

Red and white blood cells have a range of functions and a full blood count is the one of the most frequently requested routine tests to aid diagnosis

**ROUTINE BLOOD TESTS: PART 4 OF 4**

# Functions and diseases of red and white blood cells

## In this article...

- › The functions of blood cells
- › Signs, symptoms and consequences of blood cell disease
- › What full blood counts tell us

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Red and white blood cells have two main functions: the carriage of oxygen; and defence against microbial attack.

The full blood count is one of the most frequently requested routine blood tests; it provides key indices such as haemoglobin and the number of white cell subsets, and provides information to aid diagnosis of a range of conditions, including anaemia, infection, leukaemia, myeloma and lymphoma.

**R**ed and white blood cells have two main functions: the carriage of oxygen and defence from microbial attack respectively. Together, red cells (erythrocytes) and white cells (leukocytes) are part of the full blood count (FBC), one of the most frequently requested haematology tests.

## Red blood cells

A number of red cell blood tests are used in the diagnosis, treatment and management of anaemia, polycythaemia and erythrocytosis. These are:

- › Red cell count (RBC): haemoglobin is a protein found in the red cells that carries oxygen to the tissues for cellular respiration. The red cell count reveals how many red cells the blood contains; this can vary between the sexes. Lower

levels are present in menstruating women; in post-menopausal women, levels are still lower than in age-matched men, who produce testosterone, which stimulates red cell production. See Table 1 for reference values;

- › Haematocrit (Hct): this index shows the proportion of the blood made up of red cells. It is expressed as a percentage (for example 43%) or decimal (for example 0.43);
- › Mean cell volume (MCV): this is the size of the average red cell, and is important in many cases in defining the cause of many types of anaemia.

## Anaemia

Patients who have difficulty fulfilling basic physiological and lifestyle demands due to fatigue may have anaemia (insufficient red blood cells or haemoglobin) (Box 1). More serious signs of the condition include jaundice, hepatomegaly, angina and cardiac failure, although these may arise from other conditions.

Anaemia can be classified in a number of ways; the most common are described in Box 2. Red cells are produced in the bone marrow, so infiltration of the bone marrow by cancer or other cells will inevitably lead to low numbers and therefore anaemia. A poor diet, low in iron, vitamin B12 or folate, will lead to anaemia as these are essential for the production of red cells.

Problems with organs may also contribute to anaemia:

- › Liver: this organ stores iron and vitamins, so liver disease may lead to anaemia (Blann, 2014);
- › Kidneys: the kidneys produce

## 5 key points

**1** Red blood cells' main function is transport oxygen to body cells using haemoglobin

**2** Lack of red blood cells leads to anaemia, which can be acute or chronic and is associated with a number of diseases

**3** White blood cells defend the body from infection with bacteria, viruses or parasites

**4** Different types of white cells perform different functions

**5** Raised levels of white cells can be a sign of infection or a malignant condition such as leukaemia



Blood cells in leukaemia: red blood cells with B lymphocyte white blood cells

erythropoietin to stimulate the bone marrow to produce red cells, so anaemia may be present in chronic renal failure (Blann, 2014b);

- » Intestines: intestinal diseases in which iron and vitamins are unable to cross the gut wall (malabsorption) can lead to anaemia – these include gastric atrophy, inflammatory bowel diseases such as Crohn’s disease or diverticulitis; surgery for gastric cancer or any cancer that requires excision of a section of bowel can also lead to anaemia.

Haemolytic anaemia is the bursting, destruction or inappropriate break-up of red cells: causes include high fever and infections such as malaria (Blann and Ahmed, 2014). The condition can also occur when antibodies erroneously bind to red cells – this is known as autoimmune haemolytic anaemia.

Red cells may be lost by an acute or chronic bleed, such as heavy menstrual periods. Hidden or prolonged internal bleeding can lead to chronic blood loss and therefore anaemia.

The most common congenital haemoglobinopathies are sickle cell disease and thalassaemia; these genetic conditions are characterised by changes in haemoglobin that reduce its ability to transport oxygen.

The MCV can be used to classify anaemia. If the cells are larger than normal (macrocytes), the haemoglobin is low and the patient is symptomatic, macrocytic anaemia is present, for example in vitamin B12 deficiency.

## BOX 1. SIGNS AND SYMPTOMS OF ANAEMIA

### Signs

- Pallor (especially of the conjunctiva)
- Tachycardia (pulse rate over 100 beats per minute)
- Glossitis (swollen and painful tongue)
- Koilonychia (spoon nails)

### Symptoms

- Decreased work and/or exercise capacity
- Fatigue, lethargy, “Tired all the time”
- Weakness, dizziness, palpitations
- Shortness of breath (especially on exertion)

Some haemoglobinopathies and iron deficient states cause cells to be small (microcytes), leading to microcytic anaemia.

Normocytic anaemia is associated with normal-sized cells (normocytes) but a lower overall haemoglobin level. A prime reason for a normocytic anaemia is the sudden loss of a large number of healthy red cells, perhaps by an accident or bleeding gastrointestinal cancer.

### Treatment of anaemia

Anaemia and its symptoms cannot be treated without a full understanding of the aetiology of the condition.

For example, dietary iron supplements

## BOX 2. CLASSIFICATION OF ANAEMIA

### Depressed red cell production from the bone marrow

- Due to infiltrating cancer
- Due to drugs, such as the chemotherapy used to treat cancer

### Diet deficiency

- Iron
- Vitamins B12 and folate

### Loss of mature red cells

- Drugs
- Fevers, infections
- Autoimmunity
- Acute or chronic bleeding

### Haemoglobinopathy

- Sickle cell disease
- Thalassaemia

will not help anaemia caused by malabsorption, but intravenous iron may increase haemoglobin levels and so address symptoms such as fatigue and lethargy. Patients with vitamin B12 deficiency should receive regular injections of this vitamin.

Anaemia can be caused by certain drugs, such as methyl dopa, some antibiotics and hydrochlorothiazide. This should resolve when the patient stops taking the drug, ideally as soon as possible – if necessary substituting it with an alternative drug. In some cases, such as in cancer chemotherapy, cessation or substitution may not be possible, so the anaemia and its symptoms are treated by blood transfusion.

Autoimmune haemolytic anaemia may be treatable with immunosuppression.

However, some forms of anaemia, such as those caused by thalassaemia and sickle cell disease, are effectively incurable (except by bone marrow transplantation) and symptoms are managed by specialist teams.

### Increased levels of red cells

There are two types of disease where the concentration of red cells is higher than normal: both are characterised by raised haemoglobin and Hct.

- » Polycythaemia: this may arise from a rare malignancy of the bone marrow;
- » Erythrocytosis: this is often a result of the bone marrow’s response to reduced circulating levels of oxygen, often caused by heavy smoking.

**TABLE 1. SUMMARY OF REFERENCE RANGES**

| Analyte                        | Reference range | Units               |
|--------------------------------|-----------------|---------------------|
| White blood cells              | 4.0–10.0        | 10 <sup>9</sup> /L  |
| Neutrophils                    | 2.0–7.0         | 10 <sup>9</sup> /L  |
| Lymphocytes                    | 1.0–3.0         | 10 <sup>9</sup> /L  |
| Monocytes                      | 0.2–1.0         | 10 <sup>9</sup> /L  |
| Eosinophils                    | 0.02–0.5        | 10 <sup>9</sup> /L  |
| Basophils                      | 0.02–1.0        | 10 <sup>9</sup> /L  |
| Erythrocyte sedimentation rate | <10             | mm/hour             |
| Haemoglobin (female)           | 118–148         | g/L                 |
| Haemoglobin (male)             | 133–167         | g/L                 |
| Red blood cell count (female)  | 3.9–5.0         | 10 <sup>12</sup> /L |
| Red blood cell count (male)    | 4.3–5.7         | 10 <sup>12</sup> /L |
| Haematocrit (female)           | 0.33–0.47       | L/L                 |
| Haematocrit (male)             | 0.35–0.53       | L/L                 |

Blann and Ahmed (2014)

### Note

- Ranges can change over time
- Consult your organisation’s agreed reference ranges

TABLE 2. DIAGNOSIS OF LEUKAEMIA

|             | Patient factor                                       | Laboratory factor                   |
|-------------|--|-------------------------------------|
| Red cells   | Symptoms of anaemia, for example tiredness, lethargy | Low haemoglobin, low red cell count |
| White cells | Infections   | High white cell count               |
| Platelets   | Bruising, bleeding                                   | Low platelet count                  |

### White blood cells

White cells (leucocytes) defend the body from viruses, bacteria and parasites; at such times, cell numbers will be raised. High concentrations are also found in rheumatoid arthritis and cancer, and after surgery. There are five types of white cells:

- » Neutrophils: making up to 70% of the white cell count, these recognise, attack and destroy bacteria;
- » Lymphocytes: the second most common white blood cell (approximately 20-25% of the white cell count), are divided into two types – B lymphocytes make antibodies, while T lymphocytes destroy cells infected with viruses;
- » Monocytes: these have several functions, including bacteria removal, and are active in inflammation and in repair of damaged tissues;
- » Eosinophils and basophils: these cells have roles in hypersensitivity and allergy.

White cells defend the body from most microbial pathogens through two processes:

- » Inflammation: this develops rapidly and is associated with high neutrophil numbers, but can lead to the body attacking its own tissues, leading to chronic inflammation;
- » An immune response, where lymphocytes are active: this develops slowly, over days or weeks, and is focused on the invading pathogen.

Inflammatory and immune responses often cooperate. For example, lymphocytes make antibodies that bind to bacteria and yeast pathogens, making them more palatable to the neutrophils and monocytes, which aids their removal. Infections occur when either or both these processes become impaired. Antibodies can also cause autoimmune diseases such as rheumatoid arthritis and thyroiditis.

### Low white cell count: leucopenia

Virtually all cases of leucopenia are associated with the use of cytotoxic drugs, which can destroy white cells, increasing patients' risk of infections. In these cases, prophylactic antibiotics may be needed, and stringent infection prevention measures are essential.

### High white cell count: leucocytosis

Leucocytosis can be a normal response to infections and surgery. Pathological states associated with it include inflammatory and autoimmune diseases such as rheumatoid arthritis. The most serious cases of leucocytosis occur in leukaemia.

### Leukaemia and other malignancies

The high white cell count in leukaemia is due to changes to how cells develop in the bone marrow.

Leukaemic cells stop developing prematurely, entering the blood in an immature state and increased numbers. If this process develops slowly, perhaps over several years, it is said to be chronic; rapid development, for example, over months, is said to be acute.

Acute leukaemias, frequently characterised by high numbers of immature cells, are often much more aggressive than the chronic condition, and survival (unless treated) can be as short as months.

If the major affected cells in the leukaemia are of the neutrophil lineage, it is described as myeloid; when lymphocytes are predominantly affected, it is known as lymphocytic leukaemia. A leukaemia dominated by blast cells is called lymphoblastic.

## BOX 1. ONLINE RESOURCES

### NHS Choices: Anaemia

[tinyurl.com/Choices-Anaemia](http://tinyurl.com/Choices-Anaemia)  
General information on anaemia

### Haemoglobin Registry

[tinyurl.com/HReg-Haemoglobinopathies](http://tinyurl.com/HReg-Haemoglobinopathies)  
General information on haemoglobinopathies, such as sickle cell disease

### Cancer Research UK

[www.cancerresearchuk.org/leukaemia](http://www.cancerresearchuk.org/leukaemia)  
General information on leukaemia

### UK Lymphoma Portal

[www.lymphoma.org.uk](http://www.lymphoma.org.uk)  
Information and support for people with leukaemia

### Myeloma UK

[www.myeloma.org.uk](http://www.myeloma.org.uk)  
Information and support for people with myeloma

As leukaemia arises in the bone marrow, the production of other cells is reduced. Thus anaemia and low levels of platelets (thrombocytopenia, with a risk of bleeding and bruising) are invariably consequences of leukaemia (Table 2).

In advanced disease, leukaemia may invade the lymph nodes, liver and spleen, making them swollen (lymphadenopathy, hepatomegaly and splenomegaly respectively). Treatments are aimed at reducing the tumour burden, and are generally cytotoxic drugs. More severe leukaemias need transplantation of bone marrow stem cells from a donor or patients themselves.

### Differential diagnoses of leukaemia

White cell counts may also be raised in severe infections. The most dangerous and life-threatening is septicaemia (blood poisoning), where the blood itself is infected with bacteria. Patients with septicaemia are usually cared for in intensive care units on high doses of intravenous antibiotics.

### Other lymphoid cancers

Lymphoma involves malignant lymphocytes taking over lymph nodes: principle examples are Hodgkin and non-Hodgkin lymphomas. Lymphomas often progress to affect more lymph nodes; the spleen, liver and bone marrow (therefore possibly leading to anaemia) can become involved.

Important differential diagnoses of lymphoma are self-limiting cases of lymphadenopathy, which may occur in tonsillitis or a nearby infected wound.

Myeloma is a tumour of B lymphocytes, which normally make antibodies to attack pathogens; it is found in the bone marrow. Myeloma cells may make large amounts of an incorrect type of antibody, causing a high erythrocyte sedimentation rate. **NT**

### References

- Blann AD (2014a) Routine blood tests 2: what is the purpose of liver function tests? *Nursing Times*; 110: 6, 17-19.  
Blann A (2014b) Routine blood tests 1: why do we test for urea and electrolytes? *Nursing Times*; 110: 5, 19-21.  
Blann AD, Ahmed N (2014) *Blood Science: Principles and Pathology*. Chichester: Wiley Blackwell.

### Further reading

- Blann AD (2013) *Routine Blood Tests Explained*. Keswick: M&K Update.

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