Technical Papers

The Physiologic Closure of the Ductus Arteriosus in Newborn Infants: A Preliminary Report*

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The exact time of functional closure of the ductus arteriosus in the normal human infant has never been determined. Studies on anatomical specimens have shown that complete morphologic closure requires from 6 to 8 wk (*1, 2*). It is fairly well agreed, however, that the ductus arteriosus is closed to the passage of significant quantities of blood long before this occurs. Using the technique of angiocardiography, Barclay and his coworkers (*3, 4*) and Barcroft (*5*) have suggested that physiologic closure in lambs may occur within a few minutes after birth. More recent animal experiments have disputed this fact (*6*), and one study using dogs and a radioactive isotope tracer method has shown a gradual closure of the ductus over a period of days (*7*). Some authors have questioned the applicability of experiments in animals to human infants (*8*).

The present study was stimulated by the observation that newborn infants occasionally show definite cyanosis of the lower part of the body but not of the upper portion. Regional cyanosis of this variety is occasionally observed in adults and older children who have a patent ductus arteriosus with pulmonary hypertension and a right-to-left shunt through the ductus (*9, 10*); and since the infant has a physiologic right ventricular hypertrophy suggesting a high pulmonary pressure, it was felt that this cyanosis of the lower extremities occasionally seen in the newborn might be due to a flow of blood in the fetal direction through an open ductus.

To investigate this possibility, 14 studies were done on 12 normal newborn infants at varying times after birth. Arterialized capillary blood from the right hand and from the foot was obtained with minimal exposure to air by a previously described method (*11*), and the oxygen contents and capacities were determined by the microtechnique of Roughton and Scholander (*12*). The right hand was selected rather than the left because of the proximity of the left subclavian artery to the ductus and the observation that occasionally the left upper extremity will show arterial unsaturation in the presence of a veno-arterial shunt through the ductus (*13*).

In all of the infants, the blood samples from the right hand showed an oxygen saturation of more than 90 percent, indicating that true arterial blood was obtained. Of the 14 studies, 8 showed an oxygen saturation in the foot that was significantly lower than that of the right hand. Since the error of the method is approximately ± 2.5 in terms of percentage of saturation, differences falling within this limit are not considered significant. These differences in oxygen saturation between the right hand and the foot are shown in Table 1.

Table 1. Differences in oxygen saturations of the right hand and the foot.

Infant	Age-hours	Oxygen saturation of right hand (%)	Oxygen saturation of foot (%)	Percentage difference in saturation between hand and foot + Foot saturation higher − Foot saturation lower
Cl.	1	94.4	90.4	− 4.0
Ma.	1½	93.4	84.4	− 9.0
Be.	1½	92.2	83.4	− 8.8
Al.	2	93.7	82.7	−11.0
De.	2½	91.4	87.3	− 4.1
La.	11	91.3	91.5	+ 0.2
Sm.	20	97.2	90.7	− 6.5
Fr.	27	90.5	82.5	− 8.0
Mo.	42	94.3	92.0	− 2.5
Al.	46	94.0	79.5	−14.5
Mi.	81	90.0	87.3	− 2.7
Cr.	94	93.0	94.3	+ 1.3
St.	108	93.6	92.6	− 1.0
Al.	118	91.7	91.3	− 0.4

In all of the five infants studied, 1 to 3 hr after birth, the oxygen saturation of the blood from the foot was significantly lower than that from the hand, indicating the presence of a veno-arterial shunt to the lower part of the body. Three of the five infants studied, 3 to 72 hr after birth, showed a saturation in the foot significantly lower than that of the right hand. None of the four infants more than 3 days old showed a significant difference in saturation between hand and foot.

One infant (Al., Table 1) showed a marked difference in oxygen saturation between hand and foot 2 hr after birth, a similar difference at 2 days, and no difference at 5 days, indicating disappearance of the veno-arterial shunt.

These findings indicate that the ductus arteriosus is patent and that it is the site of a veno-arterial shunt of the fetal type in most newborn infants during the first 3 hr of life. This situation persists in a significant

* This study was aided in part by a grant from the San Francisco Heart Association.

number of infants up to the age of 3 days. In the infants of this age who no longer demonstrate a shunt, either functional closure of the ductus arteriosus has occurred or, owing to a decrease in pulmonary vascular resistance, flow through the ductus has changed from the fetal to the adult direction. In most infants more than 3 days old, the ductus is either closed to the passage of blood or a change in direction of flow has occurred.

Further studies are being carried out in this laboratory to determine more accurately the incidence of this phenomenon and to study the factors that affect alterations of flow through the ductus.

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Received December 22, 1953.

Evidence for a Diurnal Pulse in Stream Phytoplankton

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Since the discovery of stream plankton (potamoplankton) about 1890, an extensive literature has accumulated, which includes a number of merely qualitative lists of species from various rivers, many quantitative reports of phyto- and zooplankton, numerous 12-mo studies listing either qualitatively or quantitatively the species present in stream plankton, and a relatively small amount of experimental work. Much of this literature is reviewed by Des Cilleuls (*1*).

In small streams lacking impoundments, it appears that nearly all the organisms carried as plankters originate from the benthos as attached forms or, in many cases, as single cells or filaments mixed with the upper layer of sediments that settle in quiet areas. Steuer (*2*) lists eight environmental factors that regulate the potamoplankton both qualitatively and quantitatively, but no mention is made of the diurnal factor. It would seem that later authors would almost certainly have taken up this subject; however, a diligent search has yielded no reference to work dealing with diurnal changes in stream plankton.

During 1952 and much of 1953, the algae of the Saline River in southeastern Michigan were under close observation. The Saline is a small stream located in Washtenaw County about 7 mi south of Ann Arbor that is polluted by both domestic and industrial wastes. In the summer of both these years, this stream exhibited in its polluted portion a region about 4 km in length that was dominated by the benthic diatom *Nitzschia palea* (Kütz.) W. Smith growing in a conspicuous brown sheet or layer on submerged rocks or silt deposits. Filamentous algae were abundant at certain seasons, but at the time and place of the work here reported they did not represent a significant element of the plankton or an important vehicle for the transport of entrapped or epiphytic organisms.

A very dense net plankton composed almost entirely of *N. palea* can be collected from this stream in the summer months but only in and immediately below the course of the river within which *N. palea* is abundant as a bottom organism. The *Nitzschia* plankton is, therefore, obviously of benthic derivation. This appeared to be a favorable situation in which to find a diurnal variation in stream plankton, if indeed such a variation existed anywhere. Two locations were accordingly chosen, one near the middle (Saline Mills) and one near the downstream end of this 4-km portion, for making comparative observations at different hours of the day. At each point, the net plankton was sampled at dawn and in late afternoon of Aug. 13, 1953. Counts of this material showed that planktonic *N. palea* was much more abundant at both stations in the afternoon than at dawn.

In an effort to demonstrate a diurnal periodicity more clearly, plankton samples were then taken at approximately hourly intervals throughout a 24-hr period on Aug. 25 and 26, 1953, at the Maple Road station, which is about 5 km below the industrial and domestic sewage outfalls. Throughout the sampling period, the weather remained clear and cloudless. Fair or cloudless weather, favorable for algal growth, had furthermore prevailed for at least 2 wk prior to the sampling period. Water level remained approximately the same throughout this period, with a variation of ±1.5 mm recorded. Water temperatures varied between 17.8 (6:15 A.M., Aug. 25) and 24.0°C (4:10 P.M., Aug. 25), air temperatures between 15.0 (6:15 and 7:15 A.M., Aug. 25) and 31.7°C (2:10 and 3:10 P.M., Aug. 25). I estimate that at this time (Aug. 25–26) it required about 5.8 hr for water in midstream, at a surface speed of 1.9 m/sec, to pass from the upper reaches of the *Nitzschia* community to the sampling point at Maple Road.

All samples were surface water taken from exactly the same point in the stream. Plankton was collected, and 20-field counts made, with minor variations, according to the method of Verduin (*3*). Because of the difficulty of distinguishing dead cells from certain moribund cells, all diatoms both dead and living at the time of collection were counted. Few of the frustules were completely empty, although cells obviously dead made up a larger percentage of the total during