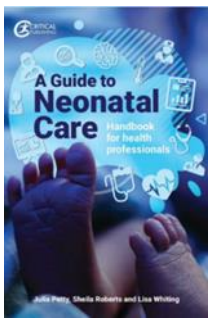
Chapter 1 Understanding neonatal anatomy and physiology.



A Guide to Neonatal Care - Handbook for Health Professionals
Petty J, Whiting L and Roberts S (2024) Critical Publishing

Supplementary information

The book chapter 1 covered the body systems of the neonate in terms of the specific features compared to older children and adults as well as, in brief, the biology of normal transition at birth. To add further detail to how the newborn adapts at birth, the web companion covers the adaptation of some important biological systems (see also Figures 1.1 to 1.3).

Respiratory adaptation

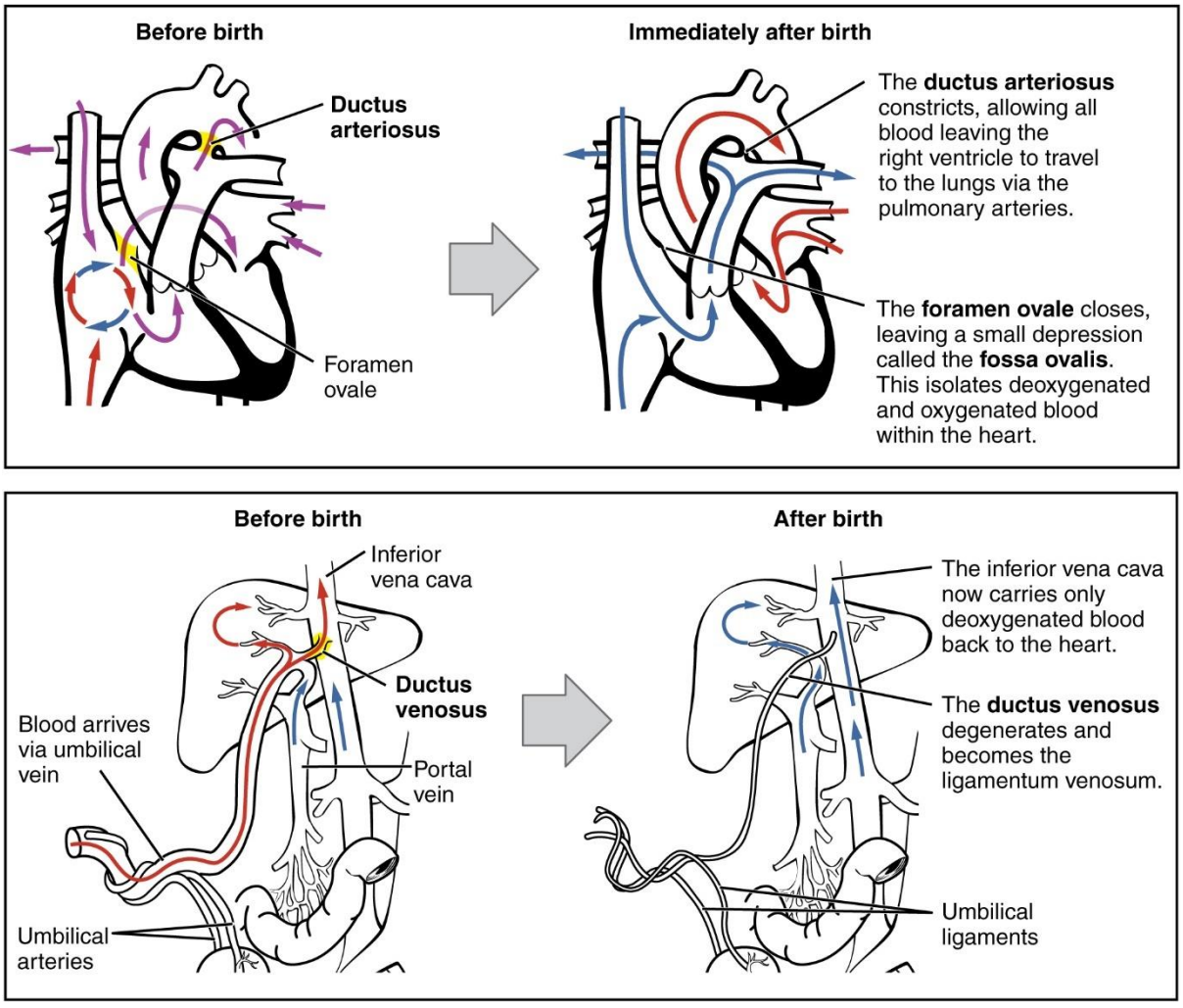
The oxygen uptake shifts from the placenta to the neonatal lungs soon after birth. For this to happen effectively, the neonate must be able to clear the fluid filled lungs and establish spontaneous breathing. Respiratory adaptation of the neonate could be influenced by the presence of surfactant, respiratory musculature, and lung perfusion. This process could be even more challenging for a preterm neonate where there is immaturity of their respiratory centre and pulmonary function along with inadequate surfactant production.

Cardiovascular adaptation

In utero, the foetal circulation provides the foetus with oxygenated blood from the mother through the placenta. This pathway is characterised by the presence of three shunts the ductus venosus which connects the umbilical vein to the inferior vena cava, the foramen ovale which links with the two atria and ductus arteriosus, which links the pulmonary artery and the aorta [Figure 1.1]. This limits the blood flow to the foetal lungs therefore causing high pulmonary vascular resistance (PVR) and a low systemic vascular resistance (SVR). The clamping of the umbilical cord signals the start of major physiological changes as the neonate must now redirect deoxygenated blood into the lungs and

distribute oxygenated blood to the heart to be pumped throughout the rest of the body. This event causes a decrease of the initially high PVR and increased SVR as more blood flows in the lungs. The cessation of the foetal circulation initiates the functional and anatomical closure of the three foetal ducts which can often take days or several weeks (Morton and Brodsky, 2016).

Figure 1.1 Foetal and neonatal circulatory systems



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Thermal adaptation

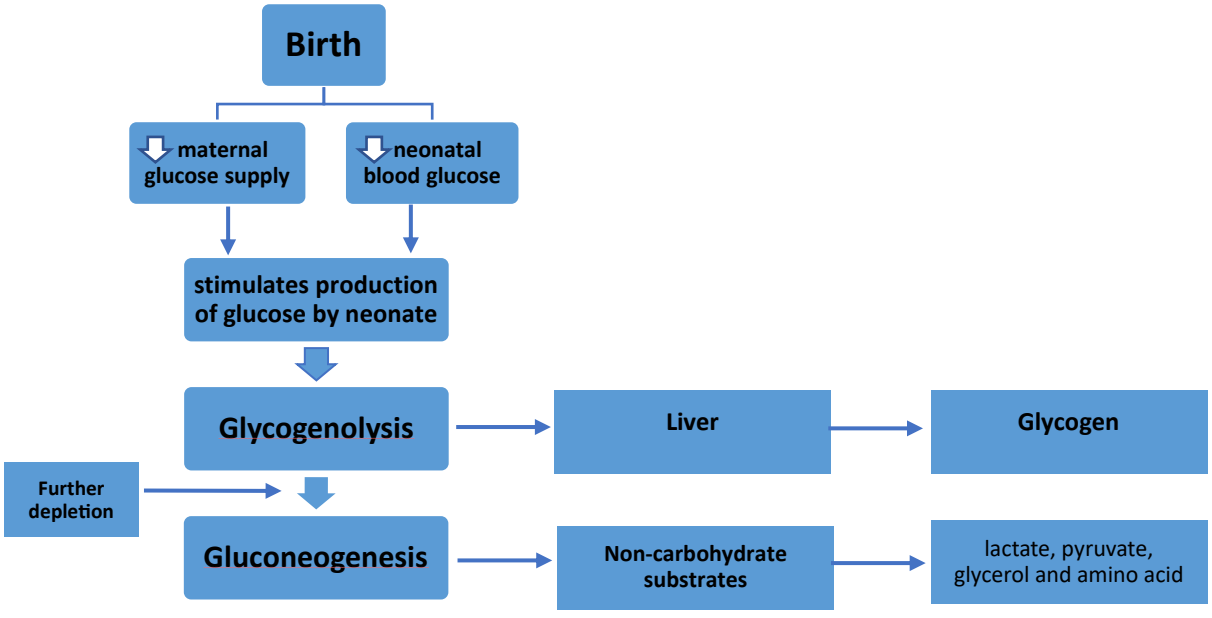
At birth the neonate usually drops their temperature at a rate of 2-3 degrees C per minute within the first 30 minutes of life and must adapt to a wet, cold, and often hostile environment. The neonates' adaptation to their new environment

can be determined by their internal physiologic response and several environmental factors. Their thermogenic response is triggered minutes after birth, and this enables the neonate to produce heat through increasing its cellular metabolic activity and through non-shivering thermogenesis to stay warm. This process could be altered by the neonates' immature thermoregulatory system hence if hypothermia persists, this could result to other problems such metabolic acidosis, hypoglycaemia and decreased surfactant production.

Glucose adaptation

At birth the continuous supply of maternal glucose via the placenta ceases and the neonate must take on the role in maintaining glucose homeostasis. The neonate's blood glucose falls rapidly soon after cord-clamping and it could reach its lowest point by one to two hours. They often try and compensate with this decline in glucose supply through using up stored hepatic glycogen through a process of glycogenolysis. Once this supply has been exhausted, this will result in the utilisation of non-carbohydrate substrates such as lactate, pyruvate, glycerol, and alanine, an amino acid. See Figure 1.2 to illustrate this process.

Figure 1.2 Glucose adaptation at birth



The neonate must also learn how to adjust and tolerating the intermittent feed cycle to ensure adequate supply of energy goes to the brain and the other organs of the body. If the neonate fails to adapt to this normal process of metabolic adaptation balancing energy requirements and the supply of substrates this will result to problems with glucose homeostasis.

Fluid adaptation

Early in the foetal period, 95% of the total body weight (TBW) is made up of water and this tends to decrease as the gestational age also increases. During this period, the intracellular fluid (ICF) and extracellular fluid (ECF) also undergoes some changes and fluid tend to shift in an opposite direction. ECF tend to decrease while ICF increases as the foetus continues to grow. Once term age has been reached, diuresis and naturesis (the excretion of sodium through the urine) occurs which causes the TBW as well as ECF to decrease. This is the reason for the physiological weight loss that the neonate experiences during the next 3-5 days of life. Figure 1.3 shows the TBW composition and ECF at birth relative to the neonate's gestational age and body weight.

Figure 1.3 Summary of total body weight and ECF composition at birth in relation to the neonate's gestational age and body weight

(Adapted from: O'Brien and Walker, 2014)

Gestational age (weeks)	Body weight (g)	Total body water (%BW)	ECF volume (%BW)
23-27	500-1000	85—90%	60-70%
28-32	1000-2000	82-85%	50-60%
36-40	>2500	71-76	~40

The neonate will continue to develop and grow in the next few weeks after birth and the understanding of the physiology of fluid homeostasis is vital to make sure adequate amounts of fluids and electrolyte are given to the neonate. Being premature could make the process of fluid homeostasis more challenging due to the immaturity of their renal physiology and will even more predispose them to have problems in maintaining fluid balance. Therefore, regular monitoring and assessment is imperative to ensure proper management of fluid imbalances.

Gut adaptation

In utero, the neonatal gastrointestinal system is sterile, and non-functioning and all the digestive functions are fulfilled by the placenta. However, soon after birth, the neonate must assume this role and must be able to adjust to the intermittent enteral feeding to ensure adequate nutrition and glucose homeostasis is maintained. The neonates' gastrointestinal tract is still functionally immature even after birth this is due to diminished levels of gastric enzymes and gastric acid which aids in absorption of complex carbohydrates and fats. Neonates is also characterised to have decreased motility, gastric emptying as well as immature lower oesophageal sphincter hence, making them at risk of developing gastroesophageal reflux. The early initiation of feeding is important to ensure gut microbial colonisation happen as this will enhance the development of the neonate's immune system. If the gastrointestinal adaptation fails, this may predispose the neonate with problems in terms of tolerating feeds, inflammation of the gut and develop necrotising enterocolitis.

Immunological adaptation

The maternal immune system is adapted to safeguard both the mother and foetus. At birth the immune response remains deficient however a term neonate would have had in utero transfer of maternal IgG via the placenta. This gives the neonate passive acquired immunity, that will provide short term

immunity after birth. However, this supply will diminish by the 3rd month of life, and this makes them more vulnerable to infection.

Glossary

Acid mantle: A fine and slightly acidic film on the surface of the skin which acts as a barrier to bacteria, viruses, and other potential contaminants.

Anterior fontanelle: Also called the soft spot is at the junction of where the two frontal and two parietal bones meet.

Autonomic control: The autonomic nervous system is a component of the peripheral nervous system that regulates involuntary physiologic processes including heart rate, blood pressure, respiration, and digestion.

Bilirubin: Bile pigment produced by breakdown of haem from red blood cell metabolism which is measured from analysing blood serum.

Cardiac output: The amount of blood pumped out of the ventricles.

Catecholamines: Hormones produced by the adrenal glands and released in response to physical or emotional stress. The main types of catecholamines are dopamine, norepinephrine, and epinephrine.

Ductus arteriosus: Small blood vessel connecting the pulmonary artery to the aorta in order to bypass pulmonary circulation during foetal development.

Endogenous: Produced inside an organism or cell.

Erythema toxicum: a common and harmless rash seen in full-term newborns with an unknown cause.

Exogenous: Introduced from or produced outside the organism or system.

Foramen ovale: The foramen ovale is a hole or flap in the muscular tissue between the left and right atrium that allows blood to cross the atria and bypass pulmonary circulation during foetal development.

Haematocrit: The packed cell volume (PCV) expressed as a percentage. Newborns have a higher haematocrit than adults and older children.

Haemoglobin (Hb): A protein found in the red blood cells that carries oxygen in the body and gives blood its red colour.

Homeostasis: The state of balance within all physical systems needed for the body to function properly.

Hypoxia: Deficiency in the amount of oxygen reaching the tissues.

Keratin: Fibrous structural protein of epithelial cells in the stratum corneum of the skin.

Kinaesthetic stimulation: Stroking of the infant's body and passive movement of the limbs.

Metabolic rate: Refers to the amount of energy the body needs to maintain homeostasis.

Milia: also known as 'milk spots'. Small keratin- filled cysts which appear as small white papules on the face and scalp or on the roof of the mouth, and which resolve spontaneously within a few weeks.

Moro reflex: When the infant's head is extended suddenly, the arms will both firstly extend with the hands and fingers fanned out, and then flex towards the body.

Myelination: The process of generating myelin which is an insulating layer, or sheath that forms around nerves, including those in the brain and spinal cord.

Myocardium: The muscle of the heart.

Neonate: Period of life up to 28 days post-term.

Opsonic activity: The process of Opsonins to act as bridging molecules between the target, for example, the bacteria and the phagocyte, bringing them into contact, and activating the phagocytic receptor to induce engulfment of the target by the phagocyte.

Phagocytes: Phagocytes are a type of white blood cell that use phagocytosis to engulf bacteria, foreign particles, and dying cells to protect the body.

Phagocytic action: The engulfing of for example bacteria or foreign particles by phagocytes to protect the body.

Plantar or Babinski reflex: when the sole of the foot is firmly stroked, the big toe hyperextends and the rest of the toes fan out.

Posterior fontanelle: A membranous gap at the junction of the two parietal bones and the occipital bone.

Pulmonary vascular resistance: The resistance against blood flow from the four pulmonary veins of the lung to the left atrium.

Stratum corneum: The outermost layer of the skin's epidermis acting as a mechanical barrier.

Systemic vascular resistance: The amount of force exerted on circulating blood by the vascular system of the body.

Tachypnoeic: A rapid respiratory rate.

Thermoregulation: The capacity to maintain homeostasis (balance) between heat production and heat loss to sustain the body temperature within a normal range.

Ventral suspension: Measures the strength of the infant's trunk and neck when they are held prone, the infant should be able to momentarily hold their head in line with their body.

Vernix caseosa: A thick, greasy substance made of water, fatty acids, and proteins, which creates a moisturizing and protective barrier for a baby's skin.

EXTRA READING – Read more about transition to extra-uterine life.....

Morton SU, Brodsky D (2016). **Fetal Physiology and the Transition to Extrauterine Life.** *Clin Perinatol*. 43(3):395-407.

O'Brien, F, & Walker, I A (2014). **Fluid homeostasis in the neonate.** *Pediatric Anesthesia*. 24(1): 49-59.
