(54) Title: METHOD FOR USE OF ACETYL-L-CARNITINE (ALCAR) FOR TREATMENT OF DEPRESSIVE DISORDERS IN HUMANS

(57) Abstract: Depression and bi-polar depression are treated with an acetyl-L-carnitine (ALCAR), thereby avoiding unwanted side-effects exhibited by conventional antidepressant agents. ALCAR also helps prevents recurrent episodes of depression and bi-polar depression and both provides beneficial membrane phospholipid and high-energy phosphate changes in a brain of human subjects with major depressive disorders (MDD).
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
METHOD FOR USE OF ACETYL-L-CARNITINE (ALCAR) FOR TREATMENT OF DEPRESSIVE DISORDERS IN HUMANS

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. application no.10/359,560, filed February 7, 2003, which claims priority to U.S. Provisional application no. 60/354,323, filed February 7, 2002, contents of both of which are incorporated by reference.

FIELD OF THE INVENTION

[0002] This invention relates to the treatment of depression. More particularly it relates to the treatment of depression in human subjects with acetyl-L-carnitine (ALCAR).

BACKGROUND OF THE INVENTION

[0003] The clinical response to antidepressant treatment in later life follows a variable temporal response, with a median time to remission of 12 weeks. Newer antidepressants still demonstrate a disturbing side-effect profile in this fragile patient population. Thus, there is a need for the development of newer antidepressants. One such candidate is acetyl-L-carnitine (ALCAR), a molecule that is naturally present in human brain demonstrating only few side effects.

[0004] Seven parallel, double-blind, placebo-controlled studies have examined ALCAR efficacy in various forms of geriatric depression. Phosphorus magnetic resonance spectroscopy ($^{31}$P MRS) directly provides information on membrane phospholipid and high-energy phosphate metabolism in defined, localized brain regions. Although in vivo $^{31}$P MRS studies in major depression are limited, there is evidence of altered high-energy phosphate and membrane phospholipid metabolism in the prefrontal and basal ganglia regions. Increased levels of precursors of membrane phospholipids [i.e., increased phosphomonoesters (PME) levels] in the frontal lobe of major depressed subjects compared to controls was reported. Other researchers also observed higher PME levels in bipolar subjects in their depressive phase compared with the euthymic state. In
terms of high-energy phosphates, reduced levels of adenosine triphosphate (ATP) have been observed in both the frontal and basal ganglia of major depressed subjects. The level of the high-energy phosphate buffer, phosphocreatine (PCr), was lower in severely depressed subjects compared with mildly depressed subjects. Accordingly, the relationship between membrane phospholipid and high-energy phosphate metabolism as assessments of beneficial results in the treatment of depression are recognized.

**EPIDEMIOLOGY OF DEPRESSIVE DISORDERS**

[0005] Depressive disorders (i.e., major depression, dysthymia, bipolar disorder) are among the most common and disabling medical conditions throughout the world. For example, about 9.5% of the US adult population will suffer from a form of depression during any given year which is approximately 18.8 million people. In addition, 16-18% of women and 10% of men (3-4 million) will experience some form of depression. The lifetime risk for depression is approximately 15-20% regardless of gender.

[0006] When one episode of depression is experienced, there is a 50% likelihood of recurrent episodes. When a second episode of depression occurs, there is a 80-90% likelihood of recurrent episodes and 75% of depressive disorders are recurrent.

[0007] It is estimated 20% of depressed individuals will attempt suicide and 6% will be successful. 75% of those committing suicide have a depressive disorder. The rate of successful suicide is four times greater in men.

[0008] About 10% of people with depression also will experience episodes of mania. Bipolar depressive episodes usually last longer, have a greater likelihood of psychotic features, and convey a greater risk of suicide. Bipolar disorder may be misdiagnosed as depression resulting in inappropriate treatment that may worsen the disease progression and outcome.

[0009] Depression is a coptraveler with a number of other medical and psychiatric conditions and numerous medications can cause depressive symptoms.

[0010] The prevailing dogma concerning the pathophysiology of depressive disorders (major depression, dysthymia, bipolar disorder) is that of an altered neurotransmitter receptor and many studies have been conducted to find such an
alteration. To date, there has been no demonstration of an alteration in the binding site for any of the targeted neurotransmitters. Another problem with the altered neurotransmitters receptor dogma is that although the tricyclic antidepressants and selective neurotransmitter reuptake inhibitor drugs quickly enter brain and bind to their targeted sites, the clinical therapeutic effect does not occur for 4-6 weeks even though the onset of side effects is immediate.

[0011] Studies by Samuel Gershon over the years, since early 1950, have questioned the concepts of the established modes of action of antidepressants and those of the etiology of affective disorders.

[0012] In the early 50's a number of papers appeared suggesting that lithium not only had anti-manic properties but that it also exhibited anti-depressant and prophylactic activity in depression. These observations were confirmed by the controlled studies carried out by Schou et al. in Denmark and Prien et al. in Australia. This tended to indicate that perhaps a single neurotransmitter and a single receptor site would not qualify as the full explanation of their effects. In 1961, Gershon published a report in the Lancet on the psychiatric sequelae of organo-phosphorus insecticides in an exposed human population. Thus a role for acetylcholine in contributing to the production of major depressive disorder (MDD) was presented. This added to the complexity of current theories. In the 1970's an antidepressant Ludiomil was marketed with the effect of being a specific norepinephrine (NE) uptake inhibitor and thus exerting its effect by this route. This was an effective agent and was taken off the market because of other adverse effects (AE). In 1970 Gershon and colleagues carried out a number of experiments with synthesis inhibitors in patients undergoing treatment with different antidepressants and showed that only the inhibition of serotonin synthesis and not NE synthesis interfered with antidepressant outcomes.

[0013] These experiments demonstrated that a single transmitter or a single receptor could not account for therapeutic activity and clearly suggested other mechanisms are involved relating to membrane effects and second messenger systems. Antidepressant use has now clearly been associated with treatment emergent mania and the induction of rapid cycling in affective disorder patients (Tamada et al., 2004).
[0014] In addition to the concerns that have been established with the more classic bipolar I (BPI) type, much controversy surrounds the use of antidepressants in bipolar II (BPII) depression, a growing population.

[0015] Antidepressant induced cycle acceleration has been reported to be more likely in BPII patients than in BPI (Altshuler et al., 1995; Joffe et al., 2002; Benazzi, 1997; Henry et al., 2001; Ramasubbu, 2001).

[0016] The data has increasingly shown the need for the use of effective antidepressants but at the same time has produced data indicating the need for caution with the agents available. These effective antidepressants cause both the risk of switch into mania and the even more serious effect of rapid cycling of the affective disorder and an alteration of the frequency and severity of episodes.

[0017] A different conceptual approach has been the subject of almost 3 decades of research by Jay W. Pettegrew. This concept is that there is nothing structurally wrong with neurotransmitter receptors, but the receptors are in a membrane environment that has altered molecular structure and dynamics. It is these membrane alterations that alter the functional dynamics of neurotransmitter receptors which in turn alters their physiological function. Dr. Pettegrew was one of the first to demonstrate alterations in membrane molecular dynamics in living cells obtained from patients with neuropsychiatric disorders. Alterations were similarly demonstrated in cells obtained from patients with depression (Pettegrew et al., 1979c; Pettegrew et al., 1980a; Pettegrew et al., 1981a; Pettegrew et al., 1981b; Pettegrew et al., 1979b; Pettegrew et al., 1980b; Pettegrew et al., 1981b; Pettegrew et al., 1982b; Pettegrew et al., 1987b; Pettegrew et al., 1993b; Pettegrew et al., 1990c; Pettegrew et al., 1993a; Pettegrew et al., 1990b).

Lithium was shown to correct the membrane dynamic alterations observed in depressive patients.

[0018] Given the rather striking changes in membrane molecular dynamics, Dr. Pettegrew turned to investigate alterations in membrane metabolism (Pettegrew et al., 1978; Pettegrew and Minshew, 1981; Pettegrew et al., 1982a; Glonek et al., 1982a) (Pettegrew et al., 1979a; Glonek et al., 1982b; Cohen et al., 1984; Pettegrew et al., 1986; Pettegrew et al., 1987a; Pettegrew et al., 1988a; Pettegrew et al., 1988b; Pettegrew et al., 1990a; Pettegrew et al., 1991; Keshavan et al., 1991; Kanfer et al., 1993; Pettegrew et al., 1994; Singh et al., 1994; Pettegrew et al., 1995; Klunk et al., 1996; Geddes et al.,
1997; Klunk et al., 1998; Pettegrew et al., 2001; Keshavan et al., 2003; Sweet et al., 2002) and again significant alterations were observed in several neuro-psychiatric disorders including major depressive disorder (Pettegrew et al., 2002). Again, lithium was shown to correct the alteration in membrane metabolism observed in patients with depression.

**CONCERNS ABOUT CURRENT CLASSES OF ANTIDEPRESSANTS IN DEPRESSIVE DISORDERS**

[0019] Concerns have been accumulating on the widespread use of all the current classes of antidepressants. This is reflected in the recently published North American based treatment guidelines (Grunze et al., 2002; Hirschfeld et al., 2002); including those of the APA (Sachs et al., 2000). These recommendations have voiced considerable limitations and a conservative attitude to their use, recommending use be restricted to severe bipolar depressions (Goodwin & Jamison, 1990; Murray & Lopez, 1996; Bostwick & Pankratz, 2000). The recommendations go on to suggest that if antidepressants are used they should be withdrawn as early as possible; thus we are now seeing a shift away from both the use of the current classes of antidepressants and recommendations for their long term use since they are associated with the following problems.

[0020] 1. The risk for induced mania. There is now established a considerable risk of antidepressant induced manic switching and/or rapid cycling. This is seen in both short term and long term exposures. For example with selective reuptake inhibitors (SRIs) clinical samples demonstrate length of switch that are not minimal, that is 15 to 27%. The authors of a number of review articles on this topic suggest that the real rates are around 40% for tricyclic antidepressants (TCAs) and 20% with new SRI antidepressants. Substance abuse has been shown to be a major predictor of antidepressant-induced mania.

[0021] 2. The risk of suicide in bipolar depressed patients. This risk is in and of itself a significant issue of concern. An analysis of SRIs and other novel antidepressants submitted to the FDA totaling nearly 20 thousand cases showed that there was no significant difference in completed or attempted suicides between patients on antidepressants and placebo treated groups. Simply stated, it appears that
antidepressants as a group have not been shown to adequately reduce suicide rates. However, the data on lithium is in contrast to this with a very well established finding of its prophylactic effects against suicidality in a variety of diagnostic categories.

[0022] 3. Antidepressant efficiency in treating bipolar depression. Prophylactic studies with antidepressants are not robust in the treatment of depressive episodes in bipolar disorders. Again, in contrast, the evidence of efficiency in treating bipolar depression with mood stabilizers is much higher (e.g., lithium and lamotrigine).

[0023] 4. The potential value of other antidepressant classes. Based on this extensive new information as to the cautions that need to be employed in the use of the standard and SRI antidepressant classes, there is an urgent need for new classes of antidepressant thymoleptics. One such agent, ALCAR has a body of literature that supports the possibility of its therapeutic value in a number of depressive categories.

[0024] In view of its unique biochemical effects on the nervous system and its stabilizing effects on membrane functions, ALCAR’s antidepressant activity may indeed provide a unique opportunity to address the above-described concerns. Since ALCAR is a natural substance and has been shown to have antidepressant properties without significant side effects and without the potential to induce mania, it is a logical new therapeutic approach.

[0025] ALCAR has been shown to have beneficial effects on age-related neurodegeneration and brain energetic stress providing a rationale for its use in Major Depressive Disorder (MDD). In European clinical trials to date, ALCAR has demonstrated antidepressant activity in MDD subjects without significant side effects (Villardita et al., 1983; Tempesta et al., 1987; Nasca et al., 1989; Bella et al., 1990; Fulgente et al., 1990; Garzya et al., 1990).

OVERVIEW OF BIOLOGICAL FINDINGS IN MAJOR DEPRESSIVE DISORDER

[0026] MDD has been shown to be associated with changes in: (1) neurotransmitter systems such as serotonin, acetylcholine, and noradrenergic; (2) membranes (e.g., composition, metabolism, biophysical parameters, signal transduction, and ion transport); (3) brain energy metabolism; and (4) brain structure. Computed tomography
(CT) and magnetic resonance imaging (MRI) studies in subjects with non-demented, geriatric, major depressive disorder suggest neurodegenerative changes are associated with vascular risk factors (Krishnan, 1993). Beyond brain structural changes, there is evidence from functional neuroimaging studies for molecular, metabolic, and physiologic brain changes suggestive of energetic stress in subjects with MDD. Positron emission tomography (PET) and single photon emission computed tomography (SPECT) studies show a reduced fluorodeoxyglucose metabolic rate (rCMRg) (Buchsbaum et al., 1986) and reduced regional cerebral blood flow (rCBF) (Schlegel et al., 1989) in the basal ganglia and a decrease in rCMRg and rCBF in the frontal lobes of subjects with MDD (Mayberg et al., 1994). Of the neuroimaging methods, $^{31}$P and $^1$H magnetic resonance spectroscopic imaging ($^{31}$P-$^1$H MRSI) studies provide direct information on membrane phospholipid and high-energy phosphate metabolism ($^{31}$P MRSI) as well as a marker for neuronal structural and metabolic integrity ($^1$H MRSI). $^{31}$P and $^1$H MRS studies of subjects with MDD indicate alterations in high-energy phosphate and membrane phospholipid metabolism in basal ganglia and prefrontal cortex (Moore et al., 1997a; Charles et al., 1994; Pettigrew et al. 2002).

**NEUROMORPHOMETRIC CHANGES IN MDD**

[0027] Neuroimaging studies have enhanced our understanding of the pathophysiology of MDD. MRI studies provide neuromorphometric correlates of MDD (reviewed by Botteron & Figiel, 1997). MRI studies of third ventricle size in major depression give mixed results; Coffey et al. (1993) report no difference in ventricle size and Rabins et al. (1991) report increased third ventricle size in subjects with MDD compared with controls. Brain MRI subcortical white matter hyperintensities have been reported in the basal ganglia, periventricular region, and frontal lobe of elderly depressed (Coffey et al., 1988; Figiel et al., 1989; Rabins et al., 1991). There have been reports of decreased volumes of the basal ganglia in MDD; Husain et al. (1991) found reduced volume in the putamen, Krishnan et al. (1993) found reduced volume in the caudate, and Dupont et al. (1995) found reduced volume in the caudate, lenticular nucleus, and thalamus. Coffey et al. (1993) report an approximately 7% reduction in bilateral frontal lobe volume in subjects with MDD.

[0028] These studies reveal neurodegenerative change in MDD. Other as yet unknown molecular and metabolic factors could predispose to both depression and the neuromorphometric changes associated with it.
MAGNETIC RESONANCE SPECTROSCOPY STUDIES OF MAJOR
DEPRESSIVE DISORDER (MDD)

[0029] While there are several MRS studies in bipolar disorder (reviewed by Moore & Renshaw, 1997b), there are only two $^{31}$P MRS studies (Kato et al., 1992; Moore et al., 1997a) and one $^1$H MRS analysis of MDD (Charles et al., 1994). Kato et al. (1992), using a coronal slice DRESS $^{31}$P MRS protocol, examined the frontal cortex of 12 subjects (age 35.3±12.1 years) with MDD, 10 subjects (age 42±8.6 years) with bipolar disorder and 22 control subjects (age 36.1±11.5 years). Although the pH and PME levels were significantly higher in euthymic MDD subjects compared with euthymic bipolar subjects, no significant differences were found for $^{31}$P MRS parameters of MDD subjects compared with control subjects. A study by Moore et al. (1997a) using a $^{31}$P MRS ISIS protocol, measured $^{31}$P metabolites in a 45 cm$^3$ voxel containing the bilateral basal ganglia in 35 unmedicated subjects (age 37.2±1.8 years) with MDD and 18 control subjects (age 38.2±9.9 years). There was a 16% reduction in ATP (β-ATP peak) in the MDD subjects. The PCr/Pi ratio of MDD subjects compared with control subjects did not change. This study indicates that an abnormality in basal ganglia high-energy phosphate metabolism is associated with MDD. A $^1$H MRS study by Charles et al. (1994), using a combination of the STEAM technique for spatial lipid suppression and 1D CSI for additional spatial localization of the basal ganglia and thalamus, examined seven subjects with MDD (age range 63-76, mean = 71.4 years) compared with ten control subjects (age range 65-75, mean = 68.9 years). The subjects with MDD were medication free for two (1 subject) or three (6 subjects) weeks. The authors report an increase in the TMA MRS peak in the basal ganglia of MDD subjects and subsequent drop in the trimethylamine (TMA) peak in four subjects after treatment. We have recently observed an increase in PME and a decrease in PCr in two subjects with MDD (Pettegrew et al., unpublished results).

MOLECULAR AND METABOLIC EFFECTS OF ALCAR

[0030] There is neuroimaging evidence for neurodegeneration and a reduction in energy metabolite levels and rCBF in MDD. These findings provide a rationale for the use of ALCAR in MDD as there is a considerable body of research that indicates that ALCAR has a positive modulating influence on membrane structure, function and metabolism, energy metabolism, and the physiology and metabolism of neurotrophic factors. There also is clinical evidence that ALCAR is beneficial in the treatment of
neurodegenerative disorders as well as normal aging-related processes and the treatment of geriatric depression. A thorough review of the possible CNS actions of ALCAR has appeared (Calvani & Carta, 1991; Pettegrew et al., 2000). What follows is a brief review of the metabolic, physiologic, behavioral, and clinical roles for ALCAR.

**ALCAR’S EFFECT ON ENERGY METABOLISM**

[0031] ALCAR has been shown to exert a beneficial effect on brain metabolism after energetic stresses. In a canine model of complete, global cerebral ischemia and reperfusion, ALCAR treated animals exhibited significantly lower neurological deficit scores (p = 0.0037) and more normal cerebral cortex lactate/pyruvate ratios than did vehicle-treated control animals (Rosenthal et al., 1992). In a rat cyanide model of acute hypoxia, increased rate of phosphatidic acid formation, possibly reflecting increased phospholipase C activity was observed and spatial navigation performance in a Morris task was impaired. Chronic treatment with ALCAR attenuated the cyanide-induced behavioral deficit but had no effect on energy-dependent phosphoinositide metabolism suggesting ALCAR affected free fatty acid metabolism by increasing the reservoir of activated acyl groups involved in the reacylation of membrane phospholipids (Blokland et al., 1993). In a canine model employing 10 minutes of cardiac arrest followed by restoration of spontaneous circulation for up to 24 hours, ALCAR eliminated the reperfusion elevation of brain protein carbonyl groups which reflect free radical-induced protein oxidation (Liu et al., 1993). In a rat streptozotocin-induced model of brain hypoglycemia, ALCAR attenuated both the streptozotocin-induced impairment in spatial discrimination learning and decrease in hippocampal choline acetyltransferase activity (Prickaerts et al., 1995). A deficiency in ALCAR has been shown to be a cause for altered nerve myo-inositol content, Na⁺-K⁺-ATPase activity, and motor conduction velocity in the streptozotocin-diabetic rat (Stevens et al., 1996). Finally, sparse-fur mice have a deficiency of hepatic ornithine transcarbamylase resulting in congenital hyperammonemnic with elevated cerebral ammonia and glutamine and reduced cerebral cytochrome oxidase activity and a reduction in cerebral high-energy phosphate levels. ALCAR treatment increased cytochrome oxidase subunit I mRNA, and restored both cytochrome oxidase activity and the levels of high-energy phosphates (Rao et al., 1997). Our studies of hypoxia in Fischer 344 rats demonstrate ALCAR’s beneficial effect on brain membrane phospholipid and high-energy phosphate metabolism (Pettegrew et al., unpublished results.)
ALCAR'S EFFECT ON MEMBRANE COMPOSITION, STRUCTURE, AND DYNAMICS

[0032] ALCAR has been shown to effect membrane structure and function in a number of different systems. ALCAR administration affects the inner mitochondrial membrane protein composition in rat cerebellum (Villa et al., 1988), increases human erythrocyte membrane stability possibly by interacting with cytoskeletal proteins (Arduini et al., 1990), increases human erythrocyte cytoskeletal protein-protein interactions (Butterfield & Rangachari, 1993), and alters the membrane dynamics of human erythrocytes in the region of the glycerol backbone of membrane phospholipid bilayers (Arduini et al., 1993).

ALCAR'S ENHANCEMENT OF NERVE GROWTH FACTOR ACTIVITY

[0033] A number of studies have demonstrated that ALCAR enhances the neurotrophic activity of nerve growth factor (NGF). ALCAR increases NGF binding in aged rat hippocampus and basal forebrain (Angelucci et al., 1988), increases NGF receptor expression in rat striatum, and increases choline acetyltransferase activity in the same area (De Simone R. et al., 1991), enhances PC12 cells response to NGF (Taglialetela et al., 1991), increases the level of NGF receptor (P75NGFR) mRNA (Taglialetela et al., 1992), increases choline acetyltransferase activity and NGF levels in adult rats following total fimbria-fornix transection (Piovesan et al., 1994; 1995), and enhances motoneuron survival in rat facial nucleus after facial nerve transection (Piovesan et al., 1995).

INFLUENCE OF ALCAR ON CHOLINERGIC AND SEROTONERGIC NEUROTRANSMITTER SYSTEMS

[0034] ALCAR has some cholinergic activity (Fritz, 1963; Tempesta et al., 1985), possibly because it shares conformational properties with acetylcholine (Sass & Werness, 1973). This is interesting as acetylcholine may play an important role in the chronobiological organization of the human body (Morley & Murrin, 1989; Wee & Turek, 1989), mediating also some effects of light on the circadian clock (Wee & Turek, 1989). Acetylcholine is implicated in the regulation of the hypothalamic-pituitary-adrenal (HPA) axis (Mueller et al., 1977; Risch et al., 1981) and cholinomimetics are effective on the HPA axis (Janowsky et al., 1981; Risch et al., 1981). ALCAR also
seems to interfere with the serotonergic system (Tempesta et al., 1982; 1985). There is ample evidence supporting a reduction in serotonergic activity in depression (Ashcroft et al., 1966; Asberg et al., 1976; Cochran et al., 1976; Traskman et al., 1981; Stanley & Mann, 1983); although these results have not always been confirmed (Bowers, 1974; Murphy et al., 1978). The efficacy of 5-HTP also has been reported in involutional depression (Aussilloux et al., 1975). Moreover the selective serotonin reuptake inhibitors (SSRI) antidepressants increase serotonergic transmission and are currently widely used in treating MDD (Aberg-Wistedt et al., 1982; Stark & Hardison, 1985). Serotonin plays an important role in the regulation of circadian rhythms (Kordon et al., 1981; Leibowitz et al., 1989) and there is consistent evidence that it affects cortisol secretion (Imura et al., 1973; Krieger, 1978; Meltzer et al., 1982).

**ALCAR'S EFFECT ON AGING-RELATED METABOLIC CHANGES**

[0035] ALCAR has been demonstrated to reverse aging-related changes in brain ultrastructure, neurotransmitter systems, membrane receptors, mitochondrial proteins, membrane structure and metabolism, memory, and behavior. ALCAR restores the number of axosomatic and giant bouton vesicles in aged rat hippocampus (Badiali et al., 1987), reduces aging-related lipofuscin accumulation in prefrontal pyramidal neurons and hippocampal CA3 neurons in rats (Kohjimoto et al., 1988; Amenta et al., 1989), and reduces aging-related changes in the rat hippocampal mossy fiber system (Ricci et al., 1989). ALCAR reduces the age-dependent loss of glucocorticoid receptors in rat hippocampus (Ricci et al., 1989), attenuates the age-dependent decrease in NMDA receptors in rat hippocampus (Fiore & Rampello, 1989; Castorina et al., 1993; 1994; Piovesan et al., 1994; and reviewed by Castorina & Ferraris, 1988), and reduces age-related changes in the dopaminergic system of aging mouse brain (Sershen et al., 1991). Age-related changes in mitochondria also are reduced by ALCAR. ALCAR increases cytochrome oxidase activity in rat cerebral cortex, hippocampus, and striatum (Curti et al., 1989), restores to normal reduced transcripts of mitochondrial DNA in rat brain and heart but not liver (Gadaleta et al., 1990), increases cytochrome oxidase activity of synaptic and non-synaptic mitochondria (Villa & Gorini, 1991), reverses age-related reduction in the phosphate carrier and cardiolipin levels in heart mitochondria (Paradies et al., 1992), reverses age-related reduction in cytochrome oxidase and adenine nucleotide transferase activity in rat heart by modifying age-related changes in mitochondrial cardiolipin levels (Paradies et al., 1994; 1995), and reverses age-related alteration in the protein composition of the inner mitochondrial membrane (Villa et al.,...
1988). ALCAR also increases synaptosomal high-affinity choline uptake in the cerebral cortex of aging rats (Curti et al., 1989; Piovesan et al., 1994), increases choline acetyltransferase activity in aged rat striatum (De Simone R. et al., 1991; Taglialatela et al., 1994), modulates age-related reduction in melatonin synthesis (Esposti et al., 1994), reverses the age-related elevation in free and esterified cholesterol and arachidonic acid (20:4) in rat plasma (Ruggiero et al., 1990), and increases PCr and reduces lactate/pyruvate and sugar phosphate levels in adult and aged rat brain (Aureli et al., 1990). Age-related changes in NGF are reduced by ALCAR: ALCAR increases NGF receptor expression in rat striatum (De Simone R. et al., 1991) and in PC12 cells (Castorina et al., 1993); enhances the effect of NGF in aged dorsal root ganglia neurons (Manfridi et al., 1992); exerts a neurotrophic effect in three month old rats after total fimbria transection (Piovesan et al., 1994); and increases NGF levels in aged rat brain (Taglialatela et al., 1994). ALCAR has been shown in aged rats to modulate synaptic structural dynamics (Bertoni-Freddari et al., 1994) and improve measures of behavior (Angelucci, 1988; Kohjimoto et al., 1988) as well as memory (Barnes et al., 1990; Caprioli et al., 1990; 1995). ALCAR has been reported to normalize the pituitary-adrenocortical hyperactivity in pathological brain aging (Nappi et al., 1988; Ghirardi et al., 1994). We have reported that ALCAR improves standardized clinical measures and measures of membrane phospholipid and high-energy phosphate metabolism in subjects with Alzheimer’s disease (AD) measured by in vivo $^{31}$P MRS (Pettegrew et al., 1995). We now have data in a rat hypoxia model which demonstrate that ALCAR has more beneficial effects on aged rats (30 months) than on adolescent (1 month) or adult (12 months) animals (Pettegrew et al., unpublished results).

ANTIDEPRESSANT EFFECTS OF ALCAR

[0036] In European clinical trials, ALCAR has been shown to have significant antidepressant activity in geriatric depressed subjects with minimal or no side effects (Villardita et al., 1983; Tempesta et al., 1987; Nasca et al., 1989; Bella et al., 1990; Fulgente et al., 1990; Garzya et al., 1990; Geccele et al., 1991). Villardita et al. (1983) reported a double-blind ALCAR/placebo study of 28 subjects (18 males, 10 females; 72.3±7.3 years). Sixteen subjects were treated with ALCAR (1.5 gm/day; baseline HDRS = 26.3±3.3) and 12 patients were treated with placebo (baseline HDRS = 26.6±3.2) for 40 days. By day 40, the ALCAR treated subjects showed significant improvement (p < 0.001) in the Hamilton Depressive Rating Scale (HDRS) but the placebo treated subjects did not. There were no side effects to ALCAR. Tempesta et al.
(1987) in an open label, cross over study of 24 subjects over the age of 70 years, all of whom were nursing home residents, reported ALCAR (2 gm/day) to be highly effective in reducing HDRS scores, especially in subjects with more severe clinical symptoms. Again there were no reported ALCAR side effects. In a simple blind ALCAR/placebo study of 20 subjects (10 ALCAR treated subjects; 62.5+5.7 years, 8 males, 2 females, baseline HDRS = 44.9+3.1 and 10 placebo treated subjects; 62.5+5.3 years, 8 males, 2 females, baseline HDRS = 43.9+2.8), Nasca et al. (1989) demonstrated a significant improvement in the HDRS scores of ALCAR treated subjects at day 40 of treatment (p < 0.001). There was no improvement in the placebo treated group. Similar significant beneficial effects of ALCAR on the HDRS were observed in randomized, double-blind, ALCAR/placebo studies of Garzya et al. (1990) (28 subjects; ages 70-80 years; ALCAR 1.5 gm/day), Fulgente et al. (1990) [60 subjects; 70-80 years; ALCAR 3.0 gm/day; baseline HDRS (ALCAR = 25; placebo = 23); day 60 HDRS (ALCAR = 12; placebo = 22); p # 0.0001], and Bella et al. (1990) [60 subjects, 60-80 years, ALCAR 3.0 gm/day; baseline HDRS (ALCAR = 22; placebo = 21); day 60 HDRS (ALCAR = 11; placebo = 20); p # 0.0001]. ALCAR was well tolerated in these studies even at the higher dosages. A double-blind, ALCAR/placebo study by Gecele et al. (1991) (30 subjects, 66-79 years, ALCAR 2 gm/day) not only showed a significant improvement in the HDRS of ALCAR treated subjects (p < 0.001) but a significant reduction in both mean cortisol levels (p < 0.001) as well as 12 am (p < 0.001) and 4 pm (p < 0.01) cortisol levels.

Since acetyl-L-carnitine (ALCAR) is a natural substance and has been shown to have antidepressant properties without significant side effects and without the potential to induce mania, it is a logical new therapeutic approach.

REFERENCES


[00249] Most of the studies have been directed toward geriatric subjects. However, it is also desirable to use acetyl-L-carnitine (ALCAR) for non-geriatric human subjects as well as for adolescent human subjects.
SUMMARY OF THE INVENTION

[00250] In accordance with preferred embodiments of the present invention, some of the problems associated with treating depression and recurring depression are overcome. A method for use of acetyl-L-carnitine (ALCAR) for treatment of depressive disorders in non-geriatric and adolescent humans is presented.

[00251] In the context of the invention described herein, it has been found that the use of a therapeutically effective amount of ALCAR or one of its pharmacologically acceptable salts, is beneficial to depressed subjects, particularly in non-geriatric and adolescent patients, without a disturbing side-effect profile exhibited by traditional antidepressants and improving the quality of life itself in the subjects treated, whether human subjects and preventing recurrent episodes of depression or bipolar depression. ALCAR also provides beneficial membrane phospholipid and high-energy phosphate changes in the brain of individuals with major depressive disorders (MDD).

[00252] The foregoing and other features and advantages of preferred embodiments of the present invention will be more readily apparent from the following detailed description. The detailed description proceeds with references to the accompanying drawings.
BRIEF DESCRIPTION OF THE DRAWINGS

[00253] Preferred embodiments of the present invention are described with reference to the following drawings, wherein:

[00254] FIG. 1B is a graph showing the correlation of PME($s$-$\tau_c$) levels from the prefrontal region with HDRS scores for both depressed patients (● subject #1; ◆ subject #2);

[00255] FIG. 1A is a graph showing the correlation of PCr levels from the prefrontal region with HDRS scores for both depressed patients (● subject #1; ◆ subject #2);

[00256] FIG. 2A is a graph showing PME($s$-$\tau_c$) and PCr levels in the a) prefrontal region of the two depressed patients (● subject #1; ◆ subject #2) and normal controls (O, n=6) at baseline and at 6 and 12 weeks follow up. The control values include mean±SD;

[00257] FIG. 2B is a graph showing PME($s$-$\tau_c$) and PCr levels in the basal ganglia region of the two depressed patients (● subject #1; ◆ subject #2) and normal controls (O, n=6) at baseline and at 6 and 12 weeks follow up. The control values include mean±SD;

[00258] FIG. 3A is a phosphorous magnetic resonance spectroscopic image showing the Z-scores of the two depressed subjects compared with controls at entry and 12 weeks for PME($s$-$\tau_c$) metabolite levels for those regions with significant differences. The intensity of the color is scaled to the z-score (mean difference/SD) given on the scale below the image. Z-scores for PME($s$-$\tau_c$) and PCr levels in the frontal region exceed 3.0 and 2.0, respectively;
[00259] FIG. 3B is a phosphorous magnetic resonance spectroscopic image showing the Z-scores of the two depressed subjects compared with controls at entry and 12 weeks for PCr metabolite levels for those regions with significant differences. The intensity of the color is scaled to the z-score (mean difference/SD) given on the scale below the image. Z-scores for PME(s-τ₅) and PCr levels in the frontal region exceed 2.0 and 2.0, respectively;

[00260] FIG. 4 is a block diagram illustrating an effect of ALCAR on in vitro ³¹P MRS α-GP and PCr levels under hypoxic (30 seconds) and normoxic conditions in Fischer 344 rats;

[00261] FIG. 5 is a block diagram illustrating an effect of ALCAR on in vitro ³¹P MRS phospholipid levels under hypoxic and normoxic conditions in Fischer 344 rats; and

[00262] FIG. 6 is a block diagram illustrating a percent change of in vivo ³¹P MRSI metabolite levels and PME, PDE linewidths [full width at half maximum (fwhm)] of 2 MDD subjects compared with 13 control subjects.
DETAILED DESCRIPTION OF THE INVENTION

[00263] Carnitines in general are compounds of including the chemical formula (1):

\[
\text{CH}_3 \begin{array}{c}
\text{CH}_3 \\
\text{N}^+ \\
\text{CH}_3
\end{array} \xrightarrow{X^-} \text{CH}_{2}CH(OH)COO \tag{1}
\]

where R is hydrogen or an alkanoyl group with 2 to 8 carbon atoms, and X^- represents the anion of a pharmaceutically acceptable salt.

[00264] The invention described herein includes both the administration of L-carnitine or an alkanoyl L-carnitine or one of its pharmacologically acceptable salts of formula (1) in the treatment of depression, and pharmaceutical compositions, which can be administered orally, parenterally or nasally, including controlled-release forms. Preferably, the alkanoyl L-carnitine is selected from the group consisting of acetyl-L-carnitine (hereinafter abbreviated to ALC or ALCAR), propionyl L-carnitine (hereinafter abbreviated to PLC), butyryl L-carnitine, valeryl L-carnitine and isovaleryl L-carnitine, or one of their pharmacologically acceptable salts. The ones preferred are acetyl L-carnitine, propionyl L-carnitine and butyryl L-carnitine. The most preferred is acetyl L-carnitine.

[00265] What is meant by a pharmacologically acceptable salt alkanoyl L-carnitine is any salt of the latter with an acid that does not give rise to toxic or side effects. These acids are well known to pharmacologists and to experts in pharmaceutical technology.

[00266] Examples of pharmacologically acceptable salts of L-carnitine or of the alkanoyl L-carnitines, though not exclusively these, are chloride; bromide; iodide; aspartate; acid aspartate; citrate; acid citrate; tartrate; acid tartrate; phosphate; acid phosphate; fumarate; acid fumarate; glycerophosphate; glucose phosphate; lactate; maleate; acid maleate; mucate; orotate, oxalate; acid oxalate; sulphate; acid sulphate; trichloroacetate; trifluoroacetate; methane sulphonate; pamoate and acid pamoate.
As used herein, a geriatric subject is an individual sixty-five years of age or older. See The Merck Manual, 15th edition (1987) p. 2389. A non-geriatric subject is less than sixty-five years old but not an adolescent.

Adolescence is the transitional stage of development between childhood and full adulthood, representing the period of time during which a person is biologically adult but emotionally may not at full maturity. The ages which are considered to be part of adolescence vary by culture. In the United States, adolescence is generally considered to begin around age thirteen, and end around twenty-four. By contrast, the World Health Organization (WHO) defines adolescence as the period of life between around age ten and end around age twenty years of age. As used herein, an adolescent subject is at least ten years old and less than twenty-six years old.

Phosphorus magnetic resonance spectroscopic imaging ($^{31}$P MRSI) analysis of two depressed elderly subjects treated with ALCAR for 12 weeks are compared with those of six normal non-demented, non-depressed subjects.

A twelve-week, open, clinical, $^{31}$P MRSI study design was used to examine the possible effects of ALCAR on brain metabolism and depressive symptomatology in non-demented geriatric major depressive disorder (NDG-MDD). Two depressed, non-demented [Folstein Mini-Mental State Exam (MMSE)>24] male subjects, 70 and 80 years old, were compared with six age, social-economic status, and medically matched non-demented controls (all male, mean age of 73.6±3.6 years, range 69.7-78.2 years). The two elderly depressed subjects completed baseline Structural Clinical Interview of DSM-IV (SCID) I/P version 2.0, HDRS (17 item), MMSE, UKU Side Effect Rating Scale (UKU), and Cumulative Illness Rating Scale (CIRS) to assess medical burden, baseline physical, ECG, and laboratory tests for hematology, urine analysis, immunopathology, and blood chemistry. Follow-up visits for the depressed subjects were done every other week for 12 weeks. Efficacy (psychiatric evaluation) was assessed by changes in the HDRS which was performed at baseline and every other week for 12 weeks along with secondary measures (MMSE; CIRS; and UKU), whereas the CIRS was performed at baseline, 6, and 12 weeks. Physical examinations and EKGs were performed at baseline, 6, and 12 weeks. The baseline MR evaluation was scheduled and completed prior to the administration of ALCAR. Follow-up MR evaluations were at 6 and 12 weeks. Acetyl-L-carnitine was administered in the form of oral tablets containing 590 mg of acetyl-L-carnitine hydrochloride (500 mg acetyl-L-carnitine). The dosage
regimen was fixed at three grams of acetyl-L-carnitine given two tablets three times a day for 12 weeks.

[00271] $^{31}P$ MRSI acquisition—A custom built, doubly tuned transmit/receive volume head coil was used to acquire the $^1H$ MRI and 2D $^{31}P$ MRSI data on a GE Signa 1.5 T whole body MR imager. First, sets of axial and sagittal scout MR images were collected. The 30 mm thick MRSI slice was positioned parallel with the anterior commissure-posterior commissure line to include the right and left prefrontal, basal ganglia, superior temporal, inferior parietal, occipital, and centrum semiovale regions. A self-refocused spin echo pulse sequence with an effective flip range of 60° and an echo time of 2.5 ms, was used to acquire the $^{31}P$ MRSI (360 mm field of view, 30 mm slice thickness, 8x8 phase encoding steps [45x45x30 mm$^3$ nominal voxel dimensions], 2 s TR, 1024 data points, 4.0 kHz spectral bandwidth and 16 NEX).

[00272] MRSI post-processing and quantification—To optimize the right and left voxel positions for the six regions, the 8x8 $^{31}P$ grid was shifted with respect to the anatomical MRI and a mild spatial apodization (i.e., Fermi window with 90% diameter and 5% transition width) was applied prior to the inverse Fourier transform. The remaining processing steps were 100% automated. A 5 Hz exponential apodization was applied and the PME, phosphodiester (PDE), PCr, $\alpha$-, $\gamma$-, and $\beta$-ATP, and inorganic orthophosphate (Pi), were modeled in the time domain with exponentially damped sinusoids and by omitting the first 2.75 ms of the free induction decay (FID) using the Marquardt-Levenberg algorithm. This approach ensured that the PME and PDE resonances primarily reflected the freely mobile, short correlation time ($s-\tau_c$), water soluble PME($s-\tau_c$) and PDE($s-\tau_c$) metabolites without the influence of relatively broad underlying signals within the PME and PDE spectral region. The PME($s-\tau_c$) (i.e., phosphaethanolamine, phosphocholine, and inositol-1-phosphate) are predominantly building blocks of phospholipids and therefore, the relative concentrations of these metabolites are a measure of the active synthesis of membranes; the PDE($s-\tau_c$) (i.e., glycerophosphocholine and glycerophosphoethanolamine) are major products of membrane degradation. To obtain intermediate correlation time ($i-\tau_c$) components within the PME and PDE spectral region, the FIDs were modeled a second time but with omitting the first 0.75 ms of the FID and then taking the difference between the PME and PDE amplitudes of the two modeled results. PME($i-\tau_c$) moieties include less mobile molecules such as phosphorylated proteins and PMEs that are tightly coupled (in terms of MRS) to macromolecules [i.e., PMEs inserting into membrane phospholipids. PDE($i-\tau_c$)
moieties include less mobile PDEs that are part of small membrane phospholipid structures such as micelles, synaptic vesicles, and transport/secretory vesicles and PDE moieties coupled to larger molecular structures (i.e., PDEs inserting into membrane phospholipid structures. The right/left side effect was eliminated by averaging the signal from the two voxels, prior to fitting (which included correcting for phase and resonance frequency). Additionally, metabolite levels are expressed as a mole % relative to the total \(^{31}\)P signal.

[00273] The statistical analysis was done using the Statview (SAS Institute, Inc.) software package. The pearson t correlation test used to correlate between variables.

[00274] The two elderly depressed subjects were diagnosed with MDD according to DSM-IV criteria. No previous antidepressant medications were taken by the subjects in the three months prior to the study. Subject #1 has baseline, 6 and 12 week HDRS scores of 15, 1 and 0 and subject #2 had scores of 20, 17, and 3, respectively. Thus both depressed subjects were clinically improved at endpoint, fulfilling criteria for remission (HDRS<8). Medical conditions diagnosed in the depressed subjects included s/p knee arthroscopy, s/p cervical disk removal, hearing loss and benign prostatic hypertrophy in subject #1 and benign prostatic hypertrophy in subject #2. No clinically significant abnormalities were found in the laboratory exams and EKG of either depressed subject. Baseline, 6, and 12 weeks CIRS were 7, 6, and 5 for subject #1; and 4, 4, and 2 for subject #2, respectively. The change reflects the improvement of depressive symptomatology. Side effects from ALCAR treatment were mild and included dry mouth in subject #1 and a slight increase in perspiration in subject #2.

[00275] FIG. 1 shows the correlation of PME(s-\(\tau_{c}\)) \((r=0.86, p=0.069\) and PCr \((r=0.97, p=0.002)\) levels from the prefrontal region with HDRS scores for both depressed subjects.

[00276] FIG. 2 illustrates the prefrontal and basal ganglia PCr and PME(s-\(\tau_{c}\)) levels at baseline, 6 and 12 weeks for the two depressed subjects and the mean PCr and PME(s-\(\tau_{c}\)) levels for the six normal controls.

[00277] Unfortunately, the 6 week \(^{31}\)P MRSI session for subject #1 produced poor quality, unacceptable data and this time point is missing from the graphs. Baseline prefrontal PME(s-\(\tau_{c}\)) levels in the depressed subjects were 1.5 to 2.0 SD higher than the mean of the controls and this increase was normalized with ALCAR treatment. Both
depressed subjects had prefrontal PCr levels one SD higher than the mean of controls and ALCAR treatment further increased PCr levels by 27% and 31%, respectively. Similar changes in PME(s-τc) and PCr levels also were observed in the basal ganglia region (FIG. 2), but these metabolite levels did not correlate with HDRS scores. Although the most marked changes occur in the prefrontal region, z-score plots of the significant PME(s-τc) and PCr changes between depressed subjects and controls illustrates the other brain regions also undergo changes with ALCAR treatment. FIG. 3 demonstrates that compared with normal subjects, the two untreated depressed subjects at baseline had increased levels of PME(s-τc) in the prefrontal region (p=0.006). After 12 weeks of ALCAR treatment, the PME(s-τc) are normalized in the prefrontal regions but elevated in the superior temporal regions (p=0.05. In addition, PCr levels are elevated in the prefrontal (p=0.001), basal ganglia (p=0.022), and occipital (p=0.027) regions after 12 weeks of ALCAR treatment. There were no significant changes in the other metabolite levels.

[00278] While not wishing to be bound by any particular theory, the above findings suggest that beneficial clinical effects of acetyl-L-carnitine appear to be associated with changes in brain prefrontal PME(s-τc) and PCr levels. In the prefrontal region, the depressed subjects compared with controls after 12 weeks of ALCAR treatment show normalization of PME(s-τc) and elevation of PCr levels.

[00279] The PME(s-τc) resonance is predominantly composed of phosphocholine, phosphoethanolamine and inositol-1-phosphate which are precursors in membrane phospholipid metabolism. The increased PME(s-τc) in depression, as also observed by others is not fully understood and will require further study. ALCAR treatment seems to restore PME(s-τc) levels to normal and there was a trend for the decreasing PME levels to correlate with clinical improvement. In the prefrontal region, twelve weeks of ALCAR treatment also elevated PCr, a high-energy phosphate metabolite which is an immediate precursor of ATP.

[00280] Compared with the control group, similar findings were observed for basal ganglia PME(s-τc) and PCr levels, but the metabolite levels did not correlate with HDRS scores. This may be due to the small number of depressed patients analyzed. Other brain regions may be affected by depression and these changes may be altered by ALCAR treatment (FIG. 3).
ACETYL-L-CARNITINE (ALCAR) RESULTS

[00281] MDD is a major, world-wide health problem. There is a need for new treatment approaches that have a wide margin of safety and can speed the onset to remission and reduce the rate of recurrence in this major mental health problem. In addition, the molecular and metabolic factors that underlie MDD and contribute to the slow and variable treatment response are further identified. Since ALCAR has demonstrated beneficial effects on neurodegenerative processes as well as beneficial effects on energy metabolism, membrane structure/function/metabolism, and neurotrophic effects, it is used in treatment of MDD. Many of the metabolic and molecular processes in adolescent and non-geriatric subjects are altered by ALCAR and thus are amenable to ALCAR treatment.

[00282] ALCAR treatment decreases levels of phosphomonoesters (PME) and increases levels of phosphocreatine (PCr) in a brain of an adolescent or non-geriatric human subject with depression or bi-polar depression. ALCAR also produces beneficial changes to membrane phospholipid and high-energy phosphate metabolism in a brain a brain of an adolescent or non-geriatric human subject with depression or bi-polar depression.

[00283] What is meant by a pharmacologically acceptable salt of ALCAR is any salt of the latter with an acid that does not give rise to toxic or side effects. These acids are well known to pharmacologists and to experts in pharmaceutical technology.

[00284] One preferred form of daily dosing of ALCAR for clinical use is a composition comprising an amount of an acetyl L-carnitine, preferably equivalent to 0.1 to 3 g, and preferably 0.5 to 3 g per day.

[00285] ALCAR does not appear to induce mania in animal models or in clinical trials to date. Since animal and basic science studies demonstrate that ALCAR shares several important molecular mechanisms with lithium, but without lithium’s potential toxicity, ALCAR could provide prophylactic effects against suicidality. Given ALCAR’s similarity to lithium at several molecular mechanistic levels, ALCAR is effective in treating bipolar depression and preventing recurrent episodes. Long-term therapy of MDD with therapeutic agents that have molecular properties that slow or reverse neurodegenerative changes as well as behavioral changes is desirable. ALCAR is one
such therapeutic agent. Few existing $^{31}$P and $^1$H MRSI studies of MDD provide findings for compounds which demonstrate both membrane phospholipid and high-energy phosphate changes in the brain of individuals with MDD. However, new studies with ALCAR demonstrate such changes (see below). Since ALCAR can interact with both cholinergic and serotonergic neurotransmitter systems, it will modulate neurobiological and psychobiological activities controlled by these two neurotransmitter systems. This partially explains ALCAR's antidepressant activity.

**EFFECT OF ALCAR ON BRAIN METABOLIC RESPONSE TO BRIEF ENERGETIC STRESS**

[00286] ALCAR has been shown to provide a protective effect in several animal models of brain energetic stress. ALCAR also has been shown to be an effective treatment of MDD which is associated with neurodegenerative and metabolic changes consistent with energetic stress.

[00287] FIG. 4 is a block diagram illustrating an effect of ALCAR on *in vitro* $^{31}$P MRS α-GP and PCR levels under hypoxic (30 seconds) and normoxic conditions in Fischer 344 rats.

[00288] FIG. 5 is a block diagram illustrating an effect of ALCAR on *in vitro* $^{31}$P MRS phospholipid levels under hypoxic and normoxic conditions in Fischer 344 rats.

[00289] The rat brain responds differentially to brief energetic stress (30 seconds of hypoxia) depending on the age of the animal. The effect of ALCAR (75 mg/kg animal weight injected intraperitoneally 1 hour before sacrificing the animal) on both normoxic rat brain and rat brain exposed to brief hypoxia (30 seconds) was investigated (FIGS. x and x). These studies were conducted on aged rats (30 months) to provide possible insights into human aged brain and MDD. While ALCAR under normoxic conditions (ALCAR/normoxia) did not alter α-GP levels, under ALCAR/hypoxia conditions, the α-GP levels were elevated higher (approximately +80% compared with controls, p = 0.01) than under 30 seconds of hypoxia alone (approximately +25% compared with controls, p = 0.06). Mirror-image findings were observed for PCR levels which decrease with hypoxia (non-significant), increase with ALCAR/normoxia (non-significant), and decrease with ALCAR/hypoxia (non-significant, p = 0.07)(FIG. 4).
[00290] The findings for brain phospholipids are particularly striking (FIG. 5) given the brevity of the hypoxia. Cardiolipin levels are increased (approx. +20%) after 30 seconds of hypoxia (p < 0.01), are unchanged with ALCAR/normoxia, and non-significantly reduced with ALCAR/hypoxia. Phosphatidylserine (PtdS) levels are unchanged with hypoxia but are decreased with both ALCAR/normoxia (approx. -50%, p < 0.01) and ALCAR/hypoxic (approx. -75%, p < 0.01).

[00291] These studies provide direct evidence for ALCAR effects on brain membrane phospholipid metabolism and the NADH/α-GP shuttle pathway under conditions of normoxia (PtdS, SPH) and brief hypoxia (α-GP, PtdS, SPH, PtdI). These mechanisms are also important in human clinical conditions that involve brain aging and possible energetic stress such as MDD.

**IN VIVO $^{31}$P MRS FINDINGS IN TWO YOUNG SUBJECTS WITH MDD**

[00292] FIG. 6 is a block diagram illustrating a percent change of in vivo $^{31}$P MRSI metabolite levels and PME, PDE linewidths [full width at half maximum (fwhm)] of 2 MDD subjects compared with 13 control subjects.

[00293] As part of an ongoing $^{31}$P-$^{1}$H MRSI study of never-medicated, first-episode schizophrenia subjects three $^{31}$P MRSI spectra on 2 MDD subjects (1 Asian male, 1 white female, 24±2.3 years) were obtained. The MDD spectral results are compared with those obtained from 13 controls (6 males; 3 white, 2 African-American, 1 Asian and 7 females; 4 white, 3 African-American; 21±1.0 years). PME levels in the MDD subjects were increased by approximately 15% (p=0.13) while there were decreases in the levels of PDE (approx. -7%; p=0.08), PCr (approx. -5%, p=0.61), and β-ATP (approx. -3%, p=0.87) (FIG. 6). Treatment with ALCAR lowered PME levels in the MDD subjects. Of note is that the PDE linewidth is decreased by approximately -15% suggesting the loss of PDE moieties is mostly those with ß-ε such as synaptic vesicles. These findings suggest molecular alterations related to both membrane phospholipid and high-energy metabolism in these subjects.

[00294] The methods describe herein treat depression and bi-polar depression with ALCAR, thereby avoiding unwanted side-effects exhibited by conventional antidepressant agents. ALCAR also helps prevents recurrent episodes of depression and bi-polar depression.
[00295] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

[00296] It should be understood that the architecture, programs, processes, methods and systems described herein are not related or limited to any particular type of component or compound unless indicated otherwise. Various types of general purpose or specialized components and compounds may be used with or perform operations in accordance with the teachings described herein.

[00297] In view of the wide variety of embodiments to which the principles of the present invention can be applied, it should be understood that the illustrated embodiments are exemplary only, and should not be taken as limiting the scope of the present invention. For example, the steps of the flow diagrams may be taken in sequences other than those described, and more or fewer elements may be used in the block diagrams.

[00298] The claims should not be read as limited to the described order or elements unless stated to that effect. In addition, use of the term "means" in any claim is intended to invoke 35 U.S.C. §112, paragraph 6, and any claim without the word "means" is not so intended.

[00299] Therefore, all embodiments that come within the scope and spirit of the following claims and equivalents thereto are claimed as the invention.
WE CLAIM:

1. A method for treating depression and preventing recurrent episodes thereof in an adolescent or non-geriatric human subject comprising an effective amount of an acetyl-L-carnitine (ALCAR) or a pharmaceutically acceptable salt thereof, wherein the effective amount of an acetyl-L-carnitine (ALCAR) or the pharmaceutically acceptable salt thereof produces beneficial changes to membrane phospholipid and high-energy phosphate metabolism in a brain of the adolescent or non-geriatric human subject.

2. The method of Claim 1 wherein the effective amount an acetyl-L-carnitine (ALCAR) or the pharmaceutically acceptable salt thereof decreases levels of phosphomonoesters (PME) in a brain of an adolescent or non-geriatric human subject with depression.

3. The method of Claim 1 wherein the effective amount acetyl-L-carnitine (ALCAR) or the pharmaceutically acceptable salt thereof increases levels of phosphocreatine (PCr) in a brain of an adolescent or non-geriatric human subject with depression.
4. The method of Claim 1, wherein the pharmacologically acceptable salt is selected from the group consisting of chloride; bromide; iodide; aspartate, acid aspartate; citrate, acid citrate; tartrate; phosphate, acid phosphate; fumarate, acid fumarate; glycerophosphate; glucose phosphate; lactate; maleate, acid maleate; mucate; orotate; oxalate; acid oxalate; sulphate, acid sulphate; trichloroacetate; trifluoroacetate and methane sulphonate.

5. The method of Claim 1, wherein the administration is in the form of a composition comprising said carnitine or a pharmaceutically acceptable salt thereof in combination with a pharmaceutically acceptable excipient and/or vehicle.

6. The method of Claim 1, wherein 0.1 to 3 g/day of the acetyl-L-carnitine or of an equivalent amount of a pharmaceutically acceptable salt thereof are administered.

7. The method of Claim 1 wherein the acetyl-L-carnitine is administered in the form of a dietary supplement.

8. The method of Claim 1, wherein the acetyl-L-carnitine is administered orally, parenterally, rectally, sublingually or transdermally, in the form of a medicament.
9. A method for treating bi-polar depression and preventing recurrent episodes thereof in an adolescent or non-geriatric human subject comprising an effective amount of an acetyl-L-carnitine or a pharmaceutically acceptable salt thereof, wherein the effective amount of an acetyl-L-carnitine or the pharmaceutically acceptable salt thereof produces beneficial changes to membrane phospholipid and high-energy phosphate metabolism in a brain of the adolescent or non-geriatric human subject.

10. The method of Claim 9 wherein the effective amount an acetyl-L-carnitine (ALCAR) or the pharmaceutically acceptable salt thereof decreases levels of phosphomonoesters (PME) in a brain of an adolescent or non-geriatric human subject with bi-polar depression.

11. The method of Claim 9 wherein the effective amount acetyl-L-carnitine (ALCAR) or the pharmaceutically acceptable salt thereof increases levels of phosphocreatine (PCR) in a brain of an adolescent or non-geriatric human subject with bi-polar depression.
FIG. 3B

Entry

12 Weeks

4/5