Course Name :An Overview on Maternal Health Antenatal, Intranatal and Postnatal Care

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Lecture:05

FETUS (Physiology and circulation)

Hello students. Welcome to our next class for the NPTEL online certified courses on the topic an overview on maternal health, the antenatal, intranatal and postnatal care. I am Dr. Barnali Ghosh, an obstetrician and gynecologist working at B.C.Roy Medical College and Research Center, IIT, Kharagpur. Today our topic of discussion is the fetus, the fetal physiology and circulation. We have read about the placenta, about the umbilical cord and the fetal membranes.

Today we are going to discuss about the fetus as a whole. Concepts covered in today's class are the periods of fetal development, fetal hematopoiesis, fetal circulation and fetal lung maturity. The keywords for the class are as shown. Now coming to the periods of fetal development.

It can be divided into three periods. Know the first is the pre embryonic or the germinal or the ovular period, then comes the embryonic period and then comes the fetal period. Before going into this I need to discuss with you regarding the fetal age and gestational age. We have already discussed that the luteal phase of the menstrual cycle of a female is constant and it is of 14 days duration. But the follicular phase which is prior to the ovulation, this follicular phase varies.

It can vary between one female to another and even in one female it varies between months. So this follicular phase is variable. For this calculation of gestational age, calculation of expected date of delivery or EDD by the Naegle's rule which we will learn in our subsequent class which is nothing but 9 calendar months and 7 days added to the first day of the last menstrual period of the mother. So when we calculate this formula we take it for granted that the female has a 28 day cycle and it is regular. So in case of 28 day cycle, say this is her menses 5 day and this is the first day of the last menstrual period which we write as LMP nothing but the first day of her last menstrual period.

So and you know this is a 28 day cycle, right. So ovulation, ovulation will be right, so I write here it is 28 days and ovulation will be in the mid cycle that is on day 14, right. This is the day of ovulation, right. So taking the day of ovulation as the day of fertilization, we know that the

ovum will be in the female genital tract for 12 to 24 hours. Within that period it needs to be fertilized with the sperm or else it will degenerate.

So on the day of ovulation is mostly the day of fertilization. So now calculating the gestational age, gestational age is calculated from the LMP or the first day of the last menstrual period. This is the gestational age, right. And from the day of fertilization, from the day of fertilization is the calculation of the fetal age, right. So this is the fetal age which is the actual age of the fetus and it is from the day of fertilization, from the day of development of the zygote.

So fetal age from this diagram we can see that this is 14 days, this is 14 days. So the fetal age, fetal age plus 2 weeks is equal to gestational age. So is it clear? This is low down, this is the gestational age, right. So this is the gestational age. Gestational age is calculated from the LMP or the first day of the last menstrual period and fetal age is more accurate which is being calculated from the day of fertilization.

And this you know difference is 2 weeks or 14 days, right because ovulation is occurring on the 14th day of the cycle. So from now onwards whenever we see the age of the fetus, it is actually the gestational age. We refer to the age of the fetus as the gestational age. The fetal age we need to know the concept of fetal age and this is the age which is determined by ultrasonography, right. So coming to this periods of fetal development, the pre embryonic period or the germinal period is from ovulation or from the day of fertilization to 2 weeks.

So 2 weeks from the day of fertilization. This is actually we are talking about the fetal age. So if a respect to the gestational age, it will be plus 2, gestational is nothing but plus 2 weeks with the fetal age. So up to 4 weeks of gestational age is the pre embryonic period. Coming to the embryonic period, it is 3 to 8 weeks from fertilization.

And if we now talk about the gestational age, it will be 5 to 10 weeks of gestational age. So we are studying 2, 3 plus 2 is 5, 5 to 10 weeks of gestational age. And fetal period is after this embryonic period so that means, 9 weeks from fertilization up till delivery, right. And if we talk in respect to the gestational age, it will be 11 weeks of gestational age up to delivery. This is the fetal period.

So these are the 3 stages of fetal development of which the embryonic period is the most teratogenic period. Most teratogenic period and it is during this period that any insult in the form of radiation, in the form of any you know drugs intake by the mother, that will cause more insult to the fetus if it occurs during this embryonic period, right. Now what I have already told, determination the age, gestational age is calculated from the first day of the last menstrual period whereas, post-conceptional fertilization age or fetal age is calculated from the day of fertilization. Now the length of the fetus is more reliable criteria than the weight in calculation

of the age of the fetus. So, know the length, how to measure the length of the fetus in first trimester which we also called as the dating scan.

In the first trimester, the scan report showing the fetal age is most accurate and it is calculated in first trimester, the fetal age is calculated by the crown rump length. So very important to note, what crown rump length we will discuss later that it is a USG finding and the fetus is in neutral position, we place the probe on the mother's abdomen, we see the USG picture and the fetus is seen and we measure the distance from the crown to the coccyx, we will measure that distance and that distance will be you know depending upon that distance we will get a chart which will tell us what is the fetal age of in that particular pregnancy. So, this is the most accurate calculation of the fetal age in first trimester. After 20 weeks onwards, from 20 weeks the age will be calculated from head circumference, biparietal diameter and femur length right. So, the length of the fetus is more important criteria in assessing the fetal age than the fetal weight.

Fetal weight is actually helpful in you know diagnosing the growth of the fetus. If there is any retarded growth of the fetus, it will be depicted from the decreased fetal weight or decrease in weight gain of the fetus, but the length of the fetus will tell us what is the gestational age of the fetus right. So, coming to the growth of the fetus, how the fetus grows firstly there is cellular hyperplasia that is increase in the number of the cells by mitotic division and then there will be both cellular hyperplasia and hypertrophy and ultimately in the later stages of pregnancy there is only cellular hypertrophy right. Growth increases linearly, it will grow in a linear fashion till 37 weeks of gestation right. And in the first half of the pregnancy the growth is controlled by the genetic factors in case of any chromosomal abnormality, in case of aneuploidy, you know in case of any genetic defect of the fetus the growth in the first trimester is hampered and it will lead to miscarriage or abortion in the early weeks of pregnancy right.

And growth in the later stages of pregnancy is primarily controlled by the environmental factors which means that the nutrients present in the mother, if the mother is deficient in nutrients say the mother is anemic right. So, there will be less iron, less you know or you know there are some deficiency in vitamins in the mother it can also lead to growth retardation in the fetus right. So, in the later half it is mostly due to the environmental factors that is the nutrients from the placenta, the factors of the amniotic fluid you know any infection of the amniotic fluid can lead to growth retardation in the later stages of pregnancy. So, the important physiological factors controlling the fetal growth, what are they? Number 1 is the race. Human babies you know by gene makeup of their genetic makeup they are heavier you know they have greater birth weight.

Next parental height and weight, if mother is longer if mother is heavy weight it is you know more probable that the fetus will be also having a high birth weight. Birth order with increase in birth order the fetal weight also grows will be going high right. Sex of the baby we know male

fetus, male fetus have higher weight than the females right. Socioeconomic factors yes the social class 1 and 2 the people belonging to this class 1 and 2 will be having you know greater fetal weight at birth right. So, these are the some of the physiological factors.

Now fetal growth which what controls the fetal growth it is the insulin growth factor 1. Insulin like growth factor 1, insulin and other growth factors will be controlling the growth of the fetus in utero very important point to note. Inside the mother's womb the growth of the fetus is mostly taken care of by insulin like growth factor 1 and insulin. So, in case of diabetic mother who have hyperglycemia high blood glucose which will be transferred to the fetus and there will be more insulin secretion thereby more insulin like growth factor causing more weight gain of the fetus. So, we say that the diabetic mothers are more likely to have macrosomic babies right.

And after birth fetal growth in utero is controlled by these factors after birth the growth of the newborn is mostly controlled by the growth hormones right. At term in Indian population average fetal weight ranges between 2.5 to 3.5 kgs. Coming to fetal hematopoiesis so, fetal hemoglobin what are the characteristics there are some very important characteristics of the fetal hemoglobin like it has more affinity for oxygen.

So, in comparison to the adult hemoglobin fetal hemoglobin has more affinity for oxygen and it will preferentially you know attach with oxygen even in decreased saturation of oxygen in the placental circulation. So, even if there is maternal hypoxia or the oxygen saturation is less still the fetal hemoglobin will bind to the oxygen and it will take the oxygen to the fetus for its you know nourishment. So, that is one fetal hemoglobin so, this is HBF and we will know regarding its formation site of synthesis, but another thing to note is the fetal RBCs. Fetal RBCs they are having the fetal hemoglobin and these RBCs have a lesser life span they have approximately 90 days of life span compared to 120 days in case of adult RBCs. Another thing is you know at term or at birth at birth what is the level of fetal hemoglobin it is 16 to 18 gram per dl.

So, if we take blood from the cord after the delivery of the baby the hemoglobin will come out to be 16 to 18 grams per dl right. Now coming to the site of fetal hematopoiesis you know right from the second week of gestation the yolk sac is the first site for fetal hematopoiesis and in that period the very first hemoglobin are the Portland hemoglobin the Gower hemoglobin 1 and Gower hemoglobin 2. From the tenth week of gestation the site of hematopoiesis changes to liver and you know and some part of spleen also takes part in hematopoiesis right and it will form hemoglobin F which is nothing, but alpha 2 gamma 2 right. And from eighteenth week onwards the bone marrow will take over the work of hematopoiesis and it will start producing hemoglobin A or adult hemoglobin which has also 4 hemoglobin chains alpha 2 beta 2 right. So, fetal hemoglobin chains are alpha 2 gamma 2 at term at term pregnancy or you know you may say also as at birth what is the percentage of fetal hemoglobin it is approximately 75 to 80 percent right.

So, mostly primarily it is of fetal type the hemoglobin in a newborn is of fetal type right then slowly the fetal hemoglobin will be replaced by adult hemoglobin and by sixth months of age after birth six months after birth the fetal hemoglobin will now become less than 1 percent. So, maximum will be hemoglobin A or adult type hemoglobin. Oxygen affinity of fetal hemoglobin yes we have learned that it is high it has high oxygen affinity and so, the oxygen dissociation curve will shift to the left it will shift to the left this helps in binding the fetal hemoglobin with oxygen right. It will help in preferential binding of the fetal hemoglobin to oxygen and helping in you know carrying the oxygen to the fetus from the placental circulation right. And it has also one criteria that is it contains low 2, 3 diphosphoglycerate 2, 3 DPG is low and it also has low carbonic anhydrase.

What is the characteristic of fetal hemoglobin? It is resistant to alkali or acid denaturation right. So, they are acid or alkali resistant that means, fetal hemoglobin when comes in contact with alkali it will not hemolyse whereas, adult hemoglobin will hemolyse this is the basis for SINGERs alkali denaturation test or APT test. This is used to differentiate the antepartum bleeding you know antepartum bleeding you know differentiate whether it is of fetal origin or maternal origin. If the blood hemolyse in contact with 1 percent NaOH or KOH then it is a matter of maternal origin and so, the antepartum bleeding you know the cause of the antepartum bleeding will be placental abruption or placenta previa. But if the blood even in contact with 1 percent NaOH or KOH does not hydrolyze that means, the blood is of fetal origin and the bleeding is due to vasapraevia right.

It is a qualitative test just helping in differentiating the fetal and maternal blood and there is use of 1 percent sorry this will be NaOH 1 percent NaOH or KOH. Coming to the kleihauer Betke test this is a quantitative test it helps to know the amount of fetal maternal hemorrhage or amount of fetal bleeding. It is used to calculate the dose of anti-D in case of Rh negative pregnancy where we will calculate the fetal maternal hemorrhage the amount of fetal maternal hemorrhage and from that we will calculate the dose of anti-D which is to be given to the mother to prevent sensitization of the mother who is Rh negative against the Rh positive blood cells of the fetus. So, we will know regarding these in our subsequent class, but it is to note that there is a test called as Kleihauer Betke test also which is a quantitative test and the reagent used is citric acid phosphate buffer as use of acid. So, it is also called as acid elution test.

Coming to the cardiac output cardiac output of fetus is 350 ml per kg per minute and cardiac output of newborn after birth is 500 ml per kg per minute just you know numericals which we you need to remember right. Coming to the fetal circulation so, what is the difference from fetal circulation and adult circulation? Here in fetal circulation the site of oxygenation is placenta whereas, in adult circulation the site of oxygenation is the lungs. In the fetus there is no gaseous exchange in the lungs and so, the blood bypasses the lungs there is very a minimum amount of

bloods go passing through the lungs and the two sides of the heart the right heart and the left heart these two sides of the heart will operate in parallel they will be operating in parallel rather than in series that is present in adult circulation. And the upper part of the body that is the brain the upper limbs the heart will be getting more oxygenated blood in comparison to the lower part of the body of the fetus right. Coming to the fetal circulation proper so, from the placenta the oxygenated blood will be carried by the umbilical vein.

So, this is also a point of difference the umbilical vein carries here the oxygenated blood with oxygen saturation of 80 percent it will go into the liver and it majority of the oxygenated blood will bypass the liver and will go into the IVC through the ductus venosus. So, there are some shunts in the fetus number one is the ductus venosus which helps in no transport of maximum amount of oxygenated blood from the umbilical vein into the IVC. A little portion will go from the IV umbilical vein to the portal vein and in the liver it will supply the liver and then through the hepatic veins it will drain into the IVC. Also IVC will be having the deoxygenated blood from the lower limbs right. So, it will be also having the deoxygenated blood.

So, now it is important to note is in the IVC there are two I mean blood flow systems where the medial portion of the IVC will be having the more oxygenated blood and the lateral portion will be having the less oxygenated or deoxygenated blood being carried from the liver and the lower limbs right. Now, this IVC will drain into the right atrium. This is the right atrium it will be draining into the right atrium and the oxygenated blood from the IVC will be shunted to the left atrium through the over foramen ovale. So, this is another shunt present in the fetal circulation. This is the second one right that will help in transport of the oxygenated blood from the right atrium to the left atrium.

Now come to the deoxygenated blood which was coming through the IVC lateral part of the IVC and also from the SVC which will be draining the blood from the upper portion of the body. This deoxygenated blood will drain into the right atrium and they will be going to the right ventricles through the tricuspid valves. And from the right ventricle they will pass on to the pulmonary arteries right. So, they will reach the deoxygenated blood will reach the pulmonary artery. Now from the pulmonary artery you know maximum deoxygenated blood will be shunted to the ductus venosus.

So, this is the third shunt present in the fetus and a very small portion like 10 percent will be flowing to the lungs and you know then to the pulmonary veins and draining into the left atrium. So, point to note that the lungs are not having much blood supply very little amount of blood will be going to the lungs and lungs have no gaseous exchange right. So, preferentially the left atrium I have drawn it with red you can see that the left atrium is actually having maximum oxygenated blood with a little portion of deoxygenated blood which is coming from the pulmonary veins right. So, this left atrium from the left atrium it will be going to the right left

ventricle and from the left ventricle to the aorta. From the aorta the oxygenated blood will then be transferred to the brachiocephalic trunk, the carotid arteries, the subclavian arteries to supply the upper portion of the fetal body that is the brain, the upper limbs, the heart which are getting more oxygen they are the you know doing more activity and they are getting more oxygen in preference to the lower limbs for the normal you know adequate development and growth of the fetus.

And the aorta will then join with the ductus venosus which will be carrying the deoxygenated blood from the pulmonary artery and then this enter the blood with containing both oxygenated and deoxygenated it will be then passing through the descending aorta to the lower portion of the body supplying the abdominal organs the lower limbs you know and the it will be going into the systemic circulation right. And from the terminal branches that is the iliac artery there will be two umbilical arteries will these are the two umbilical arteries which will arise from the internal iliac artery and they will be carrying the deoxygenated blood back to the placenta for again oxygenation right. So, this is ingest the fetal circulation here we can see it in drawing yes the fetal this is the you know placenta and this is the umbilical vein, umbilical vein carrying the oxygenated blood and going straight into the IVC through the ductus venosus. And then part will go to the portal veins supply the liver and then it will drain into the IVC right and the IVC will be having the deoxygenated blood from the lower extremities then from the IVC it will drain into the right atrium preferentially the oxygenated blood will go into the left atrium to the left ventricle to the aorta supplying the upper part of the fetal body right. And the less oxygenated or the deoxygenated blood from the right atrium will be going into the right ventricle to the pulmonary arteries and from the pulmonary arteries it will bypass through the ductus arteriosus into the descending aorta to supply the rest portion lower portion of the body and ultimately it will give rise to the two umbilical arteries which will then go to the placenta for again oxygenation right.

Now these were before birth, after birth what are the changes the shunts will close right. So, the placenta is cut or clamped right. So, there is no blood from the placenta this was the before birth foramen ovale was patent, ductus arteriosus was patent, ductus venosus was patent, after birth no supply from the placenta the foramen ovale will close right. See the from right atrium blood was going to the left atrium, but after birth this will close the ductus arteriosus will also close. So, all the blood from the right atrium will be will have to go to the right ventricle then to the pulmonary artery to the lungs where lungs will have now air because after birth the baby is you know have started respiration the lungs have aired there is gaseous exchange in the lungs the pulmonary vascular resistance will decrease and there the oxygenation will take place and this oxygenated blood will then pass through the pulmonary veins to the left atrium then to the left ventricle supplying the rest of the body right.

So, these are the changes after birth that is number 1 closure of the umbilical arteries the

umbilical arteries are clamped there is closure instantaneous closure immediately after birth actual closure or anatomical closure occurs 2 to 3 months after birth and the distal part will form medial umbilical ligament and the proximal part will remain open as superior vesicle arteries right. Coming to the umbilical vein it will close a little later and this mechanism helps in passage of the extra amount of blood from the placenta to the fetus approximately 80 ml of blood flows from the placenta to the fetus and you know after that after few minutes the ductus venosus will collapse the umbilical vein will collapse and it will lead to closure that there will be decrease in pressure of the IVC and right atrium right. And so, the change in fetal circulation to adult circulation occurs what the umbilical vein forms in adult life it will form the ligamentum teres. These are important questions right and what ductus venosus forms it will form ligamentum venosum. Coming to the closure of ductus arteriosus it occurs within few hours of respiration know there is functional closure and anatomical obliteration occurs by 1 to 3 months of birth right.

Now, coming to the closure of foramen ovale, foramen ovale will also close immediately soon after birth the left atrium pressure increases in preference to the right atrium and that will close the valve of the foramen ovale and anatomical closure you know takes time for about 1 year after birth. So, these are the changes in fetal circulation after birth. Coming to the one liners regarding fetal physiology, fetal insulin, fetal insulin secretion occurs by 12 weeks of gestational age right fetal glucagon it occurs by 8 weeks. I have you know consolidated and made it as a chart for easy remembrance fetal thyroid. So, this is the thyroid gland and this is like you know the letter 11.

So, it occurs from 11 weeks thyroid production urine production from the kidneys will start from 12 weeks. Meconium production starts from 16 to 20 weeks, but it is not passed in utero it is passed after birth in utero passage of meconium you know you know it detects that there is fetal distress right. Next is 4 vessel to 3 vessel cord this occurs at 16 weeks the left umbilical vein is left behind and the right umbilical vein will disappear. First fetal breathing movement occurs at 11 weeks right. Next coming to the development of the testis at 6 weeks it is a bipotential gonad that is it can form testis or ovary right.

So, up to 6 weeks it are they are bipotential gonads then formation of testis occurs at 7 weeks and formation of ovary occurs at 8 weeks right. So, testis are formed before the ovaries. External genitalia formation is complete by 12 weeks in USG we can assess the external genitalia by 14 weeks right. Embryo we have already learned it is from third week of fetal age. So, 3 weeks onwards we call it as embryo up to 8 weeks, 3 to 8 weeks and from 9 weeks up till delivery is the fetus or the fetal period.

Next coming to fetal limb movements, fetal limb movements you know can be seen by 7 weeks in transvaginal scan. This is to be differentiated from quickening which is nothing, but

perception of fetal movements by the mother. This is you know seen in ultrasonography in TVS transvaginal scan and quickening is perceived by the mother in case of primigravida it is perceived at 18 weeks of gestation and in multigravida it is perceived you know a little earlier that is 16 weeks. Now coming to the fetal cardiac activity in TVS it is 5 weeks of gestational age or 3 weeks post fertilization that is 21 days. 21 days from the day of fertilization the fetal cardiac activity is seen.

Surfactant yes the surfactant production in the lungs they start from 24 weeks this is a range 24 to 34 weeks. Before 24 weeks there is no surfactant and after 34 weeks the lungs are mature they have surfactant. Erythropoiesis we have already learned that it starts in the yolk sac 2, 10, 18 weeks right yolk sac then the liver then the bone marrow right and adult hemoglobin synthesis HBA it is at 24 weeks of gestation. So, come next coming to the fetal lung maturity test these are you know important to assess the fetal maturity and the time of delivery. It is done by amniocentesis by studying the amniotic fluid in the third trimester.

Number 1 is the lecithin-sphingomyelin ratio in the amniotic fluid which is less than 2 means it is not mature right 2 or more than 2 that means, the lungs are mature right. Next is phosphatidylglycerol in amniotic fluid phosphatidylglycerol presence is signifies that the lungs are mature and they are mostly done in case of diabetes females right. Next is lamellar body count what are lamellar body these are nothing, but packed surfactant bodies. So, they are present in the amniotic fluid and the lamellar body count you know if it is less than 15000 per micro litre it is not mature more than 55 0 per micro litre. So, that is signifies that the lungs are mature and in between this is indeterminate right.

So, from the counting of the lamellar body in the amniotic fluid we can assess the lung maturity. Coming to the shake test or bubble test it is a bedside test where we collect the amniotic fluid and in the test tube the surfactant we have we know that it is a soapy material in the test tube we add alcohol and there is a formation of a bubble at the you know air liquid interface. If this happens that means, that lungs are mature and lastly is the Nile blue sulphate test where we add it with amniotic fluid and in the your smear we can see orange cells. So, these are orange cells right that means, they have phospholipids which are present in mature skin cells and to note that we deduce that the if the skin cells are mature then the lung cells will also be mature right. Next is phosphatidylcholine test in the amniotic fluid if it is more than 500 nanogram per ml then lungs are mature.

Optical density test if you know at 650 nanometer if it the optical density is more than equal to 0.5 then the lungs are mature. So, these are tests taken from done with the amniotic fluid by amniocentesis in third trimester to assess lung maturity and it is important for the delivery timing the delivery. What are the drugs that accelerate the fetal lung maturity? Number one is the corticosteroids. So, what corticosteroids are given? Dexamethasone and number 2 is

betamethasone right.

We in case of preterm delivery before 34 weeks we give steroids to accelerate the lung maturity. So, that after delivery the fetus does not have respiratory distress syndrome. What is the dose? It is 6 milligram dose given total 4 doses 12 hourly right and betamethasone is 12 milligram dose given 2 doses 24 hours apart right. And you know this we have learned that is surfactant production is between 24 to 34 weeks. So, after 34 weeks the lungs are more or less mature and this surfactant will prevent respiratory distress syndrome and the corticosteroids are given to accelerate the lung maturity thereby decreasing respiratory distress syndrome and betamethasone this is for betamethasone.

Betamethasone will be you know preventing respiratory distress syndrome along with it will also prevent necrotizing enterocolitis, intraventricular hemorrhage which are the side effects or complications of preterm delivery. Coming to the MCQs now we have already learned now what are the following are related to erytheral erythropoiesis except embryonic phase the erythropoiesis first demonstrated in the primitive mesoderm no it is first demonstrated in the yolk sac. So, first only this is the answer this is wrong right by 10th week yes liver is the major site for production near term it becomes bone marrow and at term 75 percent of hemoglobin is of fetal type. Coming next all are true regarding fetal hemoglobin except it has higher affinity for oxygen yes it binds less 2 to 3 dpg yes it has more carbonic anhydrase this is wrong it has low carbonic anhydrase and it is resistant to acid and alkaline. Fetal determination by USG fetal determine a fetal I mean external genitalia fetal external genitalia determination by USG is possible by 14 weeks external genitalia is formed by 12 weeks and by USG we can see it by 14 weeks.

Median umbilical ligament so, this is median right you need to know it is a remnant of urachus. Umbilical artery will form the medial umbilical ligament right and there is another one called as the lateral umbilical ligament which is formed by the hypo inferior hypogastric artery inferior epigastric artery. So, these are from the embryology right. Next lifespan of fetal RBC yes we have read it is 90 days so, more approximately it is 80 days. So, this is all for today's class on fetal circulation keep reading take care and keep taking notes. Thank you. .