Thiamine functions and structure

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Overview

About five million individuals in America suffer from heart failure, with an additional 550, 000 new diagnosis made each year. The life expectancy of people living with this condition has gradually increased due to the availability of useful and established treatment opportunities. The percentage of mortality in the States continues to be high even though things like “ omega-3 fatty acids, β-blockers and angiotensin-converting enzyme inhibitors” have bettered the circumstances of these people. Vitamin B1, or better known as Thiamine, plays an integral part in the treatment of heart failure and is regarded as a clinical significant factor in the well-being of the heart. It also enhances the prognosis and general health of the patients. Heart failure can be caused by trace mineral deficiencies such as thiamine deficiency and therefore thiamine supplementation can be of great assistance in the treatment of this condition (DiNicolantonio, 2013).

Vitamin B1 was the first out of eight B-vitamins to be identified, and ever since the discovery it was given several names, with Thiamine being used the most (DiNicolantonio, 2013). It is a water-soluble vitamin, meaning that it cannot be stored by the body and is obtained through food sources such as beef, nuts, milk and whole-grain foods (Ehrlich, 2011).

Studies around the causes of beriberi by a Dutch physician and pathologist, Christiaan Eijkman, led to the discovery of Vitamin B1 in 1897. Beriberi is a widespread and sometimes deadly disease associated with heart failure. By

1926, vitamin B1 was separated into its pure form and given the name thiamine (Vitamins in Motion, 2013).

More about Thiamine (Vitamin B1)

Absorption

The absorption of thiamine takes place in the jejunum with the aid of two processes. An active transport system in the small intestines is responsible for the absorption of thiamine once the levels drop below normal. Once the levels are too high, an inactive mucosal process occurs. The small intestines are capable of absorbing about 5 mg of thiamine. Tissues can reserve up to 30 mg of thiamine. The storing of thiamine is very important as the body cannot produce its own. The liver, heart, kidneys and brain are some of the organs which stores thiamine, with most of it found in the skeletal muscles (Nguyen-Khoa, 2013).

Structure

The structure of thiamine consists of a pyrimidine ring with the radical $-NH_2$ and a thiazole ring. These two rings are connected with one another by means of a methylene bridge (Mouton, 2014: 4). Thiamine found within living tissues have a diphosphate ester structure known as thiamine pyrophosphate (TPP). TPP serves as a coenzyme that binds tightly to the apoenzyme (Ball, 1998: 268).

Functions

There are four structures of thiamine that are present in all human beings. They include: thiamine monophosphate, thiamine diphosphate, thiamine

triphosphate and unphosphorylated thiamine (DiNicolantonio, 2013). Thiamine is very important in the body as it operates as a coenzyme that converts carbohydrates into glucose, which in turn is used to provide energy. It also assists in the metabolism of fats and protein, and is essential for healthy eyes, hair, skin and liver (Ehrlich, 2011). Thiamine monophosphate can actively move into the central nervous system and nerves where it is capable of preserving the sodium and potassium concentrations. Sodium and potassium is required for nerve impulse conduction, and therefore it is vital for these levels to be maintained (DiNicolantonio, 2013).

Thiamine is occasionally referred to as an “ anti-stress” vitamin because of its ability to support the immune system and improve the ability of a person’s body to endure traumatic situations. People who suffer from vitamin B1 deficiency are deprived from these normal functions that the vitamin provides, and therefore they develop conditions such as dry and wet beriberi (Ehrlich, 2011).

Thiamine deficiency

Diets that are low or deficient in vitamin B1 can lead to Thiamine deficiency (beriberi) as well as constant (long-lasting) diarrhoea. Diarrhoea actually weakens the body’s capacity to take up vitamin B1 (Nguyen-Khoa, 2013).

There are two forms of beriberi namely dry and wet beriberi. Dry beriberi involves the deficiency of thiamine that affects the nervous system while wet beriberi comprises of cardiovascular complications (DiNicolantonio, 2013).

A potential reason as to why wet beriberi arises, because of thiamine deficiency, is based on the fact that ATP is depleted from the cardiac muscle cells. The decrease in ATP then leads to the weakening of the cardiac muscle, which in the long run causes heart failure. There will be an increase in the concentration of adenosine monophosphate in the cardiac muscle cells as a result of the inability of the cells to produce ATP. The adenosine monophosphate is then converted to adenosine, which then starts to accumulate in the cells and then finally leading to its release into the plasma by the aid of a nucleoside transporter. The manifestation of systemic vasodilatation and headaches is due to adenosine in the plasma (DiNicolantonio, 2013).

Features of wet beriberi

As a result of thiamine deficiency and specifically wet beriberi, patients will represent with cardiovascular symptoms. It will include swelling of cells and tissues because of excessive water build-up, lactic acidosis, fluid retention, systemic dilation of blood vessels and a high-or-low-output cardiac failure. In addition to the mentioned symptoms other signs such as increased levels of catecholamine and low diastolic pressure may be evident of wet beriberi (DiNicolantonio, 2013).

Shoshin beriberi is known as an acute version of wet beriberi and these patients may show signs of an acute cardiovascular collapse as well as metabolic acidosis. If left untreated (i. e. if thiamine is not injected immediately) it may lead to death (DiNicolantonio, 2013).

Epidemiology

The prevalence of beriberi may be associated with the fact that milled rice was consumed by some populations all over the world. The external part of the rice that contained thiamine was removed by the milling process. According to the World Health Organization (WHO) there is a significant improvement in Indonesia where this process of removing the outer crust was and still is implemented. Back in the day beriberi was widespread and a health concern, but currently the occurrence is less common than what it was. Beriberi has a tendency to affect infants between 1 and 4 months as well as adults (Knott, 2010).

Measurement of thiamine

Direct detection is one of the methods used to measure the concentration of thiamine in the system. It can also be measured by determining enzyme activity of those enzymes that require thiamine for optimal functioning. There is more than one method that can be used to measure thiamine levels. Urinary and serum thiamine level estimation, red blood cell transketolase and TPP (thiamine pyrophosphate) analysis is some of the methods available. It is important to measure thiamine stores and amongst all current tests available there is still no consistent test usable for this purpose. Thiamine will move to the liver and enter the red blood cells soon after it has been absorbed in the jejunum. The amount of thiamine in blood ranges from 60-120 µg/L. From this total volume (concentration) about 80% will be found within the red blood cells. Because thiamine has a limited duration in the body, it is not reliable to measure serum levels or use it as a marker of thiamine stores (DiNicolantonio, 2013).

Excretion of thiamine in the distal nephron is also directly associated with the amount of thiamine in blood. However, the concentration will be dependent on recent intake only, and therefore isn’t indicative of thiamine sites (for storage) in the body. 24-hour urine samples are required for evaluating thiamine levels, and this may be tiresome for the individual (DiNicolantonio, 2013).

So far the most effective and reliable test available is the “ erythrocyte transketolase activity assay” that evaluates transketolase activity. In an artificial manner thiamine is added to the red blood cells followed by the measurement of transketolase activity. Transketolase cannot function without thiamine diphospahte. Because it requires the coenzyme for optimal functioning the action of the transketolase enzyme proves that there is indeed thiamine diphosphate in the cells. Since red blood cells are one of the first cell types to be affected by thiamine deficiency, it can be considered an accurate test procedure (DiNicolantonio, 2013).

Treatment

Thiamine supplements are essential to those individuals that suffer from dry or wet beriberi. It is recommended that 1. 1-1. 2 mg of thiamine supplements are administered on a daily basis. When it comes to wet beriberi the patient may require 100 mg/day intravenous thiamine supplementation for more than a few days. It has also been suggested that individuals whose chances are higher of developing the deficiency should receive 100 mg of supplements three times daily. In instances where there is a confirmed deficiency, an increased dosage of thiamine (from 100 to 200 mg) should be

taken three times daily. The supplementation is critical for the management and treatment of this deficiency and it has been showed that there is substantial improvement in the condition after the person received treatment (DiNicolantonio, 2013).

Prognosis

Beriberi is not that difficult to treat. With proper treatment one can expect to see a significant recovery, even in more severe types of this deficiency. Within 12 hours of supplementation one can notice an improvement. Because treatment provides for more rapid recovery, it can almost be used as a diagnostic test. Overall the prognosis is fairly good (Nguyen-Khoa, 2013).

Conclusion

Individuals who suffer from heart failure are more prone to develop vitamin deficiencies such as thiamine deficiency. It is therefore important to limit any nutritional defects to prevent such deficiencies from occurring. This is a controllable condition and with necessary treatment one can expect substantial improvements. The use of vitamin B1 has demonstrated to better heart function, urinary function as well as symptoms of heart failure (DiNicolantonio, 2013).

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