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Review Article

A Review on the Biomedical Importance of Taurine

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ARTICLE INFO | ABSTRACT

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Objectives: To briefly outline the effects of taurine on different organs, in order to elucidate the biomedical importance of taurine. **Summary:** Taurine is a sulfur-containing amino acid that is found in mammalian tissues. Taurine has different biological and physiological functions. It is a component of bile acids, which are used to help absorb fats and fat-soluble vitamins. It also helps regulate the heartbeat, maintain cell membrane stability and prevent brain cell over-activity. In addition, taurine chloramine, an endogenous product derived from activated neutrophils, has been reported to suppress obesity-induced oxidative stress and inflammation in adipocytes. **Conclusion:** This review is an attempt to reveal the biomedical importance of taurine including its effect on heart, lung, kidney, bone, fetal tissue, retinal photoceptors, oxidative stress and cancer

Key words: Taurine, endothelium, lung, kidney, antioxidant

1. INTRODUCTION

Taurine originated from the Latin word taurus, which means bull or ox, as it was first isolated from ox bile in 1827 by Austrian scientists Friedrich Tiedemann and Leopold Gmelin.[1] It is often considered an amino acid in scientific literatures. It is a vital nutrient for cats, and probably also for primates, since it is essential for the development and survival of neural cell.[2] In healthy humans, dietary foodstuffs are the main sources of taurine. High concentrations of taurine are found in animal sources whilst undetectable in vegetables.[3]

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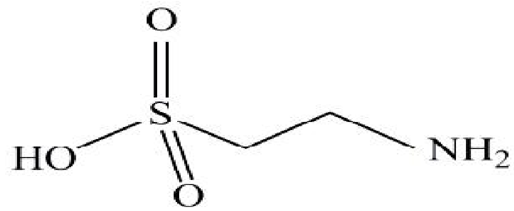

Fig 1: Structure of taurine

Since vegetarians have no dietary intake of taurine and often eat low sulphur amino acid diets, plasma concentrations are lower in vegetarians.

Methionine and cysteine are precursors of taurine, however synthesis ability varies widely amongst species, the maximal human synthesis rate is unknown. The average daily synthesis in adults ranges between 0.4 - 1.0 mmol (50-125 mg) [4] under stress the synthesis capacity may be impaired; therewith some authors consider taurine as a conditionally essential amino acid, whereas for others it remains non essential. Fish is a good source of taurine and tests for taurine content for a variety of fish have been conducted.

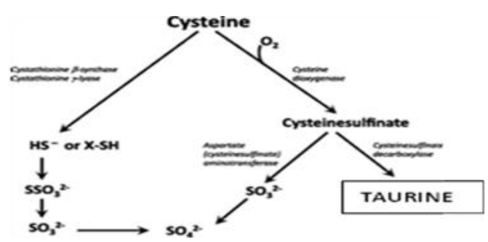

Fig 2: Biosynthesis of taurine

2. CHEMISTRY OF TAURINE

The molecular formula of taurine is $C_2H_7NO_3S$ and its molecular weight is 125.15. It has a p*K*a of 1.5 (at 25 °C) and a melting point of 300 °C (decomposition) and shows a bulk density of 0.65–0.75g/cm3 and a density of approximately 1.7g/cm3. It is soluble in water (10 g dissolves in 100 mL at 25 °C) and insoluble in ethanol, ethyl ether and acetone. The pH of a 5 % solution in water is 4.1 – 5.6. Taurine is a white crystalline powder that is almost odourless but with a slightly acidic taste. It contains by specification at least 98.0 % taurine in dried substance. Taurine is a monobasic acid that has unique physical constants compared to other neuroactive amino acids. The uniqueness of taurine is mainly due to the functional group containing sulfur, the sulfonic group, unlike the carboxylic group typical of all the other natural amino acids. This difference may provide the rationale behind the unique biological nature of taurine which is not shared with other neuroactive amino acids. With its sulfonate group, it is a stronger acid (pKa 1.5) than glycine, aspartic acid, β-alanine, and γ-aminobutyric acid (GABA). Similarly, having a pKb value of 8.82, it is less basic than GABA, β-alanine and glycine. Its solubility in water is 10.48g/100mL at 258°C, which is lower than that of β-alanine, GABA or glycine.

Table 1: Properties of taurine

Molecular formula	$C_2H_7NO_3S$
Molecular mass	125.14 g/mol
Density	1.734 g/cm^3
Melting point	305.11^0 C

3. BIOMEDICAL IMPORTANCE OF TAURINE

3.1 Taurine in Fetal Development and Neonatal Growth

The human fetus has no ability to synthesize taurine, but considerably high levels of taurine have been recorded, and this may be due to a very efficient placental role of taurine in disease prevention. The amount of taurine was found to be very high in human breast milk compared to cow’s milk, on which a large portion of infants are fed, and this may be due to the high concentration of taurine in placenta. Thus, taurine is now added to many infant formulas to provide improved nourishment.[5] Several types of organ dysfunction develop from abnormalities of taurine levels in growing children. In neonatal cardiomyocytes (as in adult ones), taurine functions as an organic osmolyte. During pregnancy, taurine accumulates in the maternal tissues, from where it is periodically released to the fetus via the placenta. In infants, taurine is acquired through the mother’s milk. This is the stage

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when taurine accumulates more in fetal and neonatal brain. A low maternal taurine concentration will lead to low fetal taurine concentration.[6]

3.2 Taurine and the Central Nervous System (CNS)

Taurine is the most abundant amino acid in the brain after glutamate, and it is found in all cell types in the CNS. A high concentration of taurine occurs in the developing brain, but with maturity, its levels fall to 30%.[7] Taurine is extensively involved in neurological activities, including protection, modulation of neural excitability, maintenance of cerebellar functions and modulation of motor behavior through interaction with dopaminergic, adrenergic, serotonergic and cholinergic receptors and through glutamate.[8] Free radicals are particularly detrimental to brain tissue where there is a high concentration of lipids, suitable target for oxidation. Taurine is now being explored for its capacity to protect tissues against oxidative stress. In cerebellar neurons, stimulation by excitatory agents was effectively countered by taurine. While taurine may not directly decrease the levels of free radicals, it does increase cell viability. This may become an important alternate protective mechanism against free radical damage to brain cells.

3.3 Taurine and the Liver

Liver synthesizes bile, which is a mixture of bile acids, salts, bilirubin, cholesterol and fatty acids, stored in the gallbladder. It is also responsible for the detoxification of harmful substances, but only if available in sufficient quantities. The bile acids act as detergents to solubilize or emulsify food into digestible components. This detergent action is due to the presence of both lipophilic and hydrophilic ends in the bile acids. The hydrophilic regions include sulfonates or carboxylate backbones. Mammals mainly use taurine and, to a lesser extent glycine, as the major amino acids that conjugate with bile acids to form biliary salts. Among the tauro-conjugates, taurocholic acid (TC), taurodeoxycholic acid (TDC), taurolithocholic acid (TLC), and taurocheno- deoxycholic acid (TCDC), can act as cholagogues (agents that promote the flow of bile into the intestine) or choleretics (agents that stimulate the liver to increase production of bile). The ratio between tauro-conjugates and glycocholate in humans is about 3: 1 and this ratio is adversely affected in cases of low taurine supply. In the absence of TC, bile salts can precipitate and form gallstones.[9]

3.4 Taurine and Hypercholesterolemia

In blood, cholesterol is carried in low density lipoproteins (LDL) and high density lipoproteins (HDL). Elevated LDL levels are implicated in a range of heart and vascular diseases, including myocardial infarction (heart attack) and atherosclerosis (clogging of the arteries). Taurine can attenuate the increased levels in total and LDL cholesterol in animals consuming a high fat, high cholesterol diet.[10] High fat diets produce hypercholesterolemia, atherosclerosis, and accumulation of lipids on the aortic valve of the heart. Dietary taurine supplements are known to be beneficial in situations when the body cholesterol status is high, as well as normal. In particular, it has been demonstrated that taurine is capable of reducing plasma lipid concentration and visceral fat in diabetic rats as well as in obese humans.[11]

3.5 Taurine and Occupational Environmental Liver Damage

Exposure to toxic chemicals, which is a common hazard for industrial workers, has been linked to birth defects, sterility, headache, chronic fatigue, arthritic-like inflammation and many other symptoms. These chemicals have a deleterious effect on the liver and taurine is able to moderate the extent and severity of their side. Furthermore, it reduces the number of cancer antigen-positive hepatocytes and in several cases of chemical exposure, taurine also protected against DNA damage.[12]

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3.6 Taurine and Diabetes

Type II diabetes mellitus is one of the most common human diseases and its prevalence is constantly growing. This pathology is characterized by the reduced sensitivity of the cellular targets, mainly adipose and muscle cells, to insulin stimulation. Such alteration can lead to insulin resistance, hyper-insulinemia, hyperglycemia, and several other metabolic dysfunctions. Lifestyle, dietary habits, and environment can influence the appearance of diabetes.[13] Taurine supplements administered to patients with type 2 diabetes were proven to be beneficial. Also, taurine alleviates clinical complications of diabetes, having beneficial effects on nephropathy and retinopathy. In animal models of experimental insulin resistance, it has been demonstrated that the metabolic alterations associated with diabetes are ameliorated by taurine administration.[14]

3.7 Taurine and the Cardiovascular System

Taurine concentration is found to be high in the mammalian heart. The maintenance of cardiac taurine content is governed by a series of processes, which include transport, accumulation, binding, release, as well as metabolism. The availability of taurine in cardiac tissue is generally dependent on the transport process, because of its limited ability to be effectively synthesized in the cardiac tissue. Taurine deficiency may possibly be linked to cardiomyopathy, as it has been well reported in cats. Furthermore, conclusive evidence of the relationship between taurine and heart health was provided by studies with transgenic mice knocked out of its taurine transporter.[15]

3.8 Taurine and Endothelial Dysfunction

Endothelial dysfunction is common among cardiovascular diseases and diabetes and it is known as one of the primary events in the development of atherosclerosis and diabetic angiopathies.[16] Taurine has been shown to be a protector of endothelial structure and function after exposure to inflammatory cells, their mediators, or other chemicals. Treatment of activated macrophages with taurine inhibits the generation of NO and other inflammatory mediators, which is present in high amounts in inflammatory cells, seems to be uniquely capable of modifying homeostasis in both target and receptor cells through antioxidant calcium flux and the osmo regulatory pathway. Finally, taurine was proven to protect endothelial cells from damage induced by hyperglycemia and oxidized LDL.[17]

3.9 Taurine and Lung Function

The depletion of taurine is particularly harmful to pulmonary tissue. Alveolar macrophages, which reside on the surface of lung alveoli, ingest inhaled particulates to clear the alveolar spaces. However, alveolar macrophages, much like the general macrophages, become more susceptible to ROS and more pro-inflammatory when deprived of the antioxidant protective capacity that taurine provides. Fibrosis may also result from toxic chemical exposure. There are numerous factors responsible for toxin-induced damage to lung cells and tissue in animal models of induced interstitial pulmonary fibrosis. In several cases, the administration of taurine, niacin or a combination of both, yielded promising results, and can reverse increased lung lipid peroxidation. Furthermore, the ability to scavenge ROS and to stabilize cell membranes contributed to the suppression of lung collagen accumulation and oxidative stress damage. Asthma is a chronic disease characterized by bronchial obstruction and airway hyper reactivity with neutrophil accumulation. There is increasing evidence that excessive production of ROS along with defective endogenous antioxidant defense mechanisms may be responsible for asthma. In an animal model of allergic asthma, taurine content was found to be reduced and

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oral treatment with taurine produced anti-inflammatory responses. Similar effects have also been demonstrated in humans.[18]

3.10 Taurine and The Kidney

In the kidneys, taurine is found at a high concentration, which is regulated by the reabsorption at the modulating proximal tubule according to its dietary intake. In alleviating the diabetic nephropathy, taurine serves as an osmolyte, an endogenous antioxidant and an inhibitor of phosphokinase C (PKC) in mesangial cells. The beneficial effects of taurine may be due to its well-known anti-oxidative, anti-inflammatory and anti-apoptotic activities.[19]

3.11 Taurine and Retinal Photoreceptor Activity

The common eye disease cataract demonstrates the importance of lens condition. It is speculated that cataract formation may be largely due to the oxidation of protein in the lens. Consequently, a lack of antioxidants could be a major factor in the development of cataracts. Since taurine acts as an antioxidant directly, it prevents changes in the levels of glutathione, ATP and insoluble proteins, molecular factors that predispose to cataract formation.[20] Furthermore, taurine plays a critical role in the structure and function of the photoreceptors, specifically rods, which are responsible for seeing in both low illumination and night conditions. The promotional effect of taurine in cellular regeneration is compromised with drugs that induce the activation of PKC or phosphate inhibitors.[21] Retinitis pigmentosa (RP) is characterized by visual field loss and night blindness. Nutritional factors are now recognized as important factors in the reversal of RP. Experimental finding suggests that RP patients recover their visual capacities with the addition of nutrients, including taurine, which has been found to be beneficial. Taurine and zinc interact with each other to influence the development of the retinal structure and function in the eye. Both molecules promote the healthy oscillatory potentials necessary for vision. Deficiency of taurine has been identified as the cause of all these diseases and clearly demonstrates its vital role in vision.[22]

3.12 Taurine in Bone Tissue Formation And Inhibition of Bone Loss

Bone tissue contains cells and the extracellular matrix, which is composed of collagen fibers and noncollagenous proteins. In bone tissue, taurine is found in high concentration, similar to that found in the liver and kidneys. This taurine-bone interaction is one of the latest added to its long list of actions.[23] In bones, taurine acts as a double agent. It is involved in both bone formation and inhibition of bone loss. In addition to these two major actions, taurine has beneficial effects in wound healing and bone repair.

3.13 Anticancer Activity of Taurine

Taurine has been found that taurine has radio protective properties and anti-mutagenic effect, reducing nucleic acid damage. The chemo-preventive activity of taurine and, in particular, 1-(2-chloroethyl)-3(2-dimethyl sulfony) ethyl-11-nitrosourea derivative (e.g., tauromustine), have been used against colon and hepatic cancers. In hepato-carcinogenesis, the degree of membrane damage and the fall in glutathione function were reduced when oral taurine was given prior to exposure to carcinogens. These findings suggest that taurine, by inhibiting lipo-peroxidation and preserving the glutathione antioxidant system, offers protection against membrane breakdown.[24]

Recombinant interleukin-2 immunotherapy is utilized as a therapeutic approach in certain types of cancers. However, it may produce a cytotoxic effect on both tumor cells and healthy vascular endothelial cells. In such cancer therapy programs, taurine reduces interleukin endothelial cell cytotoxicity without compromising the antitumor activity of the immunotherapy. In addition, when taurine is used in

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conjunction with interleukin, it actually increases the tumor cytotoxicity. For the treatment of intra peritoneal (abdominal) tumors, researchers have studied a taurine derivative, taurolidine, as both an alternative and an adjunct to heparin, a standard substance used to prolong the clotting time of blood. In certain cancers, the amino acid profile yields data about the disease that is useful to better assess the therapeutic approach. Colorectal cancer patients exhibit a characteristic amino acid profile with significantly lower intracellular levels of taurine, glutamic acid, methionine, and ornithine and elevated levels of valine. Likewise, squamous cell carcinoma of the head and neck exhibit a profile that is marked by decreased taurine.[25]

4. CONCLUSION

This review highlights the divergent effects of taurine on different tissues. Thus, further studies on taurine could exemplify the beneficial role of taurine in human health and disease.

5. REFERENCES

1. Stapleton PP, Charles RP, Redmond HP, Bouchier-Hayes DJ (1997). Taurine and human nutrition. Clin Nutr, 16:103-108.
2. Huxtable RJ (1992). Physiological actions of taurine. Physiol Rev 72:101-163.
3. Rana SK and Sanders TA (1986). Taurine concentrations in the diet, plasma, urine and breast milk of vegans compared with omnivores. Br J Nutr 1986:56:17-27.
4. Jacobsen JG, Smith LH (1968) Biochemistry and physiology of taurine and taurine derivatives. Physiol Rev, 48:424-511.
5. Rivero Urgell M, Santamarı´a Orleans A, Rodrı´guez-Palmero Seuma M. (2005). The importance of functional ingredients in pediatric milk formulas and cereals. Nutricio´n Hospitalaria, 20:135–146.
6. Aerts L, Van Assche FA (2001). Lowtaurine, g-aminobutyric acid and carnosine levels in plasma of diabetic pregnant rats: Consequences for the offspring. Journal of Perinatal Medicine, 29(1), 81–84.
7. Wu J, Kohno T, Georgiev SK, Ikoma M, Ishii H, Petrenko AB, Baba H (2008). Taurine activates glycine and g-aminobutyric acid A receptors in rat substantia gelatinosa neurons. Neuroreport, 19(3), 333–337.
8. Howland RH (2007). Glutamate-modulating drugs and the treatment of mental disorders. Journal of Psychosocial Nursing and Mental Health Services, 45(1):
11–14.
9. Haslewood GAD (1978). The biological importance of bile salts. Quarterly Review of Biology, 54(4): 445–446.
10. Murakami S, Kondo Y, Nagate T (2000). Effects of long-term treatment with taurine in mice fed a high-fat diet: Improvement in cholesterol metabolism and vascular lipid accumulation by taurine. Advances in Experimental Medicine and Biology, 483: 177–186.
11. Zhang M, Bi LF, Fang JH, Su XL, Da GL, Kuwamori T, Kagamimori S (2004). Beneficial effects of taurine on serum lipids in overweight or obese non-diabetic subjects. Amino Acids, 26(3): 267–271.
12. Wu C, Miyagawa C, Kennedy DO (1997). Involvement of polyamines in the protection of taurine against the cytotoxicity of hydrazine or carbon tetrachloride in isolated rat hepatocytes. Chemico-Biological Interactions, 103, 213–224.
13. Kelly GS (2000). Insulin resistance: Lifestyle and nutritional interventions. Alternative Medicine Review, 5:109–132.

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14. Nandhini AT, Thirunavukkarasu V, Ravichandran MK, Anuradha CV (2005). Effects of taurine on biomarkers of oxidative stress in tissues of fructose-fed insulin resistant rats. Singapore Medical Journal, 46:82–87.
15. Ito T, Kimura Y, Uozumi Y, Takai M, Muraoka S, Matsuda T, Ueki K, Yoshiyama M, Ikawa M, Okabe M, Schaffer SW, Fujio Y, Azuma J (2008). Taurine depletion caused by knocking out the taurine transporter gene leads to cardiomyopathy with cardiac atrophy. Journal of Molecular and Cellular Cardiology, 44: 927–937.
16. Pechanova O, Simko F (2007). The role of nitric oxide in the maintenance of vasoactive balance. Physiological Research, 56(2): S7–S16.
17. Ulrich-Merzenich G, Zeitler H, Vetter H, Bhonde RR (2007). Protective effects of taurine on endothelial cells impaired by high glucose and oxidized low density lipopro- teins. European Journal of Nutrition, 46, 431- 438.
18. Kim C, Choi HS, Kim JW (2006). Taurine chloramine inhibits the production of nitric oxide and superoxide anion by modulating specific mitogenactivated protein kinases. Adv Exp Med Biol, 583:493-498.
19. Suliman ME, Barany P, Divino Filho JC et al. (2002). Influence of nutritional status on plasma and erythrocytes sulphur amino acids, sulphhydryls and inorganic sulphate in end-stage renal diseases. Nephrology, Dialysis, Transplantation, 17: 1050–1056.
20. Kilic F, Bhardwaj R, Caulfeild J, Trevithick JR (1999). Modelling cortical cataractogenesis 22: Is in vitro reduction of damage in model diabetic rat cataract by taurine due to its antioxidant activity? Experimental Eye Research, 69(3): 291–300.
21. Di Leo MA, Santini SA, Cercone S, Lepore D, Gentiloni Silveri N, Caputo S, Greco AV, Giardina B, Franconi F, Ghirlanda G (2002). Chronic taurine supplementation ameliorates oxidative stress and Naþ Kþ ATPase impairment in the retina of diabetic rats. Amino Acids, 23(4), 401–406.
22. Lindholm B, Alvestrand A, Furst P, Bergstrom J (1989). Plasma and muscle free amino acids during continuous ambulatory peritoneal dialysis. Kidney International, 35, 1219–1226.
23. Kim SJ, Lee HW, Gupta RC (2008). Taurine, bone growth and bone development. Current Nutrition and Food Science, 4(2), 135–144.
24. Hartley-Asp B (1992). Genotoxicity of tauromustine, a new water soluble taurine-based nitrosourea I. Mutagenic and clastogenic activity of tauromustine in vitro. Mutagenesis, 7(6), 427–431.
25. Daigeler A, Chromic AM, Geisler A et al. (2008). Synergistic apoptotic effects of taurolidine and TRAIL on squamous carcinoma cells of the esophagus. International Journal of Oncology, 32(6), 1205–1220.

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