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ON
Total Circulation,

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To

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Prof. of Obstetrics
& Diseases of Women & Children,
of the University of Nashville,
this dissertation
is
most respectfully
inscribed or addressed
by
The Author.
FOETAL CIRCULATION

It would be inconsistent with the character and objects of this Treatise, to follow, in any detail, the history of the development of the Foetus, during its intra-uterine life. It will only be the object of this essay to give a brief history of the circulation of the human foetus, during the last half of foetal existence. We find, on examining the most recent works, in regard to the anatomy and physiology of the foetal circulation, that foetal anatomy has, for several years past, received a large share of attention, while foetal physiology has hitherto been, to a very great degree, neglected.
and left to abide in obscurity, except so far as mere development is concerned.

Since the human foetus passes through so many various and successive phases of function, as well as development, it is of no ordinary difficulty to give satisfactory and correct statements of the ideas, adopted by the highest authorities, both in regard to the course of the physiology of foetal circulation.

1. The course of the foetal circulation.

In the first place, it will be necessary to give a description of the placenta before entering into a discussion of the various points connected with this subject.

This is a soft, spongy, vascular body, formed at the surface of the chorion, adherent to the uterus, and connected with the foetus by the umbilical cord.
The placenta is not in existence during the first day of the embryo state, but its formation commences, perhaps, soon after the arrival of the embryo in the uterus.

Previous to the formation of the last named organ, the newly formed embryo is supplied by the Omphalo-mesenteric vessels, the first-developed vessels of the germ, which ramify upon the vesicular umbilical, or yolk bag. These cease to carry blood, and become mere fibrous threads, after the establishment of the placental circulation. The maternal vessels pour their fluid into the maternal side of the placenta, whence it is taken up by the uterine veins. The uterine & placental portions of the placenta, having generally been described as quite distinct from each other.
during the first 2 months, but afterwards constituting one mass; still the uterine vessels remain distinct from the fetal; the uterine arteries & veins communicating with each other, and the fetal arteries & veins with each other. No direct communication existing between the maternal and fetal vessels. The placenta being neither wholly maternal, nor entirely fetal. The placenta may be attached to any part of the uterus, but most usually to the fundus. Of its two surfaces, that, which is attached to the uterus, is divided into irregularly rounded lobes or cotyledons, & is covered by a soft & delicate cellular vascular membrane. The fetal, or umbilical surface, is smooth, polished, colored by the chorion frondosum.
exhibits the distribution of the umbilical vessels, and the mode in which the cord is attached to the organ.

Blood vessels enter this organ from two sources—the mother and the fetus. The vessels of the former proceed from the uterus, and consist of arteries and veins of considerable number. The vessels of the latter, which proceed from the fetus, constitute the umbilical cord; (the umbilical vein and umbilical arteries) the placenta performs the same function for the fetus, that the lungs do after birth: it arterializes the blood, by eliminating from it the hydro-carbon compounds, & qualifies it for nourishment of the embryo. Therefore, it is a depurating organ.

The blood, having been thus prepared by
The placenta, is received by the small capillaries of the Vena umbilicalis: This vessel, formed by the anastomosis of an infinitude of placental radicles, becoming one large trunk at the fetal surface of the placenta, enters the body of the child at the navel. From this point it is attached to the margin of the falx form ligament of the liver, passing upwards, 4 anterior to the portal vein, follows the course of the umbilical fissure; where, it divides into three branches, nearly equal in size, one of which branches, (called ductus venosus Arantii), enters the inferior vena cava, transmitting along its course 3/5 of the aerated, or arterial blood returned by the umbilical vein from the placenta.
through the umbilicus into the vena cava ascendens: the other \( \frac{1}{2} \) having been first transmitted into the left branch of sinu of the vena portae, thence through the liver into the inferior vena cava by means of the hepatic veins.

The blood of the inferior vena cava is poured into the right auricle, and it is said by some authors, to be turned across by the Eustachian valve into the left auricle through the foramen ovale, situated in the septum auricularum: and while the left auricle is thus filled, the right is filled by venous blood from the superior extremities. The non-admixture of the blood being based upon the supposed peculiar action of the Eustachian valve, which, it is said, conveys the blood
of the inferior cava, (a portion), through the foramen of Botaf. This we do not believe. If it be the function of the Eustachian valve to keep the pure blood from the inferior vena cava from mixing with the less pure blood from the superior, we should expect it would remain perfect until birth, while in fact it becomes diminished, or at least diminished from the fifth or seventh month. It continues to diminish, while the valve, which closes the foramen ovale after birth, continues to increase in size.

The Eustachian valve does not prevent an inter-mixture, in the right auricle, of the blood from the inferior extremities with that from above, by directing the current of the former through the foramen of Botaf.
What, then, is the function of this valve? It opposes the regurgitation of the blood from this auricle into the inferior venae cavae; while it also prevents the current from the superior extremities from falling too heavily, or impinging upon the current from below. The Eustachian valve cannot prevent the admixture of the blood from the two venae cavae, nor direct that from the inferior at once through the foramen ovale; but the blood arising in the right auricle from the venae cavae is completely intermixed by every diastole and systole of the right auricle; therefore, the inferior extremity, together with the lungs, receive as pure blood as the superior extremities.

It has been admitted, by high authorities, that the position of that valve is very
unfavorable for the accomplishment of that object; that is, turning the blood as before
mentioned. This valve does not always assume the same position.

Let us recur to that period of foetal existence, when there was no septum at all
between the auricles, and to the subsequent period of life when the foramen exists, but
no valve is yet formed. Surely we must admit, there will be a complete admixture
of all the blood in the auricles up to this time. Now, this admixture must con-
tinue through the foramen, diminishing in proportion only as the valve becomes
more and more complete. Now, it is during the early periods of embryonic life, when the
septum auricularrum is efficient, that
the superior extremities, together with their organs
are so rapidly developed. The septum between the two auricles, first appearing about three months, is for some time very imperfect, from the opening, called the foramen of Botaf, remaining very large. This opening continues to diminish till about eight days after birth, when it is permanently closed by the growth of the valve of this foramen. It is then, not till then, a true mammal heart is constructed—having two auricles & two ventricles, which is required after birth, or in adult life. Fetal circulation being analogous to that of a reptile. We admit, that the liver must be early & largely developed, for the purpose of carrying on the great functions allotted to it during fetal existence; that of making blood, for the fetus.
out of the materials insinibed from the mother's blood. Are not the abdominal organs called for as soon, after birth, as those of the superior extremities? Surely they are; why then say they must have the impure blood, after it has once circulated through the superior vessels.

Thus, we see, from the foregoing remarks, that of the blood arriving in the right auricle from the inferior vena cava, about $\frac{1}{4}$ is pure placental blood, $\frac{3}{4}$ are Semones, and that the Eustachian valve has little power, and certainly none in the latter part of fetal existence, to prevent the admixture of the blood arriving in the right auricle from the two vena cavae. We find a remark in Carpenter's Physiology, that the placental blood loses its
...character “in some degree,” by the time that it arrives at the heart, now from the lowest calculation, its highly venous character is established: one sixth placental of five sixths venous enters the right auricle from the inferior vena cava. If we admit that the cava, returning the blood from the superior extremities, discharge but ¼ as much blood as the inferior — which is certainly a low estimate — it will add three parts more of venous blood to the five of venous 3/4 of placental from the inferior vena cava: and thus, not more of all the blood filling the right auricle will be placental ¾ of venous. Let it be remembered also, that the blood in the left auricle is constantly rendered life pure...
by the venous blood entering it directly from
the lungs, through the pulmonary veins.
The quantity of venous blood, returned through
these veins to the heart, is far greater than
has been admitted by most of authors, being
about two-thirds of the amount sent through
the pulmonary arteries from the right ventricle.
We, therefore, perceive that the left ventricle
does not send placental, before undergoing
admixture to a very great degree with that
of venous, to the superior extremities; but
it sends a completely mixed blood, about
eighty minutes venous, into the ascending
costa. From this analogy, therefore, the
head and superior extremities are not sup-
plied with blood nearly as pure as that
from the placenta: but we see that these
parts are developed in advance of the trunk and lower
extremities.

By means of the anastomoses existing
between the bronchial veins and
pulmonary arteries (according to some)
The bronchial arteries, given off from the thoracic aorta below the entrance of the ductus arteriosus, the nutrient vessels of the lungs. Are not the lungs, together with the alimentary canal, as early needed, and equally as far developed at birth, as these organs of sensation, deglutition, &c. Surely they are, & the former are supplied with nutrient blood from the descending thoracic & abdominal aorta, while the latter are supplied with blood from the arch of the aorta. Why, then, say, that the Eustachian valve has any power to prevent the admixture of the blood arriving in the right auricle from the two venae cavae, & that the above named organs must receive entirely venous blood from the descending aorta.
which has once circulated through the superior extremities before it is sent back to that great depurating organ, the placenta, there to be prepared again for the renewed circuit, by giving off the hydro-carbon compounds, thus a supply of oxygen from the mother. May we not inquire why the posterior extremities of the dog, sheep, calf, &c., are equally developed with the anterior extremities, the head? Is not the circulation essentially the same? If a pure nutrient blood produces a more rapid development of the head and superior extremities of the human foetus—should not the same rule hold good in all the mammalia? Yes.
Physiology of the fetal circulation.

1. The blood arriving in the vena cava ascends from the umbilical arteries, "having been transmitted through the two great depurating organs - the placenta and the liver, is in the condition of arterial blood; but mixed in the vessels (the inferior cava) with that which has been returned from the trunk and lower extremities, it loses its character in some degree, by the time it arrives at the heart."

Carpenter. In the first place, what is a depurating organ? By a depurating organ must here be meant an organ that eliminates render impure or venous blood arterial; or an organ, which eliminates carbonic acid gas.
from it, and replaces the same with oxygen. Will any one, with a knowledge of the physiology of the fetal circulation, as it is at present understood, distinctly assert that the liver has any such function as this to perform, only so far as it secretes bile.

So what extent the liver secretes bile in the fetus, is an important inquiry in this connection. After birth, bile is secreted for two very distinct objects — 1st, to assist and carry on the process of digestion; 2nd, to separate certain hydrocarbon compounds from the blood as a degrading organ. It is, therefore, very well known, that the liver of the adult is an eliminator of carbonic acid gas from the blood, and in this respect is a depura—
-king organ, so far as it secretes bile; and in doing this, it cannot convert venous blood into arterial. Therefore, we may admit that the liver in the fetus, is an eliminator of carbon so far, only, as it secretes bile, so separates it from the blood circulating through that organ. While, at the same time, there is no reason to believe that it possibly change venous into arterial blood, or residual placental blood more highly oxygenized. In the adult, the blood collected by the vena portae from the alimentary canal and its appendages below the midriff contains the elements of food, abounding in the hydrocarbon compounds already alluded to, and the impurities are separated from the venous blood by the liver.
Now, in the foetus, the bile cannot be
expected to carry on digestion, when there
is none to be aided at all. Thus we see,
that the blood, transmitted by the Vena
Portae from the Chyliformic visera,
does not differ from the venous in
any other part of the foetus; its blood
not being loaded with hydro-carbon
compounds derived from the food, as
in the adult. It cannot be said, that
much bile is separated from the venous
blood of the Vena Portareme, though
there is a small quantity secreted, for the
purpose of securing the discharge of
the mucous & epithelialium scales from
the alimentary canal immediately
after birth; and thus to prepare it
for the reception of food.
It has already been admitted, by the highest authorities, that a small amount of bile may be secreted by the liver of the fetus from the venous blood derived from the branches of the vena porta, and the amount is actually small. The following facts go to prove, that the fetal liver, in the sense last explained, cannot be regarded otherwise than as a very feeble depurating organ. 1st. The whole amount of meconium secreted during fetal life is very small; stone having been discharged previous to birth; and yet about five months of the last of fetal life is required to produce this small amount found in the alimentary canal at birth; having been slowly secreted from the blood.
But, by analysis it has been proven, that only a very small amount of the mucus in the bile, not more than three or four percent in the one hundred parts.

Two-thirds of the placental blood arriving in the vein porta, mixing with the venous blood of that vessel, passing through the capillaries of the liver, is rendered impure, or venous, by giving off its oxygen and nutrient materials necessary for that viscus. By taking up the effete, or worn out tissue of the same. Consequently, the placental blood transmitted by the hepatic veins into the inferior vena cava, does not leave the fetal liver in a condition of arterial blood. To prove this, one sentence only.
from Wilson's human anatomy, is requisite. It is, that the bile is wholly secreted from venous blood, not from a trunk vein but from the capillaries of the hepatic artery, yet the very fact of the blood of the latter vessel having passed through its capillaries into the portal, or in extremely small quantity into the capillary network of the lobular plexus, is sufficient to establish its venous character. Since it has been proven, that it cannot be as a secretor of bile that the liver is so early needed, no bile being secreted previous to the fifth
month, and that only a very small quantity is found in the alimentary canal at birth. Finding the liver to be one of the first-formed organs of the embryo, constituting over one half the weight of the new creature at three weeks, we must come to the conclusion that it has an entirely distinct and more important function to perform than as a secretor of bile. Doubtless the liver is the organ most important in the blood-making process. The foetus makes its own blood, not deriving a particle of blood from the mother's vessels— but merely inbibing the elements out of which it forms its own vital fluid. But there is another important point to be no-
and that is, the liver actually diminishes in size after birth, when it
receives pure arterial blood by means of the hepatic arteries, to become
a more powerful depurating organ as a secreter of bile than
before birth; and does not again assume its original size till the
infant is near one year old. Surely, if the depurating powers of
the liver, during fetal existence, were the immediate cause of its
early development, certainly it would retain its original
bulk and continue to increase in size after birth instead of dimin-
ishing, when taking on a more powerful depurative action, as a
secreter of bile.
Its action, certainly at no time, is so minute required as when the first drop of blood is to be formed for the embryo. Is not the liver of the newly formed embryo, rapidly developed to meet this important function, previously to the establishment of the placental circulation, while it is supplied with nutritious materials from the umbilical vessels, only by the omphalo-mesenteric vessels? According to the opinions of most authors, the lungs of the fœtus are solid and almost impermeable, and that the major part of the blood in the pulmonary artery rushes through the ductus
arterosus into the descending or thoracic aorta. As soon as
the lungs have become inflated by the first act of inspiration,
the blood of the pulmonary artery
pushes through its direct & sinusia
branches into the lungs, to be
returned to the left auricle by
the pulmonary veins.

The umbilical arteries are two
in number, one on each
side. They arise from the in-
ternal iliacs. From this origin
they first curve downwards, then
ascend on the side of the bladder,
and converge towards each other
as they approach the umbilicus,
being anterior to the peritoneum; at this point they come into contact, pass out of the abdomen, then wind around the umbilical vein in a very tortuous manner, anastomosing near the placenta, and then enter that organ, wherein the capillary vessels become continuous with the umbilical vein.

The umbilical arteries convey the effete blood of the foetus back to the placenta.

The current through these vessels being arrested, contract and become impervious, and discharge into the umbilical ligaments of the bladder.
In after life, these cords remain patent for a short distance and constitute the umbilical arteries of the adult, from which the superior vesical arteries are given off to the fundus and anterior aspect of the bladder. It is when the ductus arteriosus contracts and degenerates into a fibrous cord, the foramen ovale is closed, that a true mammal circulation is established.

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Act. Vigenti et quingue