# Biological basis of child health, an introduction to understanding the embryology, composition and function of the blood

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## Abstract

This article is the most recent in the series of the Biological Basis to Child Health. It focuses on blood as the major fluid component of the body systems. The foetal origins of the main blood cells are considered. An introduction to the function of blood is provided, the homeostasis of the circulation and haemopoiesis (how blood cells are produced) are reviewed. This is essential in order to provide care for patients who have altered physiology which affects their circulatory system and blood profile. A range of conditions can affect the blood and circulatory system and some of these are considered. To provide holistic care it is important to have an understanding of this system in order to support the patient and family.

## Introduction

The aim of this article is to enable the reader to have a basic understanding of blood and how to apply this to clinical practice. By reading the article and completing the time out activities the reader will be able to:

* Identify the components of blood
* Outline the process of haemopoiesis (blood cell formation), including the embryological development of the blood system
* Discuss some of the implications of a change in blood values for patients
* Review some of the main conditions that can affect children and young people’s blood system

Blood is one of the body’s major fluid components, with an average size young person having adult circulatory volumes of 5-6L of blood (Rote and McCance, 2014). The volume of blood in the body changes from birth through childhood to adulthood, (average volumes are shown below in table 1). It is important to recognise that although the volume per kg in children is higher than that in adults – the total volume is much less. For example, blood loss of 30ml in an adult would be approximately 0.6% of their volume; in a 4kg neonate, this same loss of 30ml would represent 8% of their volume. This is why blood sampling in infants and small children is performed by extracting the most minimal volumes the laboratory can process.

## Time out 1

Discuss with your colleagues, placement teams or university teams what the local blood sampling policy/protocols are. Did this policy give guidance on sample volumes? If not, how do those involved make an assessment? Are there any other departments that they talk to for help or advice? *\*\*moved from later in the article\*\**

### Table 1: Average blood volume according to age

|  |  |
| --- | --- |
| Age | Volume in ml/kg |
| Preterm neonate | 90ml/kg (may increase to 150ml/kg in the first few days after birth) |
| Term neonate | 85ml/kg |
| Infants (<1yrs old) | 75-80ml/kg |
| Children | 70-75ml/kg |
| Young people and adults | 65-70ml/kg |

(Kline, 2014; Hazinski, 2013)

Blood has many roles in the body including transport of a variety of substances such as:

* gases (oxygen O2 and carbon dioxide CO2),
* nutrients,
* waste products,
* hormones,
* electrolytes,
* antibodies.

Blood is also involved in acid base balance, fluid balance, clotting and is a major part of the body’s defence mechanism (Blann and Ahmed, 2014). Blood is distributed around the body via a closed system of blood vessels in order to provide supplies to organs and interact with other systems and to fulfil its functions.

## Components of Blood

The composition of blood is summarised in table 2. Blood is 55% plasma (the liquid component) and 45% is made up of cellular components (Vickers 2015).

### Table 2 the composition of blood

|  |  |
| --- | --- |
| Plasma (55%) | Water  Electrolytes  Proteins  Nutrients  Gases  Waste products |
| Cellular (45%) | Platelets  White blood cells  Red blood cells |

**Plasma**

Plasma has a straw like colour and is made up mostly of water, and it carries antibodies and nutrients around the body to the tissues and removes waste products. Plasma also carries many of the essential proteins required for blood clotting: one of the other important proteins plasma carries is albumin. This protein is vital for regulating movement of water and solutes through capillaries to maintain the osmotic pressure between the vascular system and surrounding tissues, preventing tissue oedema (Rote and McCance, 2014).

**Blood Cells**

Blood contains many different cells, table 3 below details some of these, and their function. Red cells carry oxygen around the body via the protein Haemoglobin (Hb).

### Table 3: Blood cells and their function

|  |  |  |
| --- | --- | --- |
| BLOOD CELL/MEASUREMENT | FUNCTION | Lifespan |
| Foetal / neonatal erythrocytes | Transport of respiratory gases in a relatively hypoxic intrauterine environment, this is facilitated using adapted haemoglobin (see below) which has a high affinity to oxygen. | 60-90 days |
| Erythrocytes/Red Blood Cells (RBC) | Transport of respiratory gases (O2 and CO2) in the circulation. The transport mechanism is a large molecule of protein and iron in combination called haemoglobin.  A single molecule of haemoglobin contains 4 globin proteins bound to a molecule of Iron containing haem. Each haem can carry 1 oxygen molecule.  Red blood cells also have an action as a buffer maintaining the acid base balance in the circulation. | 80-120 days |
| Leucocytes/White Blood Cells (WBC) | They have a role within the body’s immune system responding to invasion by pathogens and fighting infections. (See article on Immune System) | Variable |
| Neutrophils (N) | A mechanism of defence. When a pathogen is identified by the body, these cells migrate to the site and release cytokines, which in turn amplifies the inflammatory response from other cell types. A neutrophil also has a role in the phagocytosis of pathogenic micro-organisms (Teng, Ji, Ji et al 2017). | 4 days, however once released to a site of infection/inflammation they undergo degradation within hours |
| Thrombocytes/Platelets (Plt) | Important role in coagulation | 8-11 days |

Stiner and Gallagher (2007); Mehta and Hoffbrand (2014) . Hoffbrand and Moss (2016)

## Embryologic development

The developing embryo requires a blood supply from around 3 weeks of development to allow for transport of nutrients and oxygen required for continued growth, and so from around 28 days the embryo has a very primitive circulatory system of capillaries, and a heart that pumps this blood (Webster and de Wreede, 2016). The system starts from primitive cells which are not blood cells or vessels being programmed to become haemangioblasts which will then in turn become either haemopoietic stem cells (HSC) or angioblasts. These early cells are found on the dorsal aorta of the embryo and then seed the liver, spleen and bone marrow (Hoffman and Moss, 2016). HSCs will develop into blood cells, and angioblasts will form blood vessels via a process called Angiogenesis where new blood vessels are made from existing vessels. Arteries, veins and capillaries will continue to grow as the embryo develops (Webster and de Wreede, 2016). (See Figure 1 below)

A close up of a map

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Figure 1: Angioblasts and blood vessel development (will need to be redrawn)

Although the embryo has its own blood supply, the circulatory system is different to that of an adult as the embryo depends on the mother and the placenta for most of the normal functions of blood. For example, oxygen is delivered via the umbilical vein from the placenta, as the lungs are non-functional (Roberts, 2015). The maternal and foetal blood systems are separate and are kept apart by the placental membrane. (See the CPD in this series for the development of the cardiovascular and respiratory systems).

The reliance on the mother’s blood supply to provide oxygen to the embryo means that fetal Haemoglobin (HbF) is a different structure to that described in table 3 above, meaning it is able to carry more oxygen per molecule (Yeo et al, 2013). From approximately 6 months the embryo will start to develop some adult haemoglobin (HbA), and a full term a baby will have about 70% HbF. As more HbA is produced these levels will change and by 6-12 months of age a baby will usually have adult levels of HbA around 92% (Kline, 2014). The level of red cells is higher in the fetus and neonate to carry this haemoglobin (as seen in table 4 below), with a shorter lifespan than an adult. Understanding this is important as the breakdown of red cells containing haemoglobin is the main cause of physiological jaundice (Wainwright and Rathwell, 2020). (See article on Biological Basis to Child Health – the Liver)

## Blood cell development

Blood cells develop via a process called haemopoiesis. In utero this occurs at different sites, with the yolk sac being the predominant site until 6 weeks post fertilisation when the foetal liver and spleen take over. In the last two months of pregnancy the liver and spleen still produce some cells, but the bone marrow has become the predominant site of blood cell production and remains the primary site throughout life (Howard and Hamilton, 2013). Bone marrow is a spongy tissue found in the middle of bones, in children haemopoiesis takes place in bones across the whole body. With age the composition of bone marrow changes and it’s replaced by fatty tissue, and the site of blood cell production becomes more concentrated on the central skeleton and proximal parts of long bones i.e. the pelvis, vertebrae and sternum (Gargani, 2015).

HSCs are multipotent, in that they are able to differentiate into many blood cells following two pathways – Myeloid or Lymphoid (figure 2 below is an illustration of this). HSCs will produce progenitor cells specific to one of the two pathways which will then continue to differentiate further into the designated cell at the end (Rankin and Sakamato, 2018). The pathway from HSC, to progenitor to precursor to mature cells is tightly regulated in many ways including by genes, transcription factors and growth factors (Howard and Hamilton, 2013). The regulators work at different timepoints during haemopoiesis for example Interleukin 1 (IL1) works early on to stimulate the production of other factors such as GCSF which then work on committed precursor cell lines (Mehta and Hoffbrand, 2014). Some of these factors are available as pharmaceutical products which can be given to support patients who may either lack the ability to produce their own, or who require extra support to produce cells post some treatments, for example:

* GCSF – Granulocyte Colony Stimulating Factor. A growth factor specific to promoting production of neutrophils.
* GMCSF – Granulocyte Macrophage Colony Stimulating Factor. A growth factor promoting production of many cells including neutrophils, eosinophils and macrophages.
* Erythropoeitin – A growth factor specifically promoting the production of red blood cells, mostly synthesized within the kidneys.

(Howard and Hamilton, 2013).

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Figure 2: Haematopoeisis (will need to be redrawn)

The haemopoietic process can be considered as a homeostatic response where there is a balance maintained in order to maintain the correct level of blood cells. Blood cells are produced to replace those lost, either when they reach the end of their natural lifespan (see table 2), or if they are lost due to external factors. Blood cells can be lost due to trauma or during surgery, platelets can be consumed during the haemocoagulation (blood clotting) process, and white cells are used up to fight infections. Toxins, disease, drugs or treatments can also cause loss of blood cells: For example, some anti malarials such as quinines, some antibiotics such as rifampicin, cytotoxic therapies, and diseases such as haemolytic anaemia can all have an impact.

## Blood tests and Investigations

There are many clinical situations when it is vital to know the cellular components in a patient’s blood, e.g. to provide a baseline value prior to treatment or surgery, or it may be in response to symptoms exhibited or explained by the patient or family (lethargy, unexplained bruising or frequent infections). Taking a small sample of blood for a Full Blood Count (FBC) provides a measurement which can be interpreted against the given reference range by the laboratory. Reference ranges are simply a guide, and change depending on age, sex and health status so should not be used alone but in conjunction with the patient’s clinical picture (Blann, 2013). Table 4 provides some normal values from an FBC which have been generalised for the newborn, for children over 1 year of age and for adolescents. Knowing the correct values for the patient is essential knowledge for the children’s nurse.

### Table 4 the full blood count.

|  |  |  |  |
| --- | --- | --- | --- |
| Blood cell/measurement | Normal values newborn infant | Normal values infant over one year old | Normal values for older children/adolescents |
| Leucocytes/White Blood Cells (WBC) | 10-26 x 10 x 109/L | 4.5-13.5 x109/L | 3.9-9.9 x10^9/L |
| Neutrophils (N) | 1.8-6.6 x 109/L | 1.5 – 8.0 x109/L | 1.5-5.9 x10^9/L |
| Thrombocytes/Platelets (Plt) | 140-400 x 109/L | 150-400 x109/L | 165-400 x10^9/L |
| Erythrocytes/Red Blood Cells(RBC) | 5-7 x1012/L | 4.0-5.2 x1012/L | 4-6 x10^12/L |
| Haemoglobin (Hb) | 135-195 g/L | 115 – 145 g/L | Female 115-155 g/L  Male 115-170 g/L |

Bain (2015) Generalised values for ages from newborn to adolescents.

In some instances, a patient may require further investigation if their FBC comes back with abnormal results. Taking a sample of bone marrow (See Figure 3) allows specialists to look at the haematopoietic environment to see if they can determine any irregularities (Mehta and Hoffbrand, 2014). This is important to allow for accurate diagnosis and treatment for example in patients suspected to have leukaemia.

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Figure 3 – an illustration of the site for Bone Marrow Aspiration

[www.cancerresearchuk.org.uk](http://www.cancerresearchuk.org.uk)

**The effects a low blood value in an FBC could have on a child**

As described above the body has a regulated system to produce blood cells, however if the body is unable maintain the rate of replacement required, the patient may suffer side effects of lowered levels. This may be short term, for instance sudden loss due to trauma or surgery, or it may be more prolonged such as with Bone Marrow Failure (BMF). This is a term that encompasses conditions where the bone marrow is unable to produce blood cells sufficiently, it includes a group of disorders which can be inherited or acquired and can be life threatening (Nagalla and Krishnan 2019) (see Table 5).

Treatment of BMF will depend on the cause but may include immunosuppressive therapy, cytotoxic drug therapy or a stem cell or bone marrow transplant. Sadly, treatments are not always curative and come with their own risks and side effects. Accompanying potential curative treatments, it is also essential that these patients receive supportive care which may include:

* Transfusion of the blood components
* Prophylaxis against infections (antifungal, antiviral and antibiotic medications are common)
* Aggressive treatment of infections
* High dose corticosteroids
* Haemopoietic growth stimulating agents (such as GCSF described above)

### Table 5: Summary of the effect on children of low blood cell counts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Medical term | Blood cells affected | Signs/symptoms | Caused by | Risks |
| Anaemia | Low level of haemoglobin | Tiredness  Breathlessness  Tachycardia  Dizziness  Distress  Paleness | The failure of RBC’s to deliver oxygen to the tissues. The physiologic adjustments to anaemia to compensate for the lack of oxygen delivery include increasing the cardiac output/ respiratory rate. Shunting blood to vital organs resulting in pale skin. | Tissue hypoxia to organs |
| Neutropenia | Low level of neutrophils | Frequent infections – often identified by a high temperature. | Inadequate bone marrow production or BMF (e.g. in aplastic anaemia or leukaemia)  A result of autoimmune disease.  May result from treatments such as radiation therapy or cytotoxic therapy.  Side effect of some common drugs (see above)  Infections exhausting the cellular supply. | Sepsis (see article on the Immune System)  See NICE (2012) Febrile Neutropenia guidance:  <https://www.nice.org.uk/guidance/cg151> |
| Thrombocytopenia | Low level of platelets | Bruising  Petechial rash  Bleeding (such as gums when brushing teeth, or nosebleeds) | Inadequate bone marrow production or BMF.  Destruction of cells because of idiopathic thrombocytopenic purpura, or toxins/drugs.  Increased use of cells (e.g during trauma) | Uncontrolled bleeding |
| Pancytopenia | Low level of all three above | All or some of the above | All or some of above |  |

Mehta and Hoffbrand (2014)

## Congenital conditions, screening and newborn screening:

## Time out activity 2:

Thinking about your own practice, have you nursed a child with one or more of the symptoms in Table 5? How was the cause identified and how was it managed? Discuss with a colleague and see if your nursing care differed.

Some of the conditions which affect the blood and the function of the circulatory system can be identified by screening, for example sickle cell anaemia, which is now the most common genetic disorder in the UK (De, Blackmore and Taylor 2019). A National screening programme has been in place since 2013, and it is also possible to test for thalassaemia: See this link for guidance: <https://www.gov.uk/topic/population-screening-programmes/sickle-cell-thalassaemia>. There has been some controversy over mass screening and some ethical issues have been raised, particularly with motive and with regard to levels of informed consent (Moody and Choudhry 2011) however the screening now seems to be well accepted and evidence suggests that screening works best when all parties work in partnership (James and Dormandy 2019). Screening can also be undertaken for Haemophilia where there is a known genetic risk, or a baby can be tested soon after birth. As it affects 1:5000 male infants it is one condition which could usefully be expanded to the general population through the National Newborn Screening Programme (Boardman, Hale and Young 2019).

## Common conditions affecting blood

### Anaemia

Paediatric anaemia is a generic term for low haemoglobin or haematocrit when the age adjusted reference range for the healthy infant or child is applied (Inoue and Arceci 2019). However simply using a cut off level of haemoglobin to determine anaemia is insufficient, a holistic overview needs to be considered taking into account the patient’s symptoms and any other health condition as these will guide the investigations and treatment (Blann, 2013). Anaemia is an umbrella term for a range of conditions caused by various underlying pathologic processes, it may be acute or chronic (Inoue and Arceci 2019). The underlying processes can be summarised as

* Increased haemolysis (blood cell destruction)
* Insufficient haemopoiesis
* Blood loss

The investigation of anaemia can be complex, and the treatment will depend on the cause, and some of the causes of Anaemia, as seen in Figure 4, and their treatment are now explored (See Table 6). As well as the side effects listed in Table 5, prolonged anaemia can cause tissue hypoxia (lack of oxygen) due to the inability to deliver adequate levels of oxygen via Haemoglobin in the red cells. Hypoxia, if not identified and treated, can lead to serious tissue or organ damage.

|  |  |  |
| --- | --- | --- |
| Nutritional deficiency (iron, vitamin B12, folate) | Reduced Bone Marrow function (i.e leukaemia, aplastic anaemia) | Ineffective red cell formation (i.e thalassemia, renal disease) |

|  |
| --- |
| Failure of production of red cells |

|  |
| --- |
| ANAEMIA |

|  |  |  |
| --- | --- | --- |
| Loss of red cells due to bleeding | Increased destruction of red cells (haemolytic anaemias) | Dilution of red cells by increased plasma volume |

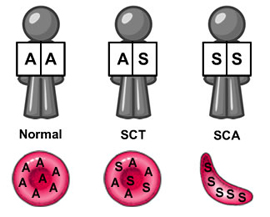
Figure 4: Some causes of Anaemia

### Table 6 Types of anaemia cause and treatment

|  |  |  |
| --- | --- | --- |
| Type | Cause | Treatment /management |
| Iron deficiency anaemia | Iron is required to make haemoglobin and Iron deficiency is one of the most common causes of anaemia across the world (Provan, 2018). Many food items contain Iron, which is absorbed by the duodenum and upper jejunum, therefore patients with some gastrointestinal disorders may suffer from malabsorption and a deficiency of iron (e.g. Crohns; Coeliac disease). Most iron, however, is obtained from the bodies recycling mechanism during the normal destruction of red blood cells (Rote and McCance, 2014). Major or chronic blood loss can cause a loss of Iron, therefore, any patients with conditions (e.g. Ulcerative Colitis) where they may bleed from their gastrointestinal (GI) tract, or females who suffer from particularly heavy bleeding during menstruation may be at risk of iron deficiency. | Iron supplements can be given orally or intravenously (parenterally) to patients who require replacement, but there are some dangers with a high level of Iron in the body (Iron overload) as it can be toxic to organs and tissues, therefore patients may have their Iron levels monitored or receive treatments to reduce their Iron loads such as chelation therapy (Hattan et al, 2017). |
| Vitamin B12 anaemia | Vitamin B12 is found in mostly animal based products and works in the body alongside folate as essential agents in DNA synthesis. B12 is absorbed in the gut and so similar to Iron, patients with malabsorption may develop B12 deficiency. A lack of B12 and or folate can lead to many health problems notably neurological symptoms but can also be a cause of anaemia due to the lack of DNA synthesis in the formation of red blood cells (Hattan et al, 2017). | B12 and folic acid can both be supplemented orally for those patients with reduced dietary intake of these elements. However, for those with malabsorption or with a condition known as Pernicious anaemia an autoimmune disorder affecting the body’s ability to bind and absorb B12 they may require parenteral supplementation of B12 (Provan, 2018). |
| Renal disease as a cause of anaemia | Anaemia is common in children and young people with kidney disease, because healthy kidneys produce erythropoietin (EPO). Damaged kidneys produce insufficient EPO and as a result the bone marrow is not stimulated to produce RBC’s. Anaemia can also occur when the child is on haemodialysis because of blood loss or haemolysis (Kidney Care UK see links). | EPO injections  Red cell transfusion |
| Aplastic anaemia | Autoimmune conditions  Toxins such as benzene, quinine, toxic /high dose of some drugs, antiepileptics and antibiotics  Radiation  Viral infection e.g. hepatitis, parvovirus | Antithymocyte globulin  Immune suppressants such as Ciclosporin  Stem cell transplant  Blood product transfusions |

### Sickle cell

Sickle cell is an inherited type of haemoglobinopathy where a gene causes the haemoglobin to be formed differently so patients have both HbA and also HbS which causes the red cells to be sickle shaped (figure 5 below). In the UK this is relatively common affecting around 1 in 2000 live births (National Institute for Health and Care Excellence, 2016). Inheritance of one copy of the gene leads to ‘sickle trait’ where the patient is unlikely to suffer symptoms, whereas inheritance of two copies (one from each parent) will lead to sickle cell disease (Howard and Hamilton, 2013). (See article on Cell and Genetics)



*Figure 4: I*nheritance of the sickle cell gene

1. HbA

S – HbS

SCT – Sickle cell trait

SCA – Sickle cell

(From: [www.coloradosicklecellcenter.org](http://www.coloradosicklecellcenter.org)) (redraw please)

Figure 5: Sickle cell shaped cells

As the sickle shaped red cells flow through blood vessel’s they can get stuck and cause obstruction restricting blood flow, leading to potentially significant and life-threatening complications such as:

* Pain
* Tissue infarction/necrosis
* Stroke
* Splenic sequestration (where sickled cells become trapped in the spleen, resulting in enlargement, damage, and the spleen not functioning correctly)
* Priapism (persistent and painful erections)
* Dactilytis (severe inflammation of the finger and toe joints)

#### Treatment for sickle cell:

Currently the only curative option for a child with sickle cell is a stem cell transplant from a matched sibling donor (NICE, 2016) so for many, their care is focused on supportive care to help them live with the condition and prevention of complications such as infections and painful crises. Caring for these patients is complex and requires an multidisciplinary team approach offering advice and support for ongoing management. It is important to identify and treat any acute episodes – sometimes referred to as ‘sickle cell crisis’ quickly to prevent the patient deteriorating (NICE, 2016). Care includes health promotion to try and help prevent crises occurring and minimize the risk of infections, and psychosocial support for living with a chronic condition.

### Blood Clotting

### Time out activity 3:

Visit <https://cks.nice.org.uk/sickle-cell-disease> to find information on the complications associated with sickle cell. Then plan how you would manage a young person who was in sickle crisis. What information would you prepare for a child’s school?

The bodies process of clotting to prevent blood loss and allow wound healing is complex, and plasma plays a major role as it contains many of the proteins required. Some of the proteins involved are referred to as ‘factors’ and most have numbers assigned to them represented by roman numerals, for example:

Factor 8 – Factor VIII

Factor 12 – Factor XII

When discussing blood clotting both ends of the spectrum can be harmful – patients whose blood is unable to clot appropriately are at risk of bleeding, but there are also situations where blood clotting can be harmful. There are many disorders, drugs and diseases which can affect a person’s ability to form clots putting them at risk of either bleeding or blood clots. One of the most commonly known drugs to affect clotting is Warfarin – in children and young people this can be post cardiac surgery if they have an artificial valve, or for some cardiac condition may be prescribed warfarin to help prevent clots blocking their circulatory system. If a patient is receiving warfarin they should be monitored closely to ensure the dose is providing adequate anticoagulation without putting the patient at risk of bleeding, one of the ways of doing this is through a blood test measuring their INR (Akunwunmi, 2011).

Blood clots can be the cause of major tissue or organ damage, and even death if not identified and treated appropriately, as they can obstruct vessels and therefore prevent oxygen flow causing tissue hypoxia. Whilst the risk is higher in people over the age of 16 years there are still times when younger people may be at risk. Patients who have difficulty mobilising or whose mobility may be affected by a period of treatment or hospitalisation should be assessed for their risk of venous thromboembolism (VTE). NICE (NICE, 2019) have produced a thromboprophylaxis guideline (NG89) guideline: <https://www.nice.org.uk/guidance/ng89/chapter/Recommendations>. This guidance covers many situations and the two main types of prevention – mechanical with the use of stockings, and pharmaceutical with the use of anticoagulants.

### Haemophilia

## Time out activity 4:

Consider patients who have limited mobility and reflect on whether they were at risk from developing VTE: did they have a care plan for prevention? If so, what strategies did this include, if not draw up a list of what might have been included to prevent risk. Find out if your area of clinical practice has a policy on this.

Haemophilia is a lifelong condition affecting the clotting mechanism, it can be an inherited condition or the result of a mutated gene. Haemophilia is an X linked recessive disorder where females can be carriers but very rarely suffer from the disorder, whereas males are affected. An example of inheritance can be seen in Figure 6 below:

A picture containing clock

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Figure 6: Inheritance in Haemophilia

The two types of Haemophilia affect two different factors;

* Haemophilia A – Reduced level of Factor VIII, affects 1:5000 males in the UK
* Haemophilia B – Reduced level of Factor IX, affects 1:30000 males in the UK

(The Haemophilia Society, 2017).

Care for patients with Haemophilia should be provided by a full multi-disciplinary team who will offer the treatment and support they require including physiotherapy and psycho-social support for living with a chronic condition (World Federation of Haemophilia, 2012).

Haemophilia ranges from mild to severe depending on the level of factor in their plasma which influences the management. Treatment for Haemophilia involves replacing the missing clotting factor, in the UK recombinant factors are used (meaning they don’t use human cells to produce these). These are given intravenously and children, young people or their parent/carers often learn to administer these themselves at home. Replacement may be given differently depending on the situation:

* Prophylactically (more common for those with severe haemophilia); factor replacement is given regularly on an ongoing basis to try and prevent bleeding. Extra replacement is still required in the event of an injury, trauma or surgery.
* As treatment to prevent bleeding for a procedure or surgery where there is a risk of blood loss.
* To treat bleeding following an injury, trauma, surgery or spontaneous bleed.

### Blood Cancer

There are many types of blood cancer, however Leukaemia and Lymphoma are the two most common occurring in children and young people. More information on blood cancers can be found at [www.bloodcancer.org.uk](http://www.bloodcancer.org.uk)

#### Leukaemia

Every year in the United Kingdom (UK) approximately 550 children under the age of 14 years will be diagnosed with a form of Leukaemia, the most common cancer in this age range. For 1-24 year olds it is a less common cancer but there are still approximately 200 cases a year (Cancer Research UK, 2015-17).

Leukaemia is an overproduction white cells early in their development during the haemopoiesis process, due to their immaturity these cells are unable to function in the body. The overproduction in the bone marrow, means there is less space for healthy cells, which can explain why patients present with signs and symptoms of anaemia, frequent infections and bruising. In children and young people the two most common types of Leukaemia are:

* Acute Lymphoblastic Leukaemia (ALL) affecting cells in the Lymphoid line
* Acute Myeloid Leukaemia (AML) affecting cells in the Myeloid line

Leukaemia treatment varies depending on many factors including; the type of Leukaemia, age, and gender, more information on childhood cancer and treatments can be found at [www.cclg.org.uk](http://www.cclg.org.uk). One group of drugs that are used during treatment for Leukaemia and Lymphoma are cytotoxic drugs.

**Effect of cytotoxic drugs on the bone marrow**

Cytotoxic drugs are commonly used in cancer care, but also in a number of other conditions, for example Juvenile Idiopathic Arthritis (JIA), Lupus (see Biological Basis to Child Health: The Immune System for further insight into these conditions). These drugs are toxic to cells but are unable to distinguish between unhealthy and healthy cells, leading to many side effects. Bone marrow suppression is relatively common as healthy blood cells are killed and the body cannot keep up with the production of new cells. The extent of suppression will depend on the drug, dose and sometimes route which is important to remember when giving advice to patients and families (Dougherty et al, 2019).

Patients who receive cytotoxic therapy will have blood tests to check their blood cell levels and may require supportive care to help with the side effects of altered levels. Supportive therapy may include prophylactic drugs to help prevent infections whilst their immune system is impaired (such as antibiotics or antifungals). It may include the use of GCSF (mentioned earlier) which can decrease the time the patient is neutropenic and at a higher risk of infection (Dougherty et al, 2019). It is likely that transfusion of blood components will also be used either:

* Platelets to increase platelet levels;
* Red cells to increase Haemoglobin levels.

**Blood component transfusions and safety**

Reflecting on what has been discussed in this article a patient may require a blood component transfusion for many reasons:

* as the result of blood loss due to surgery or trauma,
* to try and prevent further blood loss
* as a result of decreased blood levels due to treatment such as cytotoxic therapy for cancer care.

It is often assumed that blood transfusion only refers to red cells, however there are other types of blood components, which can be transfused:

* Platelets
* Plasma products to support clotting (Fresh Frozen Plasma, Cryoprecipitate, Octaplas)
* Granulocytes

## Blood Groups

Blood cells have antigens and proteins on their surface which permits identification of a person’s blood group. There are four phenotypes (or manifestations) of these which are referred to as the four blood groups: A, B, AB, and O. Table 7 shows the blood groups and their corresponding antigens and antibodies.

### Table 7: Blood groups, antigens and antibodies

|  |  |  |  |
| --- | --- | --- | --- |
| Blood Group | Antigens | Antibodies | Blood groups can receive transfusion of red cells from |
| A | A | B | A, O |
| B | B | A | B, O |
| AB | A, B | None | A, B, AB, O |
| O | None | A, B | O |

#### Safety

It is important for patients to receive appropriately matched blood components to prevent the body from mounting an immune response to what the body will think is a foreign protein. Safety of transfusions is paramount, including minimising the risk of transmitting infections. This is done in many ways including screening of donor’s and treating of components after donation. More information on blood groups and transfusion practice can be found at [www.nhsbt.org.uk](http://www.nhsbt.org.uk)

To read more information on the history of contaminated blood products used in the treatment of Haemophilia visit <http://haemophilia.org.uk/support/day-day-living/patient-support/contaminated-blood/>

All healthcare professionals are responsible for their own practice (NMC 2018) and must ensure that they follow local policies for the checking of transfusions and the care of patients prior to, during and post transfusion. There is guidance for when to transfuse and which components to use, along with suggested volumes available to support healthcare staff:

* The British Society for Haematology (BSH) guidelines on transfusion for foetuses, neonates and older children (New et al, 2016)
* The administration of blood components: a British Society for Haematology Guideline (2017) Robinson, Harris, Atkinson et al

## Conclusion

## Time out activity 5:

Visit <https://onlinelibrary.wiley.com/doi/full/10.1111/tme.12481> which is the British Society for Haematology Guideline for the Administration of blood components (Robinson, 2017) and find out what signs and symptoms a patient may exhibit if they are having a transfusion reaction. Then familiarise yourself with your local policy or national guidance for observing and monitoring patients who are receiving a blood component transfusion. After reading either the local or national guidance do you know what steps to follow if you suspected a transfusion reaction?

This article has considered the major components of blood and reviewed the origin of these cells. Provided a basic understanding of the role of the different cells and how an altered level of these may affect the child. The CPD has included a consideration of safe of transfusion practice. This article has also summarised some blood conditions that can affect children and young people and offered further resources for those who require additional information.

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