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Polyhydraminios and obstructive lesions of the small bowel

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POLYHYDRAMNIOS AND OBSTRUCTIVE LESIONS OF THE SMALL BOWEL

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The association of excessive amounts of amniotic fluid and obstructive lesions of the gastrointestinal tract has been recognized for several years. Numerous theories have been advanced to explain this association. Currently, research is providing new concepts as embryologic causes begin to be apparent and as the dynamic role of amniotic fluid in fetal development is explored.

This paper consists of two sections. The first delineates some of the physiologic aspects of formation and circulation of amniotic fluid. In this section, possible etiologic mechanisms for polyhydramnios are also discussed.

The second section deals with four anomalies of the upper gastrointestinal tract which have been associated with polyhydramnios. The association of these anomalies with polyhydramnios has been one of the arguments in favor of the fetal deglutition theory of amniotic fluid removal, which is discussed in the paper.

The purpose of the paper is twofold. First, it discusses several causes of upper small bowel obstruction in the neonate with a view toward better understanding of these lesions through knowledge of their embryogenesis. Secondly, it discusses the possible relationship of these anomalies to polyhydramnios and suggests that this relationship be considered early in babies of polyhydramniotic mothers. If such anomalies are considered in this group of children, more prompt diagnosis and more effective treatment of the lesions will result, with a diminution of morbidity and mortality in these infants.

PART I - AMNIOTIC FLUID

Two sources for amniotic fluid have been proposed - embryonic membranes and the fetus - and all theories as to its origin are constructed around these two sources.

Evidence that the membranes are a source of fluid is that the fluid is present early in pregnancy when fetal tissues are not functioning. In early pregnancy, also, the fluid is quite similar to maternal plasma and may even be a dialysate of plasma at that time. Later in pregnancy the composition of the fluid changes. It is no longer a simple ultrafiltrate of plasma, but becomes a fluid of specific electrolyte and osmotic composition. This change might be explained on the basis of a selective secretory action of the amnion. The amnion does not have a particularly rich blood supply except in the area overlying the placenta, and it is doubtful if large amounts of fluid could be secreted except by this area. Hydramnios is often associated with chorionic hemangiomata, in which case chorionic blood supply is increased. This association lends support to the theory of amnionic secretion.

The skin and skin appendages, respiratory tract, and urinary system of the fetus have been postulated as sources of fluid. The oldest theory is that of Hippocrates, who speculated that the fluid was fetal urine. It is known that fetal kidneys do function <u>in utero</u>, and urine has been found earlier than the fourteenth week of gestation in the fetal

bladder. Fetal renal agenesis is often associated with oligohydramnios.

The fetal respiratory tract may also be a source of fluid, although the alveoli are collapsed *in utero* and have a rather poor blood supply. Cannulation of the trachea and the fetal pharynx has yielded considerable amounts of fluid, so the larger respiratory passages may contribute to the fluid. Paradoxically, other recent evidence indicates that fluid may actually be absorbed by tracheal epithelium, so more than one mechanism may be operant.

Buccal and salivary glands are being reconsidered as possible sources. Fetal skin and mammary glandswwere once thought to be potential sources, but this theory has been disregarded.

Recent perfusion studies of human umbilical cord have shown a brisk exchange of water and electrolytes across the walls of the cord, and this may contribute some elements to the fluid.

Removal of the amniotic fluid is another problem, and again fetal and maternal mechanisms have been proposed. The amnion itself may have absorptive properties or may permit transudation of fluid down osmotic gradients into the maternal circulation. Fluid does disappear following intrauterine fetal death, and the fetus could not account for such removal. This observation suggests that the membranes are not impermeable to fluid and may play a role in its physiologic removal.

Fetal removal of the fluid is a more widely accepted theory, but the route of removal is in doubt. Harvey in 1651 proposed that fetal swallowing removed much of the fluid, and recent studies[20] substantiate this. It is estimated that the term fetus swallows 450 to 500 milliliters of fluid per day. Radio-opaque material introduced into the amniotic cavity has been viewed in the fetal alimentary tract. Analysis of meconium shows lanugo hair, epithelial cells, and other constituents of amniotic fluid. Swallowed fluid apparently enters the fetal circulation and is probably transported to the maternal circulation via the umbilical vein and the placenta. Plentl and Gray[19] state that of the fluid swallowed, about 40 milliliters are excreted by the fetal kidneys and 435 milliliters enter the maternal circulation.

Fetal skin may have a minor absorptive role, especially early in pregnancy when it is represented by primitive ectoderm rather than well-developed skin with vernix caseosa. Fetal respiratory epithelium may also play an absorptive role, as mentioned above, especially during the last half of pregnancy.

The definition of polyhydramnios is quite variable, but a generally accepted rule seems to be a quantity of amniotic fluid in excess of 2000 milliliters. This discussion will deal largely with fetal complications of the condition, but a number of maternal factors are also associated, the most notable of which are diabetes, preeclampsia, cardiovascular disease, anemia, and obesity.

Many fetal anomalies are associated with polyhydramnios. The one most frequently mentioned is anencephaly. This fact supports the fetal deglutition theory of fluid removal, since the anencephalic monster may not have a well-developed swallowing "center" and cannot forcefully propel fluid into the gut. Structural deformities of the oropharynx may add to the failure to swallow effectively. Apparently, vigorous swallowing is necessary to ensure adequate removal of the amniotic fluid.

The association of obstructing lesions of the upper gastro-intestinal tract with polyhydramnios supports the deglutition theory. In Lloyd and Clatworthy's[13] series of 220 infants with congenital intestinal obstruction, 30 had polyhydramniotic mothers. Of 53 cases of esophageal atresia, 13 per cent were associated with polyhydramnios; of 49 cases of obstruction of the small bowel proximal to the first 15 centimeters of jejunum, 47 per cent were associated with polyhydramnios. None of 118 cases of distal small bowel and colon atresia and stenosis was associated with polyhydramnios. The lower proportion of infants with esophageal atresia to be associated with excess amniotic fluid may be explained by the presence of a communication between the esophagus and distal alimentary canal as is provided by the trachea, since a large number of such infants have a concomitant tracheo-esophageal fistula.

Lloyd and Clatworthy[13] also describe a group of 76 hydramniotic mothers who were delivered of 33 infants with

congenital anomalies including mongolism, stillbirth, nuchal cord, disturbances of the central nervous system, and intestinal obstruction. Four of the infants had intestinal obstruction, consisting of esophageal atresia, duodenal atresia, annular pancreas, and jejunal atresia. This group of 33 infants all had some underlying abnormality which interfered with fetal deglutition.

Additional intestinal anomalies associated with polyhydramnios reported by Moya, et. al.[18] (eg. jejunal bands and common mesentery) were associated with volvulus. These authors also propose the fetal deglutition theory, but caution against assigning a complex problem a simple cause and effect relationship. They emphasize the occurrence of hydramnios in mothers with normal babies as well as the incidence of hydramnios in infants with other anomalies.

Plentl and Gray[19], on the basis of radioisotopic studies, propose a dynamic theory for the formation of polyhydramnios, with a disturbance in fluid equilibrium between mother, fetus, and amniotic fluid. Normally, water circulates from mother to fetus to amniotic fluid and back to the mother, so that the fluid is not a stagnant pool. Under conditions of polyhydramnios, there is a disturbance in this exchange equilibrium with impairment of maternal - fetal water exchange and creation of an additional pathway between mother and amniotic fluid. While the total amount of water entering and leaving amniotic fluid remains constant, the transfer is of such magnitude in the polyhydramniotic condition (about 500

milliliters each hour) that undetectably small differences in exchange rates could lead to the accumulation of fluid over an extended period of time, resulting in polyhydramnios.

These authors suggest a further possible mechanism of the formation of excessive amniotic fluid, that of placental failure. Excessive fluid is often associated with maternal diseases which are marked by abnormal placental function, such as diabetes, toxemia, and Rh incompatibility. Placental weight is greater than normal in cases of polyhydramnios, suggesting increased surface area and excessive fluid transudation as a possible additional mechanism.[6]

In summary, the amniotic fluid is in a continual flux with an equilibrium of water exchange between mother, fetus, and fluid. Water and other components are exchanged at different rates. The rates of exchange vary throughout pregnancy, but are at all times dependent upon a balance between input and outflow. If input is greater than the amount which can be removed, polyhydramnios results. Mechanisms of formation and removal of fluid are multiple. It seems, however, that emphasis must be placed upon the dynamic equilibrium of the fluid. Polyhydramnios arises when the equilibrium is disturbed at any point, and even a small disturbance might account for marked increases in fluid volume over a period of time. Proponents of the fetal deglutition theory of amniotic fluid removal present the most convincing arguments for interference with the equilibrium by a single fetal factor, although this is certainly not the sole mechanism for the production of polyhydramnios.

PART II - CONGENITAL ANOMALIES

The following discussion deals with four anomalies which have been associated with polyhydramnios.

Duodenal stenosis and atresia

Distinction between atresia and stenosis is made on the basis of the degree of obstruction present. Atresia refers to complete absence of a lumen while stenosis is a narrowing of the gut with at least minimal luminal patency. Duodenal lesions of this sort are etiologically different from similar lesions of the jejunum and ileum, and are discussed separately.

Duodenal obstruction has been well reviewed by Boyden, et. al.[4] who report on 35 cases of intrinsic duodenal obstruction encountered at the Children's Orthopedic Hospital in Seattle from 1946 to 1966, in addition to an extensive review of literature on this subject.

In 83 per cent of the cases surveyed, duodenal obstruction was associated with the major duodenal papilla, being either proximal, distal, or at the level of the papilla. In the remainder of cases, the third portion of the duodenum was obstructed.

Serial studies of sectioned human embryos show that a "solid stage"[17] exists in the development of the duodenum between the thirtieth and fiftieth gestational days, when the gut lumen in the region of the duodenum is totally or partially filled by proliferating epithelial cells and the surrounding mesenchymal walls remain narrow. The central "core" of epithelial cells is progressively loosened as vacuoles appear between the "core" and the definitive

epithelial wall of the gut. These vacuoles coalesce to form two parallel channels, into each of which open the bile duct and accessory pancreatic duct. A theoretical explanation for obstruction is that delayed coalescence of vacuoles forming two orifices of the bile duct takes precedence over vacuolization of adjacent portions of the plug, creating a "traffic jam"[4] contrary to smooth development of the main cavity. If a segment remains solidly "epithelialized" for a critical period of time, it may be resorbed and replaced by developing mesenchymal tissues and their derivatives.

The process of plugging and vacuolization involves the whole of the duodenum and obstruction may result from mechanical impediments to canalization in a small area, such as between the orifices of the developing bile duct. Stenosis may result either from delayed vacuolization or from the continued blockage of one of the main parallel channels while the other becomes once again continuous with the lumen of the gut.

The paper of Boyden, et. al. is based on the study of only a few embryos. A larger series of 89 embryos was reviewed by Linn and Espinas[16], who found epithelial plugging and vacuolization in only 27 cases, less than one-third of the total. This finding is not inconsistent with those reported above, but indicates that epithelial plugging is probably not a constant feature in duodenal development. These authors present no evidence contradictory to that in the other, more recent, paper.

Jejunal and ileal stenosis and atresia

The most recent and well documented studies on these anomalies have been done by Louw[14,15]. His experiments with fetal puppies seem to provide an adequate cause and effect relationship to explain these conditions. He lists the following four types of occlusion:

1) Stenosis
2) Type 1 atresia - membranous occlusion of the gut lumen
3) Type 2 atresia - blind ends of bowel joined, with or without a gap in the mesentery
4) Type 3 atresia - disconnected blind ends of bowel with a gap in the mesentery

The etiology of lesions of the jejunoileum has been debated for many years, and the currently accepted theory, that of an intrauterine insult to the vascular supply of the bowel, has been extant for the past century. Louw[15] reviews 72 cases of atresias of all segments of large and small bowel from 1952 to 1967 and correlates them with one of his earlier studies[14]. His principal conclusions are that at least two mechanisms may be operant, i.e. arrested intrauterine development (more commonly in the case of duodenal lesions, as discussed above) and interruption of blood supply to a segment of bowel late in fetal life. Interruptions of blood supply are most probably due to accidental factors such as herniation, volvulus, intussusception, or kinking of the bowel.

Also included in his review is a series of experiments demonstrating that infarction of the fetal bowel is a major, if not the primary, cause of jejunal and ileal obstruction. The study was conducted on 51 dogs at the 45 to 55 day stage

of pregnancy. Laparotomy was performed and hysterotomy exposed a suitable fetus. The fetal abdomen was opened and the blood supply to a loop of bowel was interrupted by ligature. The bowel was then replaced and the incisions closed. The pregnancies were allowed to continue, and in 38 of the animals normal delivery was accomplished.

The findings in puppies so treated depended upon the length of time which passed between the operation and birth. Puppies born 12 to 14 days later showed anomalies identical to those in human infants with intestinal atresia. Evolution of the lesion was studied in puppies born earlier. Devascularized bowel disintegrated rapidly with resorption of necrotic tissue until either no tissue or only a thin fibrous strand remained. Proximal and distal ends of bowel separated from the avascular segment and closed off forming blind ends. Adhesions appeared, but were seen resorbed unless perforation and meconium peritonitis ensued. After separation of the ends, the proximal portion of the gut enlarged while the distal segment emptied by peristalsis and grew smaller. The pattern was one commonly seen in the human infant with such lesions.

Incomplete rotation of the midgut

Understanding of incomplete rotation of the midgut is simplified by knowledge of the processes involved in normal rotation and the various stages at which rotation may be arrested. The midgut is defined[24] as "that part of the primitive gut which extends from Vater's papilla to approximately the middle of the transverse colon." This segment

of the bowel receives its blood supply from the superior mesenteric artery, and it is the relationships of the bowel to this artery upon which understanding of rotation is based.

Snyder and Chaffin[22,23] give a functional explanation of rotation. The two important rotational divisions of the midgut are the duodenojejunal loop and the cecocolic loop. Each of these rotates 270° counterclockwise around the axis of the superior mesenteric artery. This rotation begins between the 5 and 10 millimeter stages of embryonic life and is completed at the time of return of the intestine to the abdominal cavity from the umbilical cord. The duodenojejunal loop begins cephalad of the artery while the cecocolic segment begins in a caudad position. The duodenojejunal loop then curves beneath the artery and the cecocolic segment drapes over the artery. This arrangement accounts for the final anatomic positions of the duodenum and colon, respectively.

The above process may be arrested or interrupted at any time prior to its completion. Obstructive symptoms are produced either when the duodenum twists or when a transduodenal band is present. The majority of cases in this series were arrested in the position of 90° rotation, with duodenum and jejunum extending to the right side of the artery but not passing under it. In such a position, adhesions and bands across the proximal portion of the jejunum produce obstruction. The cecocolic loop causes most mischief when it is in the position of 180° rotation with

the cecum in the right upper quadrant. In this case the usual peritoneal attachments of the cecum are laid down as bands which cross the duodenum and produce obstructive symptoms.

A complicating factor in many cases of incomplete rotation is inadequate fixation of the mesentery of the small bowel to the posterior abdominal wall. If the jejunal segment fails to rotate normally, the mesentery fails to attach from the ligament of Treitz to the right lower quadrant. When this occurs, the only attachment of the small bowel is a small area in the region of the origin of the superior mesenteric artery. This anomaly is partly responsible for the frequency of volvulus in cases of incomplete rotation.

Reversed rotation is a much rarer condition. Rotation takes place in a clockwise direction about the superior mesenteric artery and the final result is a cecum and right colon obstructed by the overlying superior mesenteric artery, overlain as well by the duodenum and jejunum. Symptoms are those of lower obstruction. About 40 cases of this anomaly have been reported.

Annular pancreas

Development of the pancreas begins in the embryo of 3 to 4 millimeters, in which two entodermal outpocketings arise on opposite sides of the primitive foregut in the region of the hepatic diverticulum. The ventral pancreas arises on the ventral side of the gut in the caudal angle

between the gut and the hepatic diverticulum. It is probably originally a paired organ. The dorsal primordium grows more rapidly and by the sixth week of gestation has become an elongated structure extending into the dorsal mesentery, and its growth continues with that of the dorsal layer of the mesenterial sac. The ventral bud, meanwhile, is carried away from the duodenum by the lengthening common bile duct, finally arising directly from the duct. Unequal growth of the duodenal wall shifts the bile duct dorsad, bringing the ventral pancreas into the dorsal mesentery. The two primordia interlock during the seventh week of development. The dorsal portion forms the majority of the body and tail of the gland while the ventral one forms the head and uncinate process.

The pancreatic ductal system is formed by contributions from both the dorsal and ventral divisions. Each anlage has an axial duct. The dorsal duct arises directly from the duodenal wall, while the ventral duct has a common stem with the common bile duct. When the two primordia are juxtaposed, the shorter ventral duct joins the dorsal duct, forming the pancreatic duct (duct of Wirsung), while the proximal segment of the dorsal duct remains as the accessory duct (duct of Santorini) which empties into the main duct, although it may retain its duodenal outlet as well.[2]

Theories of the origin of annular pancreas have attributed the anomaly to persistence of the left ventral bud and to hypertrophy of the dorsal pancreas. The most acceptable

theory[21], however, is that of Lecce, who postulates that the right ventral bud of the pancreas remains adherent at its point of origin on the duodenum and continues to grow to keep apace with the rotation of the common bile duct. This theory is most tenable on examination of the ductal system in cases of annular pancreas. In such specimens it originates in the portion of the ring overlying the left anterior portion of the duodenum then sweeps behind the duodenum, crosses the gut posteriorly from right to left, and empties into the main pancreatic duct close to the ampulla.

Hays, et. al.[9] point out that since union of pancreatic anlagen takes place between the 14 and 22 millimeter stages, the ring of tissue is virtually complete by the eighth week of gestation. At this time the duodenal lumen is quite small, and its further growth is severely curtailed by this ring. The situation is one of functional stenosis of severe degree. This may account for the frequent report of associated "duodenal atresia and stenosis". It also speaks against the wisdom of surgical division of the ring to free a severely narrowed duodenum whose functional ability is limited at best.

PART III - CONCLUSION

This paper has dealt with the pathogenesis of four specific lesions of the upper small bowel in the newborn. Current theories provide sound and reasonable explanations of these anomalies with regard to embryogenesis. A knowledge of their development will provide the physician with a rational approach to their treatment, with resultant increased longevity of infants so affected.

The association of polyhydramnios with these lesions is still not causally established. Evidence does suggest, however, that fetal deglutition plays a major role in amniotic fluid equilibrium. Polyhydramnios occurs when this dynamic equilibrium is interrupted, as is the case with impaired deglutition. Other derangements of both maternal and fetal factors can cause accumulation of fluid, but interference with swallowing is indeed one cause and is likely to be the primary mechanism responsible for the formation of excessive amniotic fluid when it is associated with these anomalies.

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