

THE  
Journal of Obstetrics & Gynaecology  
of India

VOLUME XVII, NO. 3

JUNE 1967

BLOOD VOLUME CHANGES DURING NORMAL PREGNANCY†

by

RAM SINGH,\* M.D., M.R.C.P.,

NAWAL KISHORE,\*\* M.S., F.A.C.S.,

PADMA HINGORANI,\*\*\* M.S.,

and

D. S. GAHLAUT,\*\*\*\* M.D., M.R.C.P.

Changes in the body weight of pregnant women in excess of what could be accounted for by the weight of the enlarging uterus and the growing foetus were usually designated by the vague term "Plethora of Pregnancy". De Lac (1928) stated that the quantity of blood was augmented during pregnancy especially in the last two months, thus causing a true plethora. Dieckmann and Wegner (1934) reported that total blood and plasma volumes began to increase in the first trimester of pregnancy, becoming 16 to 18% higher respectively than what they were in non-pregnant women. There was an average increase of 23% in total blood volume and of 45% in plasma volume 60 days before delivery. At the end of the first week postpartum these figures decreased by 22% but both plasma volume and blood volume did not return to non-pregnant levels until two months after delivery. Tysoe and Lowensten (1950) on the other hand found no significant difference in blood volume values immediately before and after delivery. Despite several studies, there is as yet no agreement regarding the extent of changes in blood volume during pregnancy. This study was therefore planned to determine blood volume

\*Professor of Clinical Medicine.

\*\*Professor of Obstetrics & Gynaecology.

\*\*\*Gynaecologist.

\*\*\*\*Physician.

†From Depart. of Medicine, G. S. V. M. Medical College, Kanpur, and Depart. of Gynaecology & Obstetrics, S. N. Medical College, Agra.

Received for publication on 6-1-67.

during second and third trimesters of pregnancy and one week after delivery.

#### Material and Methods

Twenty-five normal pregnant women, ranging in age from 25-30 years, who attended the antenatal clinic at the S. N. Hospital, Agra, were taken up for this study. Only those cases were accepted who were free from any disease and in whom haemoglobin concentration was not less than 10 gms per cent. In each case blood volume was estimated on two occasions, first time between 14th and 18th weeks and next between 30th and 34th weeks. In 10 cases it was estimated a third time, one week after delivery. The dye dilution method using Evan's blue described by Dawson *et al* (1920) was used for blood volume determination.

#### Observations

##### *In normal non-pregnant women*

The plasma volume, blood volume and red cell volume values observed in 10 normal non-pregnant women, ranging in age between 19-26 years, are given in Table I.

##### *During second trimester of pregnancy*

The observations on blood volume, plasma volume and red cell volume during the second trimester of pregnancy are given below in Table II.

The average plasma volume was 2645 ml with a range of 2330 to 3250 ml. Expressed in terms of ml./sq. meter the respective figures were 1895 ml. and 1705 ml./sq. meter. All the cases showed an increase in plasma volume as compared with average plasma volume in normal non-pregnant women. The average increase was 12% with a range of 0.9 to 31.2%.

The blood volume varied between 3411 to 4895 ml. with an average value of 3992.0 ml. and the per sq. meter reading between 2497 and 3146 ml. with an average of 2857.8 ml./sq. meter. In 19 cases (76%) the blood volume was 0.6% to 13.8% higher than the average blood volume in normal non-pregnant women. In the remaining 6 cases (24%) the values were less than the average blood volume in normal non-pregnant women, but in none of them was it less than the lowest figure observed in normal non-pregnant women. The average increase for the group as a whole was 3.1%.

The red cell volume ranged between 1114 and 1661 ml. with an average of 1346.8 ml. Compared with the average red cell volume in normal non-pregnant women, only 4 cases (16%) showed an increase in red cell volume from 0.9 to 7.6%. In the remaining 21 cases (84%) it was less than in normal non-pregnant

TABLE I  
Showing values in normal non-pregnant women

	Plasma volume		Blood volume		Red cell volume	
	Total in ml.	ml./sq. Met.	Total in ml.	ml./sq. Met.	Total in ml.	ml./sq. Met.
Average	2556	1690	3940	2755	1524	1053
Range	2250-2700	1572-1776	3388-4482	2548-2867	1138-1807	855-1114



TABLE II

Showing Plasma Volume, Blood Volume and Red Cell Volume during Second Trimester of Pregnancy

Sl. No.	Name	PLASMA VOLUME			BLOOD VOLUME			RED CELL VOLUME		
		Total in cc	Cc/sq meter	% Increase or decrease	Total in cc	cc/sq metre	% increase or decrease	Total in cc	cc sq. meter	% increase or decrease
1.	M.	2400	1920	+13.6	3728	2982	+8.2	1328	1062	+0.9
2.	S.	2725	1974	+16.8	4103	2974	+0.9	1378	1000	-5.0
3.	G.N.	2750	1993	+18.0	4083	2958	+7.4	1333	965	-18.4
4.	M.I.	2900	2028	+20.0	4498	3146	+10.6	1598	1118	+5.2
5.	R.K.I.	2975	1970	+4.7	4545	3030	+9.3	1570	1040	-1.3
6.	S.I.	2525	1844	+9.1	3820	2775	+8.8	1277	931	-11.7
7.	K.	2575	1752	+3.7	3718	2529	-8.2	1143	777	-26.3
8.	V.L.	2700	1901	+12.5	3953	2784	-1.0	1253	983	-21.1
9.	R.K.II	2500	1865	+10.4	3819	2850	+3.0	1319	985	-6.5
10.	M.II	3250	2097	+24.0	4895	3137	+13.8	1645	1040	-1.3
11.	K.W.	2600	1893	+12.7	3973	2900	+5.3	1373	1002	-4.8
12.	S.I.	2500	1953	+15.6	3659	2859	+3.8	1159	906	-14.0
13.	K.	2775	1838	+8.7	4304	2850	+3.5	1529	1012	-3.9
14.	S.II	2330	1835	+8.6	3411	2686	-2.0	1081	851	-19.2
15.	R.S.	2600	1819	+7.6	3860	2700	-2.0	1260	881	-16.4
16.	P.W.	3175	2043	+31.2	4782	3085	+12.00	1607	1037	-1.7
17.	R.M.	2575	2028	+20.0	38.78	30.54	+10.9	1303	1026	-2.6
18.	G.D.	2400	1818	+7.6	3514	2662	-3.4	1114	844	-19.8
19.	K.	2575	1705	+0.9	3770	2407	-9.4	1195	792	-34.8
20.	S.	2475	1847	+9.3	3851	2874	+3.8	1376	1027	-2.9
21.	S.III	2375	1885	+11.5	3428	2720	-1.0	1053	835	-20.7
22.	P.I.	2800	1867	+10.5	4279	2853	+3.2	1479	986	-6.4
23.	S.II	2775	1885	+11.5	4436	3018	+9.6	1661	1133	-7.6
24.	S.W.	2375	1842	+9.0	3576	2772	+0.6	1201	1130	-7.3
25.	P.II	2500	1760	+4.1	3936	2771	+0.6	1436	1010	-4.1
Average		2645.2	1894.9	+12.0	3992.0	2857.8	+3.1	1346.8	974.9	-8.1

TABLE III  
Showing Plasma Volume, Blood Volume and Red Cell Volume during  
Third Trimester of Pregnancy

Sl. No.	Name	PLASMA VOLUME			BLOOD VOLUME			RED CELL VOLUME		
		Total in cc	cc/sq meter	% increase or decrease	Total in cc	cc/sq meter	% increase or decrease	Total in cc	cc/sq meter	% increase or decrease
1.	M.	2775	2102	+24.5	4240	3212	+16.6	1465	1110	+5.4
2.	Q.S.	3250	2289	+35.4	4754	3351	+21.6	1504	1062	+0.8
3.	G.	3725	2586	+53.0	5304	3683	+33.7	1579	1097	+4.5
4.	M.I.	3425	2345	+32.8	5084	3481	+26.3	1659	1136	+7.8
5.	R.K.	3670	2347	+39.0	5693	3625	+31.2	2023	1278	+21.3
6.	S.I.	2750	1978	+17.9	4083	2937	+6.6	1333	959	-9.0
7.	K.	2750	1833	+9.5	3862	2575	-6.6	1112	742	-29.6
8.	V.L.	3400	2267	+34.1	4977	3318	+20.4	1577	1051	-0.2
9.	R.K.	2975	2095	+24.0	4355	3067	+11.3	1380	972	-7.7
10.	M.	2900	1847	+9.3	4245	2704	-1.9	1345	857	-18.7
11.	K.	3300	2357	+39.5	4899	3499	+30.6	1599	1142	+8.4
12.	S.	3200	2370	+40.2	4435	3285	+19.2	1235	915	-13.1
13.	K.	3625	2309	+36.6	5459	3477	+26.2	1834	1168	+10.9
14.	S.	2700	2046	+21.1	3845	2913	+5.7	1145	867	-17.7
15.	R.S.	3200	2192	+29.7	4556	3120	+16.9	1356	928	-11.9
16.	P.W.	3885	2391	+41.5	5679	3550	+28.8	1854	1159	+10.0
17.	R.M.	2500	1937	+14.6	3761	2918	+5.9	1264	981	-6.9
18.	G.D.	2650	1934	+14.4	3721	2716	-1.4	1071	773	-27.7
19.	K.	3250	2097	+24.0	4628	2986	+8.4	1378	889	-16.7
20.	S.	2975	2140	+26.6	4480	3223	+17.0	1505	1083	+2.8
21.	S.	2675	2034	+20.4	3861	2936	+6.6	1186	905	-14.1
22.	P.	3575	2849	+33.0	5234	3292	+12.2	1659	1043	-1.0
23.	S.	3600	2353	+39.2	5584	3650	+32.5	1984	1297	+23.2
24.	S.	2775	2071	+22.5	4005	2989	+8.5	1230	918	-12.7
25.	P.	2975	2018	+19.4	4014	3129	+13.6	1639	1111	+5.5
Average		3137.8	2167.5	+28.01	4614.4	3185.4	+15.6	1476.6	1017.7	+4



women by 1.3 to 26.3%. The average fall in red cell volume was 8.1%.

#### *During third trimester of pregnancy*

The values of blood volume, plasma volume and red cell volume observed during the third trimester of pregnancy are given in Table III.

The plasma volume during the third trimester of pregnancy ranged between 2650 and 3825 (average 3137.8) ml. or between 1833 and 2588 (average 2176.5) ml./sq. meter. There was an increase in plasma volume over the average plasma volume values in normal non-pregnant women in all the cases. The average increase was 28.1% with a range of 3.5% to 53.0%. Twenty-three of the 25 (92%) cases had higher plasma volume levels than the average plasma volume during the second trimester of pregnancy. Of the remaining two cases the plasma volume was either equal to or less than the average plasma volume level during the second trimester.

The blood volume ranged between 2111 to 5693 (average 4613.4) ml or 1575-3683 ml./sq. meter. All but two cases showed an increase in blood volume varying from 5.7 to 33.7% (average 15.6%) over the average blood volume level in normal non-pregnant women.

The red cell volume ranged between 1071 to 2023 (average 1476.6) ml. or 742-1297 (average 1017.7) ml./sq. meter. It was increased in 11 cases (44%) by 0.8% to 23.2% and decreased in the remaining 14 (56%) cases in comparison to the average red cell volume in normal non-pregnant women. In all but 3, the level was higher than that observed during

second trimester of pregnancy. Out of the remaining 3 cases it was unchanged in one case and came down in the other two.

#### *One week postpartum*

The levels of plasma volume, blood volume, and red cell volume observed in 10 cases one week postpartum are given in Table IV.

The plasma volume ranged between 2200-2775 (average 2474) ml. or between 1650-1805 ml./sq. meter. In each case the level was lower than its own level during the third trimester of pregnancy. The average fall in plasma volume from the levels in the third trimester of pregnancy was 691 ml. or 22%. However, the average plasma volume was still higher as compared to the average non-pregnant level.

The blood volume ranged between 3463 and 4304 ml (average 3734) or between 2566 and 2869 ml./sq. meter. In all cases, the blood volume levels fall from their own levels during the third trimester of pregnancy. The average fall in blood volume was 909 ml. or 19.7%. However, the blood volume level was still higher than the average blood volume level in non-pregnant women by 2.2%.

The red cell volume varied between 1144 and 1422 (average 1280) ml. or between 812 and 1219 (average 938) ml./sq. meter. Compared with the values during the third trimester of pregnancy it was less in all cases except one, and the average decrease was 224 ml. or 15.1%. Similarly 24 cases were found to have red cell volume 11% lower than the average level in non-pregnant women.

TABLE IV  
 Showing Plasma Volume, Blood Volume and Red Cell Volume  
 One Week after Delivery

Sl. Name No.	PLASMA VOLUME			BLOOD VOLUME			RED CELL VOLUME		
	Total in cc	cc/sq. meter	% increase or decrease	Total in cc	cc/sq meter	% increase or decrease	Total in cc	cc/sq meter	% increase or decrease
1. M.	2200	1705	+ 0.8	3463	2685	- 2.5	1263	980	- 7.0
2. S.	2560	1910	+13	3770	2813	+ 2.1	1210	903	-14.3
3. G.N.	2475	1768	+ 4.3	3617	2584	- 6.2	1142	815	-22.5
4. M.	2528	1806	+ 6.8	3950	2921	+ 2.4	1422	1016	- 3.6
5. R.K.	2775	1650	- 1.2	4304	2869	+ 4.9	1530	1219	+14.8
6. S.	2375	1781	+ 5.4	3526	2645	- 4.0	1151	864	-18.0
7. K.	2525	1753	+ 3.7	3695	2566	- 6.9	1170	812.7	-22.0
8. V.L.	2475	1730	+ 2.4	3727	2604	- 5.5	1252	875.9	-16.8
9. R.K.	2300	1725	+ 2.1	3625	2719	- 1.3	1325	994.0	- 5.6
10. M.	2525	1712	+ 1.3	3858	2616	- 5.0	1333	904.0	-14.2
Average	2474	1754	+ 3.9	3754	2692	- 2.2	1280	938	-11.0



### Discussion

Considerable changes have been observed in blood volume during pregnancy in this study. The blood volume increased by 3.1% over the average normal non-pregnant levels in 76% cases during the second trimester of pregnancy. The plasma volume was 12% higher in second trimester of pregnancy than the average level in non-pregnant women. The plasma volume, therefore, increased more than the blood volume during the second trimester of pregnancy. Gomzell *et al* (1954), taking blood volume and plasma volume values four weeks post-partum as normal, found much higher average increase in blood volume than observed by us during this period of pregnancy. Roscoe and Donaldson (1946), on the other hand, reported an average increase of 1.5% in the blood volume and of 7.2% in plasma volume. They took, like us, healthy-non-pregnant women as controls. Our figures resemble more those of the latter workers.

Blood volume starts increasing late in the first trimester of pregnancy and increases steadily thereafter till the latter part of pregnancy (Dieckmann and Wegner 1934; Roscoe and Donaldson 1946; Caton *et al* 1951; Naltaniel, 1953). Like these workers we observed that in the third trimester of pregnancy, in 92% cases both, blood volume and plasma volume increased by 16.5% and 18.1% above the second trimester level.

One week after delivery the blood volume as well as the plasma volume fell by 19.7% and 22% respectively from the respective levels during the

third trimester of pregnancy. These levels were, however, a little higher (2.2% and 3.9% respectively) than the average levels in non-pregnant women. Red cell volume fell to a level 11% below the level in normal non-pregnant women. Although all the workers agree that blood volume and plasma volume come down to normal after delivery the time taken by these to return to normal levels has varied from two weeks (Thomson *et al* 1938; McLennan and Thourin, 1948; Tysoe and Lowensten, 1950) to 4 weeks (Caton *et al*, 1950; Gomzell *et al*, 1954) or even longer (Dieckmann and Wegner, 1934).

### Summary and Conclusions

A study of blood volume changes during normal pregnancy in 25 healthy women has been reported. Ten normal non-pregnant women ranging in age from 19 to 26 years were also studied to serve as controls.

The blood volume was estimated by the dye dilution method using Evans blue, as described by Dawson *et al* (1920).

The control values of blood volume, plasma volume and red cell volume were found to be 3940 ml, 2556 ml and 1524 ml respectively.

During second trimester of pregnancy the blood volume remained within normal limits in 24% and increased by 3.1% (0.6-13.8%) over the control values in the remaining 76% cases; plasma volume was increased in all the cases and the levels were 12% (0.9-31.2%) higher than the control levels. Red cell volume increased in only 16% cases and fell in 84% cases.

During the third trimester of preg-

nancy 92% showed further increase in blood volume and plasma volume (16.5% and 18% respectively). Red cell volume also increased in all but three cases.

One week post-partum both blood volume and plasma volume fell to a level which was still slightly higher (2.2% and 3.9% respectively) than the control levels in all the cases. Twenty-four out of 25 cases in the present study showed a conspicuous fall in red cell volume which was 11% lower than the control values.

These findings have been discussed and compared with those reported in literature.

References

1. Caton, W. L., Reid D. E. and Roby, C. C.: Am J. Obst. & Gynec. 62: 827, 1951.
2. Dawson, A. B., Evans, H. M. and

Whipple, G. H.: Am. J. Physiol. 51: 232, 1920.

3. Delec, J. B.: Principles & Practice of Obstetrics. ed. 5, Philladelphia, 1928, p. 105.
4. Dickmann, W. J. and Wegner, C. R.: Arch. Int. Med. 53: 71, 1934.
5. Gomzell, C. A., Hgords, Robbe and Torggney, S.: Act. Obst. & Gynec. Scand. 289: 411, 1954.
6. Melennan, C. E. and Thourin, L. G.: Am. J. Obst. & Gynec. 55: 189, 1948.
7. Naltaniel, D.: Surg. Gynec. & Obs 97: 173, 1953.
8. Roscoe, M. H. and Donaldson, G. M.: J. Obst. & Gynec. Brit. Emp 53: 527, 1946.
9. Tysoe, P. W. and Lowesten, L.: Am. J. Obst. & Gynec. 60: 1187, 1950.
10. Thomson, J., Chhen, M. E. and Burton, H. E.: Am. J. Med. Sc. 196: 819, 1938.