

Chapter 1



MATERNAL PHYSIOLOGY DURING PREGNANCY

S. Yeliz HISIM UZUN¹

Pregnancy is a systemic condition which affects all the body systems. These interactions are interlinked and due to hormonal influences of the placenta together with the adaptation mechanisms the body undergoes to accommodate the fetus. These immense changes result in a totally different physiology. The aim of this chapter is to describe maternal adaptations in pregnancy thus having an understanding of these adaptations will help during counseling of patients regarding the physiology that underlies various “normal” symptoms that they may experience.

Cardiovascular System Changes

The heart is displaced upward-left due to both the displacement of the diaphragm and the effect of pregnancy on the shape of the rib cage. This causes an increased cardiac silhouette on imaging studies however there is no evident change in the cardiothoracic ratio. The pulmonary conus is physiologically more evident. Thus cardiomegaly during pregnancy must be confirmed by an echogram. Also eccentric cardiac hypertrophy is encountered due to the expanded blood volume. This causes a monumental increase in the cardiac output. The increased cardiac output is mostly directed to the uterus, placenta, and breasts.

¹ Op. Dr. Alanya Başkent University Hospital, Department of Obstetrics and Gynaecology, yelizhisim@gmail.com

play a role in fetal development. Similar to other insulin resistant states ghrelin increases and peaks at mid pregnancy and decreases until term.⁽⁵⁷⁾ Electrolyte and mineral metabolism is also altered significantly. During normal pregnancy, nearly 1000 mEq of *sodium* and 300 mEq of *potassium* are retained despite the increase in glomerular filtration of sodium and potassium the excretion of these electrolytes is unchanged due to augmented tubular resorption.^(58,59) However the increased total accumulation of sodium and potassium doesn't lead to an increase in plasma volume due to expanded total plasma volume. Total serum calcium levels decrease during pregnancy however levels of ionized calcium remain unchanged. Serum magnesium levels are also decreased. A study showed that both total and ionized magnesium was significantly lower during normal pregnancy.⁽⁶⁰⁾ Serum *phosphate* levels are within the non-pregnant range however the renal threshold for inorganic phosphate excretion is elevated in pregnancy due to increased calcitonin.⁽⁶¹⁾

References

1. Hunter S, Robson SC. Adaptation of the maternal heart in pregnancy. *Br Heart J*. 1992;68:540–[PMC free article] [PubMed] [Google Scholar]
2. Meah VL, Cockcroft JR, Backx K, et al. Cardiac output and related haemodynamics during pregnancy: a series of meta-analyses. *Heart* 2016; 102:518.
3. Lang RM, Borow KM. Heart disease. In: *Medical Disorders During Pregnancy*, Barron WM, Lindheimer MD, (Eds), Mosby Year Book, St. Louis 1991. p.184.
4. Estensen ME, Beitnes JO, Grindheim G, Aaberge L, Smiseth OA, Henriksen T, Aakhus S. Altered maternal left ventricular contractility and function during normal pregnancy. *Ultrasound Obstet Gynecol*. 2013 Jun;41(6):659-66. doi: 10.1002/uog.12296. PMID: 23001841.
5. Simmons LA, Gillin AG, Jeremy RW. Structural and functional changes in left ventricle during normotensive and preeclamptic pregnancy. *Am J Physiol Heart Circ Physiol*. 2002 Oct;283(4):H1627-33. doi: 10.1152/ajpheart.00966.2001. PMID: 12234817.
6. Knock GA, Poston L. Bradykinin-mediated relaxation of isolated maternal resistance arteries in normal pregnancy and preeclampsia. *Am J Obstet Gynecol*. 1996 Dec;175(6):1668-74. doi: 10.1016/s0002-9378(96)70123-0. PMID: 8987958.
7. Sladek SM, Magness RR, Conrad KP. Nitric oxide and pregnancy. *Am J Physiol*. 1997 Feb;272(2 Pt 2):R441-63. doi: 10.1152/ajpregu.1997.272.2.R441. PMID: 9124465.
8. Edouard DA, Pannier BM, London GM, Cuche JL, Safar ME. Venous and arterial behavior during normal pregnancy. *Am J Physiol*. 1998 May;274(5):H1605-12. doi: 10.1152/ajpheart.1998.274.5.H1605. PMID: 9612370.
9. Shotan A, Ostrzega E, Mehra A, Johnson J V, Elkayam U. Incidence of Arrhythmias in Normal Pregnancy and Relation to Palpitations. *Am J Cardiol*. 1997;79(8):1061-1064.

10. de Haas S, Ghossein-Doha C, van Kuijk SM, et al. Physiological adaptation of maternal plasma volume during pregnancy: a systematic review and meta-analysis. *Ultrasound Obstet Gynecol* 2017; 49:177.
11. World Health Organization. Iron deficiency anaemia: Assessment, prevention, and control. A guide for programme managers. http://www.who.int/nutrition/publications/en/ida_assessment_prevention_control.pdf (Accessed on September 06, 2011).
12. Harstad TW, Mason RA, Cox SM. Serum erythropoietin quantitation in pregnancy using an enzyme-linked immunoassay. *Am J Perinatol* 1992; 9:233.
13. Maternal physiology. In: Williams Obstetrics, 24th ed, Cunningham FG, Leveno KJ, Bloom SL, et al (Eds), McGraw-Hill Education, 2014. p.55.
14. Pitkin R, Witte D. Platelet and leukocyte counts in pregnancy. *JAMA*. 1979;242:2696-2698.
15. Molberg P, Johnson C, Brown TS. Leukocytosis in labor: what are its implications? *Fam Pract Res J* 1994; 14:229.
16. Acker DB, Johnson MP, Sachs BP, Friedman EA. The leukocyte count in labor. *Am J Obstet Gynecol* 1985; 153:737.
17. Clark P, Brennand J, Conkie JA, Mccall F, Greer IA, Walker ID. Activated protein C sensitivity, protein C, protein S and coagulation in normal pregnancy. *Thromb Haemost*. 1998;79:1166-1170.
18. Gilroy RJ, Mangura BT, Lavietes MH. Rib cage and abdominal volume displacements during breathing in pregnancy. *Am Rev Respir Dis* 1988; 137:668.
19. Turner AF. The chest radiograph in pregnancy. *Clin Obstet Gynecol* 1975; 18:65.
20. Thomson, K, Cohen, M. Studies on the circulation in normal pregnancy: II. Vital capacity observations in normal pregnant women. *Surg Gynecol Obstet* 1938; 66:591.
21. Weinberger SE, Weiss ST, Cohen WR, et al. Pregnancy and the lung. *Am Rev Respir Dis* 1980; 121:559.
22. prowse cm, gaensler ea. respiratory and acid-base changes during pregnancy. *Anesthesiology* 1965; 26:381.
23. Hytten FE, Leitch I. Respiration. In: *The Physiology of Human Pregnancy*, Blackwell Scientific Publications, Oxford 1971.
24. Maternal Physiology. In: Williams Obstetrics, 25th, Cunningham FG, Leveno KJ, Bloom SL, Dashe JS, Hoffman BL, Casey BM, Spong CY (Eds), McGraw-Hill Education/Medical, New York 2018.
25. Linheimer MD, Katz AI: Renal physiology and disease in pregnancy. In Seldin DW, Giebisch G (eds): *The Kidney: Physiology and Pathophysiology*, pp 3d ed. Philadelphia, Lippincott Williams and Wilkins, 2000
26. Gant NF, Chand S, Whalley PJ, MacDonald PC. The nature of pressor responsiveness to angiotensin II in human pregnancy. *Obstet Gynecol* 1974; 43:854.
27. Davison JM, Hytten FE. The effect of pregnancy on the renal handling of glucose. *Br J Obstet Gynaecol* 1975; 82:374.
28. American College of Obstetricians and Gynecologists, Task Force on Hypertension in Pregnancy. Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. *Obstet Gynecol* 2013; 122:1122.

29. Beydoun SN. Morphologic changes in the renal tract in pregnancy. *Clin Obstet Gynecol* 1985; 28:249.
30. Bronshtein M, Gover A, Beloosesky R, et al. Characteristics and Outcomes of Pylalism Gravidarum. *Isr Med Assoc J* 2018; 20:573.
31. Shah S, Nathan L, Singh R, Fu YS, Chaudhuri G. E2 and not P4 increases NO release from NANC nerves of the gastrointestinal tract: implications in pregnancy. *Am J Physiol Regul Integr Comp Physiol*. 2001;280: R1546-R1554.
32. Christofides ND, Ghatei MA, Bloom SR, et al. Decreased plasma motilin concentrations in pregnancy. *Br Med J (Clin Res Ed)* 1982; 285:1453.
33. Wiznitzer A, Mayer A, Novack V, et al. Association of lipid levels during gestation with preeclampsia and gestational diabetes mellitus: a population-based study. *Am J Obstet Gynecol* 2009; 201:482.e1.
34. Lockwood CM, Grenache DG, Gronowski AM. Serum human chorionic gonadotropin concentrations greater than 400,000 IU/L are invariably associated with suppressed serum thyrotropin concentrations. *Thyroid* 2009; 19:863.
35. Nolten WE, Lindheimer MD, Oparil S, Ehrlich EN. Desoxycorticosterone in normal pregnancy. I. Sequential studies of the secretory patterns of desoxycorticosterone, aldosterone, and cortisol. *Am J Obstet Gynecol*. 1978;132(4):414-420.
36. Lowe SA, MacDonald GJ, Brown MA: Acute and chronic regulation of atrial natriuretic peptide in human pregnancy: A longitudinal study. *J Hypertens* 10:821, 1992
37. Resnik JL, Hong C, Resnik R, et al: Evaluation of B-type natriuretic peptide (BNP) levels in normal and preeclamptic women. *Am J Obstet Gynecol* 193:450, 2005
38. Mittal P, Espinoza J, Hassan S, et al. Placental growth hormone is increased in the maternal and fetal serum of patients with preeclampsia. *J Matern Fetal Neonatal Med*. 2007;20(9):651-659. doi:10.1080/14767050701463571
39. Kovacs CS, Kronenberg HM. Maternal-fetal calcium and bone metabolism during pregnancy, puerperium, and lactation. *Endocr Rev*. 1997;18(6):832-872.
40. Spyridon N, Karras, Carol L, Wagner, V, Daniel Castracane, Understanding vitamin D metabolism in pregnancy: From physiology to pathophysiology and clinical outcomes, *Metabolism*, Volume 86, 2018, Pages 112-123, ISSN 0026-0495
41. Kaushal M, Magon Vitamin D in pregnancy: a metabolic outlook. *Indian J Endocrinol Metab*. 2013;17:76-82.
42. Foti T, Davids JR, Bagley A. A biomechanical analysis of gait during pregnancy. *J Bone Joint Surg Am* 2000; 82:625.
43. Ivell R. Endocrinology. This hormone has been relaxin' too long! *Science* 2002; 295:637.
44. Marnach ML, Ramin KD, Ramsey PS, et al. Characterization of the relationship between joint laxity and maternal hormones in pregnancy. *Obstet Gynecol* 2003; 101:331.
45. Barankin B, Silver SG, Carruthers A. The skin in pregnancy. *J Cutan Med Surg*. 2002;6:236-40.
46. Tunzi M, Gray GR. Common skin conditions during pregnancy. *Am Fam Physician*. 2007;75:211-8.

47. Kroumpouzou G, Cohen LM. Dermatoses of pregnancy. *J Am Acad Dermatol.* 2001;45:1-19.
48. Zeeman GG, Hatab M, Twickler DM: Maternal cerebral blood flow changes in pregnancies. *Am J Obstet Gynecol* 189:968, 2003
49. Edman CD, Toofanian A, MacDonald PC, et al: Placental clearance rate of maternal plasma androstenedione through placental estradiol formation: An indirect method of assessing uteroplacental blood flow. *Am J Obstet Gynecol* 141:1029, 1981
50. Hytten FE: Weight gain in pregnancy. In Hytten FE, Chamberlain G (eds): *Clinical Physiology in Obstetrics*, 2nd ed. Oxford, Blackwell, 1991, p 173
51. Cunningham FG, Leveno KJ, Bloom SL, Hauth JC, Rouse DJ, Spong CY. *23rd Edition Williams Obstetrics*. New York: McGraw Hill; 2010.
52. Phelps RL, Metzger BE, Freinkel N. Carbohydrate metabolism in pregnancy. XVII. Diurnal profiles of plasma glucose, insulin, free fatty acids, triglycerides, cholesterol, and individual amino acids in late normal pregnancy. *Am J Obstet Gynecol.* 1981;140(7):730-736.
53. Butte NF: Carbohydrate and lipid metabolism in pregnancy: Normal compared with gestational diabetes mellitus. *Am J Clin Nutr* 7:1256S, 2000
54. Herrera E, Amusquivar E, Lopez-Soldado I, Ortega H: Maternal lipid metabolism and placental lipid transfer. *Horm Res* 65:59, 2006
55. Hauguel-de Mouzon S, Lepercq J, Catalano P: The known and unknown of leptin in pregnancy. *Am J Obstet Gynecol* 194:1537, 2006
56. Gohlke BC, Huber A, Bartmann P, et al: Cord blood leptin and IGF-I in relation to birth weight differences and head circumference in monozygotic twins. *J Pediatr Endocrin Metabol* 19:1, 2006
57. Fuglsang J: Ghrelin in pregnancy and lactation. *Vitam Horm* 77:259, 2008
58. Lindheimer MD, Richardson DA, Ehrlich EN, et al: Potassium homeostasis in pregnancy. *J Reprod Med* 32:517, 1987
59. Brown MA, Gallery EDM, Ross MR, et al: Sodium excretion in normal and hypertensive pregnancy: A prospective study. *Am J Obstet Gynecol* 159:297,1988
60. Bardicef M, Bardicef O, Sorokin Y, et al: Extracellular and intracellular magnesium depletion in pregnancy and gestational diabetes. *Am J Obstet Gynecol* 172:1009, 1995
61. Weiss M, Eisenstein Z, Ramot Y, et al: Renal reabsorption of inorganic phosphorus in pregnancy in relation to the calciotropic hormones. *Br J Obstet Gynaecol* 105:195, 1998