Normal Fetal Reference Ranges for Cardiac Output and Peak Systolic Velocity in the Aorta and Pulmonary Arteries

Lee-Tannock A, Hay K, Kumar S
UQ, QMIR Berghofer. Brisbane Australia

Abstract

Purpose: To construct longitudinal fetal reference ranges for cardiac output (CO) and peak systolic velocity (PSV) of the left and right ventricles in the second half of pregnancy.

Methods: A blinded, prospective, observational, longitudinal, study of 120 women with uncomplicated singleton pregnancies. Ethical and governance approvals were granted by the Mater Human Research Ethics Committee and Research Governance Office respectively (Ref no: HREC/14/MHS/182). Informed consent was obtained from all women. Estimated gestational age (GA) was calculated based on a first trimester ultrasound scan.

The participants underwent ultrasound scans every four weeks from enrolment (18-28 weeks) until delivery. CO and PSV were measured at each examination using Pulsed Wave (PW) Doppler at zero degrees angle of insonance. At each visit estimated fetal weight (EFW) was estimated using Hadlock's formula.[1] All ultrasound and cardiac examinations were performed by a single experienced perinatal cardiac sonographer (ALT). Changes in these parameters as functions of gestational age were modelled using Bayesian mixed effects models.

Results: Left ventricular CO is calculated by measuring the aortic valve diameter and the PW Doppler waveform of blood flow through the valve. The right ventricular CO is calculated by performing the same measurements of the pulmonary valve. In total 406 longitudinal measurements from both left and right ventricles of 120 participants in the normal cohort were obtained.

The formulae used were: SV (stroke volume) = valve area (cm2) x VTI(velocity time integral) and thus CO(L/min) = SV (cc) x HR/1000.

CO and PSV increased with increasing gestational age in the both ventricles. The results showed that the left and right cardiac output increase linearly with gestation, with the right cardiac output greater than the left at all time points.

The PSV is a measure of the maximum speed of the blood flow through the pulmonary and aortic valves. The technique to obtain this parameter is as previously described to obtain CO, with measurement obtained of the peak velocity through the aortic and pulmonary valves. The results show that the aortic and pulmonary artery peak velocities increased linearly with gestation, with the aortic valve peak velocity greater than the pulmonary valve peak velocity at all time points. The tables of these parameters to gestational age are shown below.

Conclusion: To our knowledge these are the first nomograms to be developed longitudinally with the most measures per participant for these parameters. This can be used to assess and monitor cardiac function in fetuses with cardiac dysfunction or during fetal therapy.

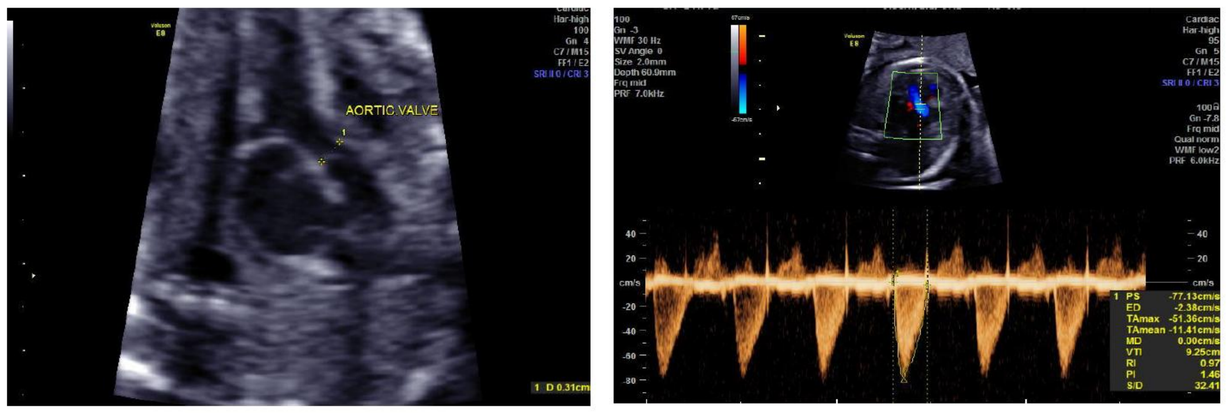
Right Cardiac Output vs Gestational Age

Gestational age weeks	Centile								
	2.5	5	10	25	50	75	90	95	97.5
18	16	22	30	47	70	98	127	146	164
19	27	35	46	66	93	125	157	179	198
20	41	51	64	88	119	155	191	215	236
21	58	70	85	113	148	188	229	255	279
22	78	92	109	140	180	225	270	299	325
23	100	116	135	171	216	265	315	346	375
24	125	142	164	205	254	309	363	397	429
25	152	172	196	241	296	356	415	453	487
26	181	204	231	280	341	407	471	513	550
27	212	237	268	323	389	462	532	577	617
28	246	273	307	368	441	520	596	645	688
29	282	313	349	416	495	581	664	716	764
30	319	353	394	466	553	646	736	793	844
31	359	396	440	519	613	715	812	873	928
32	401	441	490	575	677	787	892	958	1017
33	446	489	542	634	745	863	976	1047	1111
34	491	539	596	696	815	943	1064	1141	1208
35	539	591	652	761	889	1026	1157	1239	1312
36	589	644	711	827	965	1112	1253	1341	1420
37	641	701	772	898	1046	1204	1353	1448	1531
38	696	760	836	970	1129	1297	1457	1557	1648
39	751	820	901	1045	1215	1394	1566	1673	1770
40	810	883	971	1124	1305	1496	1678	1792	1894

Left Cardiac Output vs Gestational Age

Gestational age weeks	Centile								
	2.5	5	10	25	50	75	90	95	97.5
18	12	18	25	41	63	89	117	136	153
19	19	26	36	54	79	109	139	159	178
20	29	37	48	69	97	130	163	185	205
21	40	49	62	86	117	153	189	213	234
22	52	63	77	104	138	178	217	242	266
23	66	79	95	124	162	204	247	275	300
24	82	96	113	146	187	233	279	309	336
25	99	114	134	170	214	264	314	346	374
26	117	135	156	195	243	297	350	384	415
27	137	156	179	222	274	332	389	426	458
28	158	179	204	250	307	370	431	469	505
29	181	203	231	281	342	409	474	515	552
30	205	229	259	312	378	450	519	564	604
31	230	256	288	346	416	493	567	615	657
32	257	285	319	381	456	538	618	668	713
33	285	315	352	418	498	586	670	723	771
34	314	346	385	456	542	635	725	781	831
35	344	379	420	496	588	687	782	842	896
36	375	412	457	537	635	740	842	905	963
37	408	447	495	581	684	796	904	972	1032
38	443	484	535	626	735	854	968	1039	1103
39	477	521	575	672	788	914	1034	1110	1177
40	513	561	618	720	843	976	1104	1184	1255

CO of LV calculated from measuring valve diameter on B-mode (right image) and HR and VTI on PW Doppler (left image)



Peak Systolic Velocity vs Gestational Age

Gestational age	PVPSV percentile (cm/s)			AVPSV percentile cm/s		
(weeks)	50th	5th	95th	50th	5th	95th
18	50.7	35.4	66.0	55.9	31.5	80.5
19	52.4	37.0	67.8	58.5	34.0	83.1
20	54.2	38.7	69.7	61.1	36.5	85.8
21	55.9	40.3	71.5	63.7	39.1	88.5
22	57.7	42.0	73.4	66.4	41.6	91.2
23	59.4	43.6	75.3	68.9	44.1	93.9
24	61.2	45.1	77.2	71.6	46.6	96.7
25	62.9	46.7	79.2	74.2	49.1	99.4
26	64.6	48.2	81.2	76.8	51.5	102.2
27	66.4	49.7	83.2	79.4	54.0	104.9
28	68.1	51.1	85.3	82.0	56.4	107.7
29	69.8	52.6	87.3	84.6	58.8	110.6
30	71.6	54.0	89.4	87.3	61.2	113.4
31	73.3	55.4	91.6	89.9	63.6	116.2
32	75.1	56.8	93.6	92.5	66.1	119.0
33	76.8	58.2	95.7	95.1	68.4	121.9
34	78.5	59.6	97.9	97.7	70.8	124.8
35	80.3	60.9	100.1	100.3	73.1	127.7
36	82.0	62.2	102.2	102.9	75.4	130.5
37	83.8	63.6	104.5	105.6	77.8	133.5
38	85.5	64.8	106.7	108.1	80.1	136.4
39	87.2	66.1	108.9	110.8	82.4	139.4
40	89.0	67.4	111.1	113.4	84.7	142.2

PVPSV – pulmonary valve peak systolic velocity
AVPSV – aortic valve peak systolic velocity

References

1. Hadlock F, Harrist R, Martinez-Poyer J. In utero analysis of fetal growth: A sonographic weight standard. Radiology 1991;181:129.