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BY

William Marshall Turner

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No

John M. Watson M. D.,
Prof. of Obstetrics
& Diseases of Women & Children,
of the University of Nashville,
this dissertation

is

most respectfully
inscribed or addressed

by
the Author.

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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 & successive phases of function, as well as development (is concerned); it is of no ordinary difficulty to give satisfactory & correct statements of the ideas, adopted by the highest authorities, both in regard to the course & the physiology of foetal circulation.

1st 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 days 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 foetal; the uterine arteries & veins communicating with each other, and the foetal arteries & veins with each other. No direct communication existing between the maternal and foetal vessels. The placenta being neither wholly maternal, nor entirely foetal. 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 cellulo-vascular membrane.

The foetal, or umbilical surface, is smooth, polished, covered by the chorion & amnion,

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 foetus. The vessels of the former proceed from the uterus, & consist of arteries & veins of considerable number. The vessels of the latter, which proceed from the foetus, constitute the umbilical cord; (the umbilical vein & umbilical arteries.) The placenta performs the same function for the foetus, 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

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The placenta, is received by the small capillaries of the vena umbilicalis: this vessel, formed by the anastomoses of an infinitude of placental radicles, becoming one large trunk at the foetal surface of the placenta, enters the body of the child at the navel. From this point it is attached to the margin of the falciform ligament of the liver, passing upwards, & anterior to the peritoneum, 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 $\frac{1}{3}$ of the aerated, or arterial blood returned by the umbilical vein from the placenta,

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through the umbilicus into the vena cava
ascendens: the other $\frac{2}{3}$ having been first
transmitted into the left branch of
sinus of the vena portarum, thence throu-
gh 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, ($\frac{5}{6}$ venous), 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 atrophied from the sixth or seventh month, & 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 vena cava; 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 arriving in the right auricle from the venae cavae is completely interrupted by every diastole & systole of the right auricle; therefore, the inferior extremities, together with the lungs, receive as pure blood as the superior extremities.

2^{dly} 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 continue through the foramen, diminishing in proportion only as the valve becomes more & more complete. Now, it is during the early periods of embryonic life, when the septum auricularum is deficient, 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 Botal, remaining very large: this opening continuing 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. Foetal 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 foetal existence; that of making blood, for the foetus,

out of the materials inscribed 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 $\frac{1}{6}$ is pure placental blood, & $\frac{5}{6}$ are venous; and, that the Eustachian valve ^{has} but little power, and certainly none in the latter part of foetal existence, to prevent the admixture of the blood arriving in the right auricle from the two venae cavae. We find a remark in Carpenter's physiology, that the placental blood loses its

arterial character "in some degree", by the time that it arrives at the heart. Now, from from the lowest calculation, its highly venous character is established: one sixth placental & 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 $\frac{1}{2}$ 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 & one of placental from the inferior vena cava: and thus, not more ^{than} $\frac{1}{9}$ of all the blood filling the right auricle will be placental & $\frac{8}{9}$ venous. Let it be remembered also, that the blood in the left auricle is constantly rendered up 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 ~~that~~ the left ventricle does not send placental ^{blood} before undergoing admixture to a very great degree with that of venous, to the superior extremities; but it sends a completely mixed blood, about eight ninths venous, into the ascending aorta. From this analogy, therefore, the head & superior extremities are not supplied with blood nearly as pure as that from the placenta: but we see that these parts are developed in advance of the trunk & lower extremities.

* By means of the anastomosis existing between the bronchial veins & pulmonary arteries, (according to some authors.)

Are not the bronchial arteries, given
 off from the Thoracic aorta below
 the entrance of the ductus arteri-
 osus, the nutrient-vessels of the lungs?
 Are not the lungs, together with
 the alimentary ^{& the urinary apparatus} canals, as early
 needed, & equally as far developed
 at birth, as those organs of sen-
 sation, deglutition, &c? Surely
 they are, & the former are supplied
 with nutrient blood from the
 descending or 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, & receiving 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.

Physiolog of the foetal circulation.

1st The blood arising in the vena
cava ascends from the umbilical
arteries, "having been transmitted thro-
ugh the two great dep~~urating~~urating organs
- the placenta & 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 renders 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 foetal 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.

To what extent the liver secretes bile in the foetus, is an important inquiry in this connection. After birth, bile is secreted for two very distinct objects—1st to assist & carry on the process of digestion; & 2^d, to separate certain hydrocarbon compounds from the blood, as a depurating organ. It is, therefore, very well known, that the liver of the adult is an eliminator of carbonic acid gas from the blood, & in this respect is a depura-

-ting 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 foetus, is an eliminator of carbon so far, only, as it secretes bile, or 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 render placental blood more highly oxygenized. In the adult, the blood collected by the vena portae from the alimentary canal & 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 secreted 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 chylific viscera, 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 portarum, though there is a small quantity secreted, for the purpose of securing the discharge of the mucus, & epithelium 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 ^{authorities} highest, that a small amount of bile may be secreted by the liver of the foetus from the venous blood derived from the branches of the vena portae; and the amount is actually small.

The following facts go to prove, that the foetal liver, in the sense last explained, cannot be regarded otherwise than as a very feeble depurating organ. 1st The whole amount of mucus secreted during foetal life is very small; none having been discharged previous to birth; and yet about five months of the last of foetal life is required to produce this small amount found in the alimentary canal at birth; having been slowly secreted from the blood.

But, 3^{dly} analysis has proven, that only a very small amount of the meconium is bile: not more than three or four percent in the one hundred parts. Two-thirds of the placental blood arriving in the vena portae, mixing with the venous blood of that vessel, passing through the capillaries of the liver, & taken up by the vena hepatica, is rendered impure, or venous, by giving off its oxygen & 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 foetal 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 who-
 ly secreted from venous blood, & not from
 a mixed venous & arterial blood, as is
 stated by Miller; for although the por-
 tal vein receives its blood from two
 sources, viz., from the chylipoietic vis-
 cera & 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 pe-
 nus, 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

mouth, & 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 & more important function to perform, than as a secreter 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 imbibes the elements out of which it forms its own vital fluid. But there is another important point to be noticed;

and that is, the liver actually diminishes in size after birth, when it receives pure arterial blood by means of the hepatic arteries, & becomes a more powerful depurating organ as a secretor 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 foetal existence, were the immediate cause of its early development, certainly it would retain its original bulk & continue to increase in size after birth instead of diminishing, when taking on a more powerful depurative action, as a secretor of bile.

Its action, certainly, at no time, is so much 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 vesicular umbilicalis only by the omphalo-mesenteric vessels? According to the opinions of most autho

The lungs of the foetus are solid and almost-imperious, and that the major part of the blood in the pulmonary artery rushes through the ductus

arteriosus 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
 rushes through its dextral & sinistral
 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 peritonium;
 at this point they come into con-
 tact, pass out of the abdomen,
 then wind around the umbilical
 vein in a very tortuous mann-
 er, 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 currents through these ves-
 sels being arrested, contract &
 become imperious, and degenerate
 into the umbilical ligaments
 of the bladder.

In after life, these cords remain
 pervious for a short distance and
 constitute the umbilical arteries of
 the adult, from which the
 superior vesical arteries are given
 off to the fundus & anterior aspect
 of the bladder. It is when the duc-
 tus arteriosus contracts & degenerates
 into a fibrous cord, & the foramen
 ovale is closed, that a true mam-
 mae circulation is established.

September the 26th 1856.

William Marshall Turner.

Act. viginti et quinque