test of long-term cardiovascular health for the mother. In pregnancy there is increased blood volume, heart rate (HR), stroke volume (SV), and cardiac output (CO). CO increases by 30 to 50% during pregnancy. It has been reported that maternal blood volume and CO increases in hypertensive disorders of pregnancy, and there is decreased maternal blood volume in conditions like fetal intra uterine growth restriction and oligohydramnios.

2. Aim
Aim of the present study was to assess the predictive value of serial measurements of cardiac output between 8 – 32 weeks of pregnancy for prediction of materno-fetal outcome. Cardiac output was calculated from stroke volume and heart rate of the pregnant women reporting to the antenatal clinic between 8 to 32 weeks of pregnancy and the trends were analyzed.

3. Material and Methods
Present prospective study was carried out in the department of Obstetrics and Gynecology with the help of department of Physiology of Mahatma Gandhi Institute of Medical Sciences, Sevagram, after taking approval of the ethics committee of the institute. The study subjects were pregnant women reporting to outpatient department from early gestation of 10 ± 2 weeks and were followed till delivery and post partum. A detailed history was taken, examination and investigations were done.

CO was measured by thoracic electrical impedance plethysmography at 10 ± 2 weeks, 14 ± 2 weeks, 18 ± 2 weeks, 22 ± 2 weeks, 26 ± 2 weeks, 30 ± 2 weeks of pregnancy after explaining the procedure, and these women were followed till delivery and post partum. During the study period the new pregnant women presenting to outpatient were 7285. Out of which 568 women of early gestation (10± 2) weeks were registered for the study after taking informed consent. During the study period the outcome of pregnancies of all study subjects was observed and recorded, however of the 568 registered in the beginning, 68 were lost to follow up. So 500 were the study subjects.

4. Observations
It was revealed that the CO at 10 ± 2 weeks has positive and high degree of correlation with CO at increasing gestation (P= < 0.001).
Out of total 500 women, 63 had CO of < 5 L/min, which is less than the mean (5.44 L/min) at 10 ± 2 weeks gestation, of them 33 (52.38%) had FGR, and 3 (4.76 % ) had oligo. 236 women had CO between 5-5.49 L/min of them 200 (84.74%) had no disease, 10 (4.23%) had oligo, 22 (9.32%) had FGR, and 4 (1.69 %) later had HD. 157 women had CO between 5.5- 5.99 L/min, of them 96 (61.14%) had no disease, 11 (7.0%) had oligo, 17 (10.82%) had FGR, and 30 (19.10 %) had HD, and 3 were anaemics. 4 women had CO between 6-6.5 L/min, all of them were anaemic throughout pregnancy. (Table1).

At 20 ± 2 weeks , out of 500 women, 10 had CO between 5-5.49 L/min which is less than the mean (5.99 L/min) of them 8(80%) had FGR. 173 women had CO between 5.5- 5.99 L/min, of them 89 (50.58%) had no disease, 24 (14.11%) had oligo, 59 (34.7%) had FGR. 191 women had CO between 6-6.5 L/min, of them 185 (.96.85%) had no disease, 3 (1.57%) had FGR and 3 (1.57%) had HD. 126 women had CO above 6.5 L/min, of them 78 (.61.9) had no disease, 33 (26.19%) had HD and 15 (11.9 %) were anaemic throughout pregnancy (Table 2).

The mean CO at 30 ± 2 weeks was 6.36 L/min .Out of total 500 women, 153 had CO less than the mean for that gestation. Of them only 5 women had CO between 5-5.49 L/min and all had FGR rest 147 women had CO between 5.5-5.99 L/min, of them 70 (47.6%) had no disease, 22 (14.96%) had oligo, 54 (36.73%) had FGR, and 1 had HD. 132 women had CO almost equal to the mean i.e between 6-6.5 L/min, of them 120 (90.90%) had no disease, 2 (1.36%) had oligo, 10 (6.80%) had FGR. 216 women had CO more than the mean, i,e > 6.5 L/min, out of them 164 (75.92%) had no disease, 36 (16.66%) had HD (Table 3).

### Table I. Correlation Between CO at 10 ± 2 Weeks And Effect On Mother

| CO In L/min | TOTAL | Effect On Mother | Pregnancy Disease | Distribution of women |
|-------------|-------|------------------|-------------------|-----------------------|
| > 5         | 63    | No Disease       | No Disease        | No: 027, %: 42.85    |
|             |       | Disease          |                   |                       |
|             |       | Oligo            |                   | 003, 04.76            |
|             |       | FGR              |                   | 033, 52.38            |
|             |       | HD               |                   | 000, 00.00            |
|             |       | Anaemia          |                   | 000, 00.00            |
|             |       | Total            |                   | 063, 100.00           |
| 5-5.49      | 236   | No Disease       | No Disease        | No: 063, %: 84.74     |
|             |       | Disease          |                   |                       |
|             |       | Oligo            |                   | 010, 04.23            |
|             |       | FGR              |                   | 022, 09.32            |
|             |       | HD               |                   | 004, 01.69            |
|             |       | Anaemia          |                   | 000, 00.00            |
|             |       | Total            |                   | 236, 100.00           |
| 5.5-5.99    | 157   | No Disease       | No Disease        | No: 096, %: 61.14     |
|             |       | Disease          |                   |                       |
|             |       | Oligo            |                   | 011, 07.00            |
|             |       | FGR              |                   | 017, 10.82            |
|             |       | HD               |                   | 030, 19.10            |
|             |       | Anaemia          |                   | 003, 01.91            |
|             |       | Total            |                   | 157, 100.00           |
| 6-6.49      | 42    | No Disease       | No Disease        | No: 031, %: 73.80     |
|             |       | Disease          |                   |                       |
|             |       | Oligo            |                   | 000, 00.00            |
|             |       | FGR              |                   | 000, 00.00            |
|             |       | HD               |                   | 003, 07.14            |
|             |       | Anaemia          |                   | 008, 19.04            |
|             |       | Total            |                   | 042, 100.00           |
| > 6.5       | 04    | No Disease       | No Disease        | No: 000, %: 00.00     |
|             |       | Disease          |                   |                       |
|             |       | Oligo            |                   | 000, 00.00            |
|             |       | FGR              |                   | 000, 00.00            |
|             |       | HD               |                   | 000, 00.00            |
|             |       | Anaemia          |                   | 004, 100.00           |
|             |       | Total            |                   | 004, 100.00           |
| Total       | 500   | No Disease       | No Disease        | No: 000, %: 100.00    |

**Oligo- Oligohydramnios; FGR- Fetal Growth Restriction; HD - Hypertensive Disorder**
### Table II. Correlation Between CO at 20 ± 2 Weeks And Effect On Mother

| CO In L/min | TOTAL | Effect On Mother | Pregnancy Disease | Distribution of women |
|-------------|-------|------------------|-------------------|-----------------------|
| 5-5.49      | 10    | No Disease       | No Disease        | 02 20.00              |
|             |       | Disease          | Oligo             | 00 00.00              |
|             |       |                  | FGR               | 08 80.00              |
|             |       |                  | HD                | 00 00.00              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 10 100.00             |
| 5.5-5.99    | 173   | No Disease       | No Disease        | 89 50.58              |
|             |       | Disease          | Oligo             | 24 14.11              |
|             |       |                  | FGR               | 59 34.70              |
|             |       |                  | HD                | 01 00.50              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 173 100.00            |
| 6-6.49      | 191   | No Disease       | No Disease        | 185 96.85             |
|             |       | Disease          | Oligo             | 00 00.00              |
|             |       |                  | FGR               | 03 15.76              |
|             |       |                  | HD                | 03 01.57              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 191 100.00            |
| > 6.5       | 126   | No Disease       | No Disease        | 78 61.90              |
|             |       | Disease          | Oligo             | 00 00.00              |
|             |       |                  | FGR               | 00 00.00              |
|             |       |                  | HD                | 00 00.00              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 126 100.00            |

Figures in bracket indicate %. **Oligo**- Oligohydramnios; **FGR**- Fetal Growth Restriction; **HD**- Hypertensive Disorder

### Table III. CO at 30 ± 2 Weeks And Effect On Mother

| CO In L/min | TOTAL | Effect On Mother | Pregnancy Disease | Distribution of women |
|-------------|-------|------------------|-------------------|-----------------------|
| 5-5.49      | 05    | No Disease       | No Disease        | 00 00.00              |
|             |       | Disease          | Oligo             | 00 00.00              |
|             |       |                  | FGR               | 05 100.00             |
|             |       |                  | HD                | 00 00.00              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 05 100.00             |
| 5.5-5.99    | 147   | No Disease       | No Disease        | 70 47.60              |
|             |       | Disease          | Oligo             | 22 14.96              |
|             |       |                  | FGR               | 54 36.73              |
|             |       |                  | HD                | 01 19.46              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 147 100.00            |
| 6-6.49      | 132   | No Disease       | No Disease        | 120 99.00             |
|             |       | Disease          | Oligo             | 02 15.15              |
|             |       |                  | FGR               | 10 07.57              |
|             |       |                  | HD                | 00 00.00              |
|             |       |                  | Anaemia           | 00 00.00              |
|             |       | Total            |                   | 132 100.00            |
| > 6.5       | 216   | No Disease       | No Disease        | 164 75.92             |
|             |       | Disease          | Oligo             | 00 00.00              |
|             |       |                  | FGR               | 01 00.46              |
|             |       |                  | HD                | 36 16.66              |
|             |       |                  | Anaemia           | 15 06.94              |
|             |       | Total            |                   | 216 100.00            |

Figures in bracket indicate %. **Oligo**- Oligohydramnios; **FGR**- Fetal Growth Restriction; **HD**- Hypertensive Disorder
5. Discussion
Rosso\(^9\) has carried out a study to determine the hemodynamic characteristics of 11 normotensive gravidae with FGR. At 36-38 weeks of gestation, P\(\text{Vol}\) was 3,161 +/- 121 ml in controls and 2,624 +/- 95 ml in the FGR group (p < 0.003); CO was 6,191 +/- 132 ml/min in controls and 5,483 +/- 186 ml/min in the FGR group (p < 0.01). TPVR was lower in controls than in FGR (1,031 +/- 33 vs. 1,306 +/- 62 dyn/s/cm\(^5\); p < 0.001). Birth weight was correlated with both P\(\text{Vol}\) (r = 0.61; p < 0.01) and CO (r = 0.53; p < 0.02) and inversely correlated with TPVR (r = -0.69; p < 0.001).

These results are in line with the hypothesis that a reduced P\(\text{Vol}\) leads to a lower CO, and, secondarily, to reduced uterine blood flow to FGR.

Bamfo et al\(^{10}\) compared maternal cardiac function in women with FGR to those with SGA pregnancies (non-FGR). In the FGR (compared to the non-IUGR) group, maternal CO was lower (4.7 vs. 6.1 L/min, P value < 0.001) and total vascular resistance was higher (1444 vs. 1088 dynes/s/cm\(^5\), P value < 0.001). The lower CO was due to a lower preload, demonstrated by a reduced SV (59.9 vs. 73.6 mL, P < 0.01) and smaller left atrial diameter (LAD) (31.5 vs. 34.1 mm, P value = 0.01).

Ross\(^{11}\) has also found that oligohydramnios is associated low CO.

Easterling et al\(^{12}\) have considered women to be at risk for PE if their CO was greater than 7.4 L/min before 24 weeks’ gestation. Nulliparous and diabetic subjects at risk were treated with 100 mg of atenolol or placebo. CO was measured by Doppler technique. They concluded that measurement of CO in the second trimester identified women at risk for PE and treatment with atenolol decreased the incidence of PE.

Bosio\(^{13}\) conducted a longitudinal study of 400 primigravidae who were monitored throughout pregnancy using doppler echocardiography to document maternal central hemodynamics during preclinical and clinical phases of nonproteinuric gestational hypertension and PE. Multinomial logistic regression was used to identify variables associated with risk of hypertension. Gestational hypertension developed in 24 (6.34%) women and PE developed in 20 (5.29%) women out of the 378 women who completed the pregnancy. Compared to normotensive controls, women who had PE had significantly elevated CO before clinical diagnosis.

Study by Blyton\(^{14}\) suggests a specific association between FGR that commonly occurs in PE and decreased maternal CO. Sleep is associated with marked hypertension in PE. Therefore the study aimed to determine how sleep influences other hemodynamic parameters in PE, specifically to determine if sleep-induced exacerbation of hypertension was associated with reductions in CO. Randomized controlled trial of nasal continuous positive airway pressure was done. Twenty-four women with severe PE and 15 control nulliparous subjects were included in the study. Full polysomnography including beat-to-beat blood pressure recording was done. SV, HR, CO, TPR and ejection duration were derived from the blood pressure waveform. Half of the 24 preeclamptic subjects were randomly assigned to receive treatment with nasal continuous positive airway pressure and the other half to receive no treatment. HR, SV and CO were similar in controls and patients with preeclampsia during wakefulness, while total peripheral resistance was significantly elevated. Sleep induced marked decrements in HR, SV and CO in preeclamptic subjects and resulted in further increments in total peripheral resistance. CO during sleep was correlated with fetal birth weight (r\(^2\) = 0.64, P < .001). When preeclamptic subjects were treated with continuous positive airway pressure, reductions in CO were minimized, while increments in total peripheral resistance were also reduced. These data indicate that sleep is associated with adverse hemodynamic changes in women with preeclampsia. These changes are minimized with the use of continuous positive airway pressure. Reduced CO during sleep may have an adverse effect on fetal development.

Conclusion
An attempt has been made in the present study for prediction of pregnancy specific disorders and materno-fetal outcome by estimating the CO from early pregnancy, the conclusions drawn from the study are:

- The CO at 10 ± 2 weeks has positive and high degree of correlation with CO at increasing gestation (P\(=\) < 0.001).
- The CO was maximum at 22± 2 weeks and was the best predictor of CO at 30 ±2 weeks.
- High CO was associated with hypertensive disorders.
- Low CO was associated with intrauterine growth restriction and oligohydramnios.
Recommendations

- Further studies with larger sample size are needed to study the correlation and prediction of pregnancy specific disorders by estimating maternal CO from early pregnancy.
- Further studies are needed to find deviations in maternal CO and the etiology, when FGR and HD occur together.
- Further studies are needed to study the evolution of Impedance Cardiovasography as a non invasive, cheap, reliable and safe method for estimation of CO during pregnancy for pregnancy disorders for prevention strategies of many killer conditions.

References

1. O’Toole, M.L. Physiologic aspects of exercise in pregnancy. Clin Obstet Gynecol 2003; 46(2):379-389.
2. Foley MR, Maternal cardiovascular and hemodynamic adaptation to pregnancy. Up-to-date patient information. 2007; 15,3
3. David F, Maternal cardiac disease, Developing Anaesthesia.org 2007.
4. Carr DB, McDonald GB, Brateng D, Desai M, Thach T, Easterling TR. The relationship between hemodynamics and inflammatory activation in women at risk for preeclampsia. Obstetrics & Gynecology 2001; 98:1109-1116.
5. Bamfo JE, Kametas NA, Turan O, Khaw A, Nicolaides KH. Maternal cardiac function in fetal growth restriction. BJOG. An Int J Obst Gynae. 2006; 113: 784-91.
6. Ross MG, Idah R, Correlation of maternal plasma volume and composition with amniotic fluid index in normal human pregnancy. Journal of Maternal-Fetal and Neonatal Medicine, 2004; 15(2); 104-108.
7. Easterling T, Brateng D, Schmucker B, Brown Z, Millard S. Prevention of preeclampsia: A randomized trial of atenolol in hyperdynamic patients before onset of hypertension. Obstet Gynecol. 1999; 93:725–33.
8. Rosso P, Donoso E, Braun S, Espinoza R, Fernández C, Salas SP. Maternal hemodynamic adjustments in idiopathic fetal growth retardation. Gynecol Obstet Invest. 1993; 35(3):162-5.
9. Heinroth KM, Elster M, Nuding S, Schlegel F, Christoph A, Carter J, Buerke M, Werdan K. Impedance cardiography: a useful and reliable tool in optimization of cardiac resynchronization devices, Europace 2007 ; 9(9):744-750.
10. Bamfo JE, Kametas NA, Chambers JB, Nicolaides KH.Maternal cardiac function in fetal growth-restricted and non-growth-restricted small-for-gestational age pregnancies Ultrasound in Obstetrics and Gynecology. 2007; 29: 151-57.
11. Ross MG, Idah R, Correlation of maternal plasma volume and composition with amniotic fluid index in normal human pregnancy. Journal of Maternal-Fetal and Neonatal Medicine, 2004; 15(2); 104-108.
12. Easterling T, Brateng D, Schmucker B, Brown Z, Millard S. Prevention of preeclampsia: A randomized trial of atenolol in hyperdynamic patients before onset of hypertension. Obstet Gynecol. 1999; 93:725–33.
13. Bosio PM, McKenna PJ, Conroy R, O’Herlihy C. Maternal central hemodynamics in hypertensive disorders of pregnancy. Obstet Gynecol. 1999; 94:978–984.
14. Blyton DM, Sullivan CE, Edwards N. Reduced nocturnal cardiac output associated with preeclampsia is minimized with the use of nocturnal nasal CPAP. Sleep. 2004 Feb 1; 27(1):79-84.