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BIOCHEMICAL ROLE OF METAL IONS IN HUMAN HEALTH: IMPLICATIONS FOR DISEASE AND TREATMENT

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Abstract:

Metal ions are essential for several metabolic reactions that are vital to human health. A wide range of enzymatic reactions, cellular activities, and structural roles include essential metal ions, such as iron, zinc, copper, and manganese. A wide variety of disorders can develop when there is an imbalance in these metal ions. This can happen due to things like environmental exposures, genetic predispositions, or dietary inadequacies. The complex functions of vital metal ions and their effects on human health are the subject of this investigation. Haemoglobin transports oxygen and produces energy, two processes that rely on iron. Copper is involved in the metabolism of iron and the creation of neurotransmitters, whereas zinc is involved in the immune system and DNA synthesis. Metabolic function and antioxidant defence are two areas where manganese is involved. Essential metal ion imbalances, whether toxicities or deficits, are linked to several disorders. Anaemia can result from low iron levels, while hemochromatosis can be caused by high iron levels. Alterations to zinc levels can influence immunological function, and disturbances to copper homeostasis are associated with Wilson's disease. The field of disease prevention, diagnosis, and therapy stands to benefit greatly from a better understanding of the metabolic functions of metal ions. This understanding is used to treat metal ion imbalances and related health issues through therapeutic techniques including chelation therapy and tailored supplements.

keywords: *Metal Ions, Health, Treatment*

Introduction

Important physiological activities rely on metal ions, which are involved in a wide range of metabolic reactions throughout the body. Metal ions, often called trace elements or micronutrients, are essential for human health and well-being. Activation of enzymes, cellular signalling, transport of oxygen, and structural support are just a few of the many biochemical processes in which they participate. While these metal ions play an important role in health, an excess or deficiency can cause a host of problems.

Many different types of metal ions, both necessary and optional, are needed by the human body. The correct operation of enzymes and proteins need trace quantities of essential metal ions as iron, zinc, copper, manganese, and others. However, lead and cadmium are examples of non-essential metal ions that, when present in excess, can be harmful.

Disruptions to this delicate metal ion balance in the body can have serious consequences for human health, as it is essential for homeostasis. Nutritional deficiencies, environmental exposures, and hereditary factors can all contribute to imbalances, which in turn can cause a variety of illnesses and disorders. If we want to find better ways to diagnose, treat, and prevent diseases, we need to know what these metal ions do biochemically.

The particular functions of key metal ions in different metabolic pathways and their effects on human health will be the focus of this investigation. The effects of metal ion imbalances, including toxicities, deficiencies, and their link to illness, will also be discussed. Additionally, we will go into how this understanding is utilised to create therapeutic approaches and therapies for diseases associated with metal ion imbalance.

As we explore the complex relationship between metal ions and human health, our goal is to understand how this knowledge might be used to avoid diseases, diagnose them early, and treat them specifically. Discovering the intricate connections between metal ions and metabolic reactions will lead to new developments in individualised treatment and creative solutions to health problems caused by metal ion imbalances.

Iron (Fe):

- Iron is crucial for oxygen transport in the blood, as it is a key component of hemoglobin and myoglobin.
- It plays a vital role in cellular respiration and energy production as part of the heme group in cytochromes.
- Iron is essential for DNA synthesis, and it is involved in various enzymatic reactions, such as those related to the tricarboxylic acid (TCA) cycle.

Zinc (Zn):

- Zinc is a co-factor for numerous enzymes involved in DNA synthesis, repair, and transcription.
- It plays a role in immune function, wound healing, and the maintenance of skin integrity.
- Zinc is essential for the proper function of antioxidant enzymes, helping to protect cells from oxidative stress.

Copper (Cu):

- Copper is a co-factor for enzymes involved in iron metabolism, neurotransmitter synthesis, and connective tissue formation.
- It plays a role in cellular respiration as a component of cytochrome c oxidase.
- Copper is crucial for the formation of melanin, which is responsible for skin and hair pigmentation.

Manganese (Mn):

- Manganese is a co-factor for enzymes involved in amino acid, cholesterol, and carbohydrate metabolism.
- It plays a role in bone formation and the synthesis of connective tissues.
- Manganese contributes to the activation of antioxidant enzymes, protecting cells from oxidative damage.

Implications for Human Health:

Deficiencies:

- Inadequate intake of essential metal ions can lead to deficiencies, resulting in health issues. For example, iron deficiency can cause anemia, zinc deficiency can impair immune function, and copper deficiency can lead to neurological problems.

Toxicities:

- Excessive levels of certain metal ions can be toxic. For instance, chronic exposure to high levels of lead can lead to neurotoxicity, affecting cognitive function and development.
- Accumulation of iron beyond normal levels can lead to conditions such as hemochromatosis, causing damage to organs like the liver and heart.

Disease Associations:

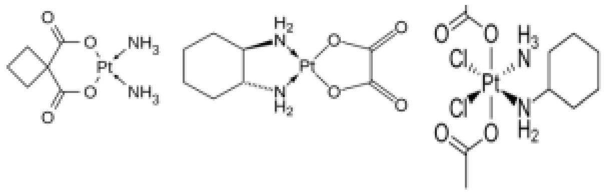
- Dysregulation of metal ions has been linked to various diseases. For example, alterations in copper metabolism are associated with Wilson's disease, while disturbances in iron homeostasis are implicated in conditions like hemochromatosis and thalassemia.

Therapeutic Approaches:

- Understanding the roles of metal ions in disease pathogenesis has paved the way for targeted therapeutic interventions. Chelation therapy, for instance, is used to remove excess metal ions from the body.
- Iron supplementation is commonly prescribed to treat iron-deficiency anemia, showcasing the application of metal ions in medical interventions.

Metal containing therapeutic agents

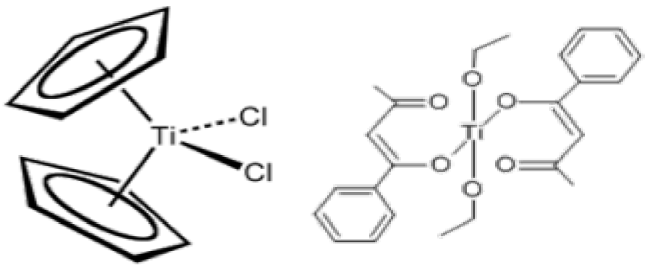
Cisplatin (1) is only one of several medicines that may be complexed with platinum. The following malignancies can be treated with cisplatin: germ-cell cancers, trophoblastic tumours during pregnancy, epithelial ovarian cancer, small cell lung cancer, cervical, nasopharyngeal, esophageal, head and neck, and bladder cancers. Several negative effects were also discovered to be connected with cisplatin, and it was discovered that certain tumours were resistant to it. As a result, carboplatin (3) was created as an alternative to cisplatin; it exhibited somewhat reduced toxicity but was not much more effective against cancer. Actually, cisplatin continued to outperform carboplatin as a treatment option for some tumour types. In August 2002, the new medication oxaliplatin (4) was approved for use in the US for colorectal cancer in combination with 5-fluorouracil (5-FU). This came after further attempts to decrease toxicity and drug resistance. Several years prior, it had served its purpose in Europe. An other platinum-based antineoplastic drug, satraplatin (5, JM216), is being studied for the treatment of advanced prostate cancer; however, it has not yet been authorised by the U.S. Food and Drug Administration. Even though Pt (IV) compounds are said to be inert, satraplatin biotransforms quickly in human RBCs.14 Comparable to cisplatin, satraplatin is an analogue (1). The biological effects and potential spectrum of clinical action of cisplatin's structurally distinct direct structural analogues are extremely similar because they all form a comparable array of adducts on target DNA.



3, Carboplatin 4, Oxaliplatin 5, Satraplatin (JM-216)

Titanium complexes

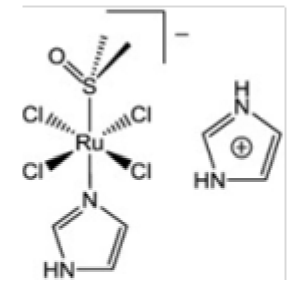
Both titanocene (6, MTK4) and budotitane (7, INN) are examples of titanium complexes that have been discovered to possess anticancer properties. Titanocene was the first non-platinum complex to be tested in clinical trials as a chemotherapeutic medication. It had demonstrated anticancer efficacy and was the first complex to be tried.a 19The non-platinum compound known as budotitane (INN) is considered to be one of the most sophisticated combinations. At the moment, it is participating in clinical studies. Budotitane demonstrates encouraging benefits in an autochthonous colorectal tumour model, which is highly predictive for the clinical scenario. Budotitane is extremely active in a number of tumours that are able to be transplanted.

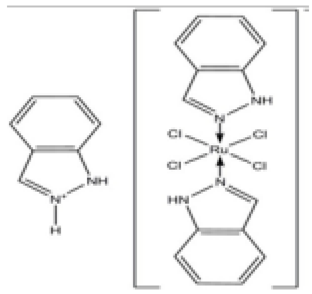


6, Titanocene (MTK4) 7, Budotitane (INN)

Ruthenium complexes

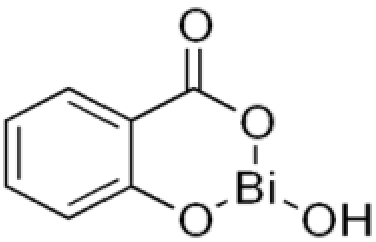
Although no direct analogues have made it to the clinic just yet, ruthenium has developed compounds with the most potential. Two ruthenium anticancer drugs, NAMI-A (8) and KP1019 (9) respectively, have started clinical studies.21,22 Metastatic tumours and cis-platin resistant tumours are treated with KP1019, whilst NAMI-A is effective against tumour cell invasion in vitro and lung metastasis in vivo. Particularly effective against colorectal cancer and other primary tumours, it demonstrates strong cytotoxicity.





Bismuth complexes

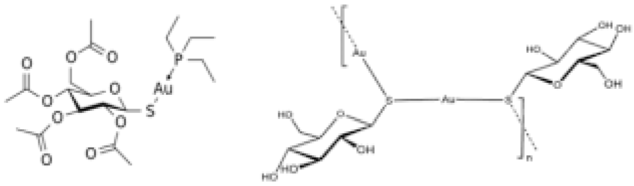
The antacid and astringent effects of several bismuth-containing compounds have made them useful in the treatment of a number of gastrointestinal diseases. An essential ingredient, bismuth subsalicylate (10, Pepto-Bismol) is an antacid that alleviates short-lived gastrointestinal issues such nausea, indigestion, heartburn, and diarrhoea. Additional compounds are being worked on.



0, Pepto-Bismol

Gold complexes

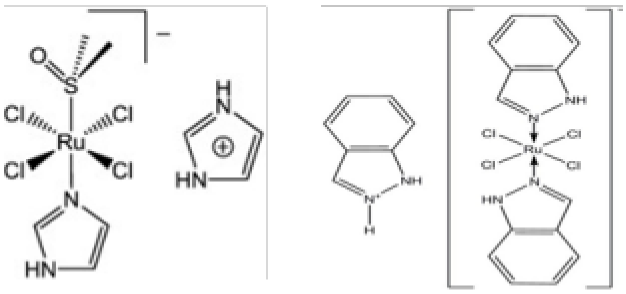
Two gold complexes, auranofin and aurothioglucose (sometimes called gold thioglucose), were developed to treat rheumatoid arthritis. Contrarily, auranofin reduces arthritic symptoms including morning stiffness, edoema, and pain in the joints. More than seven decades have passed since aurothioglucose was first used to treat rheumatoid arthritis.30 Unfortunately, the US market has just pulled it and other gold complexes intended to treat RA off the shelves. Consequently, auranofin is the sole gold salt that may be bought in the US right now.



11,Auranofin 12,Aurothioglucose

Ruthenium complexes

The most promising compounds have been created using ruthenium, although no direct equivalents have reached the clinic as yet. Two ruthenium anticancer medications, NAMI-A and KP1019, are now participating in clinical trials. Although NAMI-A is successful in preventing tumour cell invasion and lung metastasis in vitro and in vivo, KP1019 is more useful in treating tumours that have spread or are resistant to cis-platin treatments. Its cytotoxicity against primary tumours makes it an excellent tool for fighting colorectal cancer.



8, NAMI-A 9, KP1019

Conclusion

It is crucial to maintain a precise equilibrium for optimal physiological functioning, since the complex relationship between critical metal ions and human health is evident. The importance of iron, zinc, copper, and manganese ions in a variety of metabolic reactions, including energy generation, immune system function, and antioxidant defence, has been brought to light by this investigation. Various disorders have been linked to imbalances in metal ion levels, which can be caused by shortages or toxicities. The importance of these micronutrients for fundamental cellular processes is highlighted by deficiencies, such as iron-deficiency anaemia or zinc deficiency affecting the immunological response. On the flip side, toxicities highlight the possible damage linked to elevated quantities of metal ions; examples include lead-induced neurotoxicity and iron overload illnesses. Metal ion dysregulation has far-reaching consequences for human health that go beyond illness connections. New insights into these connections have cleared the path for more precise forms of treatment. Methods such as chelation treatment and metal supplementation show how scientific understanding is being applied to improve health by reestablishing a balance of metal ions.

References

[1] Metal Ions in Biological Systems. In: Seiler HG, Sigel H, Sigel A, editors. 14:1982.

[2] Holm RH, Pierre Kennepohl P, Solomon EI. Structural and Functional Aspects of Metal Sites in Biology. Chem Rev. 1996;96(7):2239–2314.

[3] Lippard SJ, Berg JM. Principles of Bioinorganic Chemistry. Mill Valley: University Science Books; 1994.

[4] Cowan JA. Inorganic Biochemistry/An introduction. New Jersey: Wiley-VCH Inc;1994. 5. Tietz Textbook of Clinical Chemistry. 2nd ed. In: Carl A, Burtis CA, et al, editors. Saunders: Philadelphia; 1994.

[5] De Silva JJRF, Williams RJP. The Biological Chemistry of the Elements. Clarendon Press: Oxford; 1991.

[6] Weiss RB, Christian MC. New Cisplatin Analogues in development. A review. Drugs. 1993;46(3):360–377.

[7] Lebwohl D, Canetta R. Clinical Development of Platinum Complexes in Cancer Therapy: an historical perspective and an update. Eur J Cancer. 1998;34(10):1522–1534.

[8] O'Dwyer PJ, Johnson SW, Hamilton TC. Cisplatin and its Analogues. In Cancer Principles and Practice of Oncology. 5th ed. In: DeVita VT, Hellman S, Rosenberg SA, editors. Lippincott-Raven: Philadelphia; 1997. 418–431 p

[9] O'Dwyer PJ, Stevenson JP, Johnson SW. Clinical Status of Cisplatin, Carboplatin, and Other Platinum-based Antitumor Drugs. In Cisplatin: Chemistry and Biochemistry of a Leading Anticancer Drug. In: Lippert B editor. Wiley-VCH: New York; 1999. 31–72 p.

[10] Highley MS, Calvert AH. Clinical Experience with Cisplatin and Carboplatin. In: Kelland LR, Farrell NP, editors. Platinum-Based Drugs in Cancer Therapy. Cancer Drug Discovery and Development. New Jersey: Humana Press; 2000. 89–113 p.

[11] Macdonald JS, Astrow AB. Adjuvant Therapy of Colon Cancer. Semin Oncol. 2001;28(1):30–40.

[12] Pelley RJ. Oxaliplatin: a new agent for colorectal cancer. Curr Oncol Rep. 2001;3(2):147–155.

[13] Carr JL, Tingle MD, McKeage MJ. Rapid biotransformation of satraplatin by human red blood cells in vitro. Cancer Chemother Pharmacol. 2002;50(1):9–15.

[14] Farrell N, Qu Y, Hacker MP. Cytotoxicity and Antitumor Activity of Bis(Platinum) Complexes. A Novel Class of Platinum Complexes Active in Cell Lines Resistant to Both Cisplatin and 1,2-Diaminocyclohexane Complexes. J Med Chem. 1990;33(8):2179–2184.