

Treatment of attention deficit hyperactivity disorder with monoamine amino acid precursors and organic cation transporter assay interpretation

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Background: This paper documents a retrospective pilot study of a novel approach for treating attention deficit hyperactivity disorder (ADHD) with amino acid precursors of serotonin and dopamine in conjunction with urinary monoamine assays subjected to organic cation transporter (OCT) functional status determination. The goal of this research was to document the findings and related considerations of a retrospective chart review study designed to identify issues and areas of concern that will define parameters for a prospective controlled study.

Methods: This study included 85 patients, aged 4–18 years, who were treated with a novel amino acid precursor protocol. Their clinical course during the first 8–10 weeks of treatment was analyzed retrospectively. The study team consisted of PhD clinical psychologists, individuals compiling clinical data from records, and a statistician. The patients had been treated with a predefined protocol for administering amino acid precursors of serotonin and dopamine, along with OCT assay interpretation as indicated.

Results: In total, 67% of participants achieved significant improvement with only amino acid precursors of serotonin and dopamine. In patients who achieved no significant relief of symptoms with only amino acid precursors, OCT assay interpretation was utilized. In this subgroup, 30.3% achieved significant relief following two or three urine assays and dosage changes as recommended by the assay results. The total percentage of patients showing significant improvement was 77%.

Conclusion: The efficacy of this novel protocol appears superior to some ADHD prescription drugs, and therefore indicates a need for further studies to verify this observation. The findings of this study justify initiation of further prospective controlled studies in order to evaluate more formally the observed benefits of this novel approach in the treatment of ADHD.

Keywords: attention deficit hyperactivity disorder, 5-hydroxytryptophan, tyrosine, L-dopa, organic cation transporter assay interpretation

Introduction

A large meta-analysis (n = 171,756) published in 2007 involving the review of 303 literature articles placed the worldwide pooled incidence of attention deficit hyperactivity disorder (ADHD) at 5.29%. However, this review suggested that geographic location plays only a limited role in the reasons for the large variability of ADHD/hyperactivity disorder prevalence estimates worldwide.¹ This paper documents the results of a retrospective chart review relating to a novel serotonin and dopamine amino acid precursor treatment approach to ADHD which integrates organic cation transporter (OCT) assay interpretation.^{2–7} Our hypothesis was that this novel approach of admin-

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istering amino acid precursors of serotonin and dopamine with OCT assay interpretation when indicated may have efficacy that is superior to some of the prescription drugs currently used in the treatment of ADHD.

The diagnosis of ADHD is dependent upon meeting the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria in the areas of inattention, hyperactivity, and impulsivity which negatively affect performance in school and work, as well as in relationships with others.⁸ It is a generally accepted premise that a primary factor in development of ADHD is the status of the monoamine system to include serotonin, dopamine, norepinephrine, and epinephrine. In response, the pharmaceutical industry has demonstrated, to the satisfaction of the US Food and Drug Administration (FDA), that certain drugs that impact the monoamine systems meet FDA efficacy standards. Examples of these drugs include neutral sulfate salts of dextroamphetamine and amphetamine,⁹ methylphenidate,¹⁰ dexmethylphenidate,¹¹ atomoxetine,¹² and lisdexamfetamine dimesylate.¹³

Side effects and adverse reactions associated with ADHD prescription medications are significant, serious, and potentially life-threatening. The following is a limited list of these events associated with the ADHD group of drugs as a whole, which include, but are not limited to:⁹⁻¹³

- Black box warning of increased risk of suicidal ideation
- Severe liver injury
- Sudden death in cases with pre-existing structural cardiac abnormalities or other serious heart problems
- Risk of stroke and myocardial infarction
- Exacerbation of symptoms of behavior disturbance and thought disorder in patients with a pre-existing psychotic disorder
- Induction of mixed/manic episodes
- Treatment by stimulants at usual doses can cause emergent psychotic or manic symptoms, eg, hallucinations, delusional thinking, or mania in children and adolescents without prior history of psychotic illness or mania
- Amphetamines may impair the ability of the patient to engage in potentially hazardous activities such as operating machinery or vehicles
- Higher incidence of infection, photosensitivity reaction, constipation, tooth disorders, emotional liability, decreased libido, somnolence, speech disorder, palpitation, twitching, dyspnea, sweating, dysmenorrhea, and impotence
- Integument disorders including, but not limited to, urticaria, rash, and hypersensitivity reactions, including

angioedema and anaphylaxis; serious skin rashes, including Stevens Johnson syndrome and toxic epidermal necrolysis

- Lowering of seizure threshold
- Increased aggression and hostility
- Contraindicated in patients with marked anxiety, tension, and agitation, because the drugs may aggravate these symptoms
- Risk of drug dependence
- Development of leukopenia and/or anemia.

These drugs do not increase the total number of neurotransmitter molecules in the central nervous system. Their primary mechanism of action is thought to be reuptake inhibition which sets up conditions that move neurotransmitters from one place to another.⁴⁻⁸ However, previous writings suggest that the process of reuptake inhibition may deplete neurotransmitters throughout the body.^{4,14-19} The administration of amphetamine stimulants creates another potential area of concern relating to neurotoxicity.²⁰⁻²²

There has been no previous peer-reviewed literature published addressing the efficacy of amino acid precursors of serotonin and dopamine simultaneously administered in the treatment of ADHD. The immediate amino acid precursors of serotonin and dopamine are 5-hydroxytryptophan (5-HTP) and L-3,4-dihydroxyphenylalanine (L-dopa), respectively. They freely cross the blood-brain barrier and are then synthesized into serotonin and dopamine without biochemical feedback inhibition. L-tryptophan and L-tyrosine are immediate precursors of 5-HTP and L-dopa, respectively. L-tryptophan and L-tyrosine have the ability to be synthesized into serotonin and dopamine, respectively. They are actively transported across the blood-brain barrier in competition with other amino acids. Synthesis of serotonin and dopamine from L-tryptophan and L-tyrosine, respectively, is regulated by biochemical feedback. Under the approach of this pilot study, optimal results are dependent upon achieving a proper balance between the administered serotonin and dopamine precursors.²⁻⁷

This study reviews the effects of a novel method of treatment involving the use of monoamine amino acid precursors that do what drugs are unable to do. This novel approach has the ability to increase the total number of neurotransmitter molecules in the central nervous system,³⁻⁷ leading to efficacy observations that appear greater than those of prescription drugs without the potential for neurotransmitter depletion, neurotoxicity issues, and severe potentially life-threatening drug side effects associated with prescription drugs.

Material and methods

The study included 85 children aged 4–18 years who had been diagnosed as having ADHD under the DSM-IV criteria by a licensed PhD clinical psychologist. The patients were then treated by a clinical psychologist. The medical charts and treatment results were reviewed retrospectively. Patients were evaluated twice during treatment with the ADHD Rating Scale (ADHD-RS).¹⁷ Other variables assessed via a questionnaire included: taking/not taking ADHD medicine; previous history of taking stimulant drugs; gender; age; perceived amount of improvement as noted by a conversation between the parent (or patient alone if an adult over 18 years) and the psychologist; and number of comorbid factors (eg, depression, cerebral palsy, chronic indigestion, hair pulling, seizures, autism, obsessive compulsive behavior).

The time period covered in the review was 18 months. The individual patients were treated for a period of 8–10 weeks with staggered starting of treatment. If no relief of symptoms was observed in the first 3–4 weeks of treatment, while administering the amino acid dosing protocol values of Tables 1 and 2, a urine sample was collected. Urinary serotonin and dopamine assay results were then subjected to OCT assay interpretation in order to define the needed change in amino acid dosing values. The goal of treatment was resolution of symptoms or achieving urinary serotonin and dopamine in the phase 3 therapeutic ranges, whichever came first.^{3–7} The amino acid dosing values of the protocol were developed by NeuroResearch Clinics Inc, Duluth, MN.^{3–7}

The statistician performing data analysis had no exposure to any aspects of active patient treatment, prior hypotheses, treatment expectations, and anticipated results in the data relating to the study. The researchers performing the charting were also blind to any hypotheses being evaluated. A *P* value ≤ 0.05 was considered statistically significant. JMP (SAS Institute, Cary, NC) software was used to perform the statistical analysis.

For the purposes of the study, participants 16 years of age and younger were placed on the pediatric dosing protocol (Table 1). Participants 17 years of age and older were placed on the adult dosing protocol (Table 2).

Table 1 Pediatric protocol for patients aged 16 years of age and younger

	mg 5-HTP/mg L-tyrosine		
	Morning	4 pm	7 pm
Level 1	75/750	75/750	–
Level 2	112.5/1125	112.5/1125	–
Level 3	112.5/1125	112.5/1125	112.5/1125

Table 2 Adult protocol for patients 17 years of age and older

	mg 5-HTP/mg L-tyrosine		
	Morning	Noon	4 pm
Level 1	150/1500	–	150/1500
Level 2	225/2250	–	225/2250
Level 3	150/1500	150/1500	225/750

In addition to the basic amino acid dosing values, other daily cofactors generally required for synthesis of the monoamine and maximum benefit from the protocol were administered. These included vitamin C 1000 mg, calcium citrate 220 mg, vitamin B6 75 mg, folate 400 μ g, L-lysine 500 mg, L-cysteine 4500 mg for adults and 2250 mg for children, and selenium 400 μ g for adults and 200 μ g for children. In general, L-dopa in the form of standardized mucuna pruriens 40% was added when the recommendation of the first urinary OCT assay interpretation demonstrated its need, which was a frequent occurrence.⁴

Patients were seen weekly. The initiation of a treatment prescription with amino acid precursors of serotonin and dopamine was at the level 1 dosing values of Tables 1 and 2. If the symptoms persisted after one week of treatment, the dosing was advanced week to week to level 2, then level 3. Patients who did not achieve relief of symptoms on level 3 dosing values had a urine sample collected after one week on that dosage; serotonin and dopamine levels were determined and reported in μ g of monoamine per g of creatinine. Reported values were then subjected to OCT assay interpretation. Reporting of urinary monoamine levels as μ g of monoamine per g of creatinine compensated for the specific gravity of the urine.^{3–7}

OCT assay interpretation

Peer-reviewed publications from 2009 and 2010 outlined a novel urinary “three-phase model” of urinary serotonin and dopamine response to simultaneous administration of serotonin and dopamine amino acid precursors in significant amounts. This three-phase model is the basis for OCT assay interpretation.^{2–7} A 2010 paper proposed a novel renal organic cation transporter model which potentially describes the etiology of the “three-phase response” of serotonin and dopamine during simultaneous administration of their amino acid precursors in varied daily dosing values.³

The urinary neurotransmitter testing model should with the OCT assay interpretation model used in this study. The urinary neurotransmitter testing model merely attempts to determine if urinary neurotransmitter levels are high or low, making no provision for phase determination or OCT

functional status interpretation. The flawed science behind the urinary neurotransmitter testing model was discussed in a 2010 paper.⁶

The serotonin and dopamine filtered at the glomerulus are metabolized by the kidneys, and significant amounts do not reach the final urine. Serotonin and dopamine found in the urine, in patients not suffering from a monoamine-secreting tumor, primarily represent monoamines that are newly synthesized in the proximal convoluted renal tubule cells of the kidneys and have never been in the central nervous system or peripheral system. The fate of the newly synthesized serotonin and dopamine inside the proximal convoluted renal tubule cells is primarily dependent upon the interaction of the basolateral monoamine transporters and the apical monoamine transporters of these proximal tubule cells. The basolateral monoamine transporter transports both serotonin and dopamine to the renal interstitium where they ultimately end up in the peripheral system via the renal vein. The apical monoamine transporters transport the newly synthesized serotonin and dopamine not transported by the basolateral monoamine transporter to the proximal nephrons and, from there, ultimately end up in the final urine as waste.^{3,24}

Serotonin and dopamine are found in two states. The endogenous state is found when no amino acid precursors are administered. The competitive inhibition state is found when significant amounts of both serotonin and dopamine precursors are simultaneously administered. Proper OCT assay interpretation requires that the serotonin and dopamine systems be simultaneously placed in the competitive inhibition state prior to OCT assay interpretation.^{3-7,24}

The basis for OCT assay interpretation requires that two or more urinary serotonin and dopamine assays be performed while taking serotonin and dopamine amino acid precursors at significantly varied dosing values. The results are then compared to determine the change in urinary serotonin and dopamine levels in response to the change in amino acid precursor dosing values.²⁻⁷

A urinary serotonin or dopamine value less than 80 μg or 475 μg of monoamine per g of creatinine, respectively, is defined as a phase 2 response. A urinary serotonin or dopamine value greater than 80 μg or 475 μg of monoamine per g of creatinine, respectively, is interpreted as being in phase 1 or phase 3. Differentiation of phase 1 from phase 3 is as follows. If a direct relationship is found between amino acid dosing and urinary assay response, it is referred to as a phase 3 response. An inverse relationship is referred to as a phase 1 response. The phase 3 therapeutic range for urinary

serotonin is defined as 80–240 μg of serotonin per g of creatinine. The phase 3 therapeutic range for urinary dopamine is defined as 475–1100 μg of dopamine per g of creatinine.²⁻⁷

Processing, management, and assay of the urine samples collected for this study were as follows. Urine samples were collected about six hours prior to bedtime, with 4 pm being the most frequent collection time point. The samples were stabilized in 6 N HCl to preserve the dopamine and serotonin. The urine samples were collected after a minimum of one week during which time the patient was taking a specific daily dosing of amino acid precursors of serotonin and dopamine where no doses were missed. Samples were shipped to DBS Laboratories (Duluth, MN) which is operated under the direction of one of the authors (TU, hospital-based pathologist, dual board-certified in laboratory medicine and forensic pathology). Urinary dopamine and serotonin were assayed utilizing commercially available radioimmunoassay kits (3 CAT RIA IB88501 and IB89527, both from Immuno Biological Laboratories Inc, Minneapolis, MN). The DBS laboratory is accredited as a high complexity laboratory by CLIA to perform these assays. OCT assay interpretation was performed by one of the authors (MH, NeuroResearch Clinics Inc).

Results

The retrospective chart review of this pilot study covered the treatment of 85 children aged 4–18 years diagnosed under DSM-IV criteria to have ADHD. The age distribution of the study group was 4–8 years ($n = 7$), 9–12 years ($n = 36$), and 13–18 years ($n = 22$). The mean age of the subjects was 12.2 years. There were 51 boys and 34 girls evenly distributed across the three age ranges.

Of the 85 patients, 62 (72.9%) had previously taken a stimulant drug for ADHD, and 23 (27.1%) had no history of treatment with an ADHD stimulant drug. There were 28 patients (30.0%) currently taking an ADHD drug while 57 (70.0%) were not. The breakdown of drugs taken at the start of treatment was as follows: 14 were taking amphetamine enantiomers; five were taking methylphenidate; five were taking atomoxetine; three were taking other drugs not specifically defined; and one was taking a combination of amphetamine enantiomers with atomoxetine. Parents sought treatment under this novel approach primarily due to concerns over lack of drug efficacy and/or drug side effects.

The ADHD-RS inventory was administered at the start and end of treatment. Results indicated that group

Table 3 Changes in Attention Deficit Hyperactivity Disorder Rating Scale scores at initiation and end of treatment

Group ADHD-RS changes				
	Pre-Rx	End-Rx	t-test	P
2s	4.6	1.2	8.42	<0.001
3s	8.3	2.3	12.26	<0.001

Abbreviations: Rx, treatment; ADHD-RS, Attention-Deficit-Hyperactivity Disorder Rating Scale.

scores (2 and 3) on the ADHD-RS scale (behavioral symptoms of ADHD) decreased significantly ($P < 0.001$) from the first to the second testing. ADHD-RS results are shown in Table 3.

The decrease in 2 and 3 scores shown in Table 3 occurred regardless of the variable being investigated, including age and gender. This reduction in symptoms is noteworthy. Prior to treatment, the number of significant ADHD behavioral indicators that were displayed as “often” or “very often” were in the 5–9 range. Only two post-treatment behavioral indicators were noted. The only variable that approached significance ($P < 0.08$) was gender. More males experienced a decrease in symptoms in the ADHD-RS (3) from 8.9 to 2.3 versus females in whom this score decreased from 7.1 to 2.2.

In addition to the statistical analysis parameters that were identified on the DSM-IV, the following observations were calculated relating to other issues. Some of the more compelling findings are included in the tables.

The results shown in Table 4 revealed that 67% of the participants achieved significant improvement with only amino acid precursors of serotonin and dopamine. Patients who achieved no significant relief of symptoms with only amino acid precursors represent a subgroup in whom urine samples were collected and OCT assay interpretation was utilized. In this subgroup, 30.3% achieved significant relief of symptoms following two or three urine assays. The total percentage of patients showing significant improvement was 77%.

Referring to Table 6, a further 10% of patients who had taken stimulant drugs in the past reported complete symptom relief. There seems to be some advantage for the effectiveness of the amino acid supplement treatment when there is a history of having taken stimulant drugs in the past.

Table 4 Percentage of the entire group (n = 85) achieving significant relief of symptoms by weeks 3 and 8 ($P < 0.05$)

	Week 3	Week 8
Significant relief	67%	77%

Table 5 Percentage of the entire group (n = 85) achieving complete relief of symptoms by weeks 5 and 8

	Week 5	Week 8
Complete relief	30%	33%

As noted in Table 7, a potential advantage was identified with the administration of amino acid precursors relating to taking ADHD drugs.

Urine tests did not typically occur until visit 4, and were indicated if the patient did not show significant improvement with relief of the majority of major ADHD symptoms after one week taking level 3 dosing values of Table 1 or Table 2. Those who experienced control of symptoms prior to or at visit 4 were excluded from urine testing. Results of the patients who had an OCT assay are shown in Table 8.

Therefore, it appears that urine testing with OCT assay interpretation was beneficial because urinary serotonin and dopamine assay interpretation defined the proper dosing values. To establish urinary serotonin and dopamine phases firmly requires two assays performed with varied amino acid precursor dosing values. The significant relief values of 64% prior to testing and 70% after two assays noted in Table 7 and Table 8 represent only one amino acid dosing change, with the confidence of knowing the serotonin and dopamine phases.

Discussion

The data generated in the study were compared with data generated in double-blind, placebo-controlled studies. Tables 9 and 10 summarize the results of this literature search. It would appear that the placebo effect is strong in ADHD studies, because 28%–40% of placebo patients achieved significant relief of symptoms in the atomoxetine studies reviewed (Table 10), and 14%–31% had a placebo benefit in the methylphenidate study (Table 9).

To meet the criteria for approval under FDA guidelines, a drug has to demonstrate efficacy and safety.³² The amino acids and cofactors used in this retrospective study are classified by the FDA as generally recognized and accepted as

Table 6 The percentage of patients with and without a history of taking a stimulant for treatment of ADHD who experienced complete relief of symptoms at weeks 5 and 8

	Week 5	Week 8
No stimulant drug in past	22%	28%
Stimulant drug in past	32%	35%

Table 7 Effect of taking and not taking a prescription ADHD drug on the endpoint of the study

	Week 5	Week 8
	Significant relief	Complete relief
Not taking a drug	64%	28%

safe (GRAS), in the same category as supplemental vitamins and minerals.³³ There are no safety concerns with the amino acids based on this FDA position. All of the amino acids and components used in the study are sold in the US over the counter without a prescription.

The drugs prescribed for ADHD have potentially controversial concerns associated with them, including neurotransmitter depletion, neurotoxicity, drug side effects, and adverse reactions; this amino acid approach in comparison has none of these concerns associated with it. This gives a significant advantage to this amino acid approach if studies continue to bear out that it is similar or superior to prescription ADHD drugs in its efficacy.

This retrospective study was performed in order to focus on the structure needed for a formal prospective study. In the course of this study, the following observations and considerations came to light. The administration of properly balanced amino acid precursors of serotonin and dopamine with OCT assay interpretation resulted in improvement that appears to be superior to methylphenidate and atomoxetine (Tables 9 and 10). This certainly provides encouragement to undertake further studies.

Even if the finding was that use of serotonin and dopamine amino acid precursors with OCT assay interpretation was equal to reported efficacy values found with atomoxetine and methylphenidate, it is asserted that this approach would be superior because it does not share the adverse reactions,

Table 8 Approximately 59% of patients in the group achieved relief of symptoms with administration of amino acids and no testing

	Urine test group
Two tests	70%
Three tests	78%

Notes: If no response was observed after treatment with the three amino acid dosing levels of Table 1 or Table 2, organic cation transport assay interpretation was initiated leading to an increase in the number of patients in the study who experienced significant relief of symptoms.

potential depletion of neurotransmitters, and neurotoxicity concerns reported with the group of drugs prescribed for ADHD treatment.

There is variance identified and reported in children who were and were not taking drugs during this study. Future studies need to be designed to address the impact of amino acids on subgroups such as this. A further identified issue in this study that needs to be corrected in future studies is the timeline of the study. In response to the lack of amino acid efficacy at visit 4 (taking level 3 dosing values for one week from Tables 1 and 2), OCT assay interpretation was started. For children in the study for 10 weeks, three urinary tests were obtained. Experience leading up to this study suggested that a significant number of patients with ADHD do not achieve relief of symptoms until both urinary serotonin and dopamine are in the phase 3 therapeutic ranges. Data analysis revealed that it typically takes 2–8 urine tests with OCT assay interpretation to achieve this goal. Provisions need to be made in future studies to move away from rigid time guidelines and position the studies as a process independent of time where the endpoint is urinary serotonin and dopamine in the phase 3 therapeutic ranges or relief of symptoms, whichever comes first.

Table 9 Retrospective study results, significant improvement in patients (Table 4) versus reported results in double-blind, placebo-controlled studies taking methylphenidate

	Pilot study results	Methylphenidate studies		
	AA with OCT assay interpretation	Study 1 ²⁶	Study 2 ²⁷	Study 3 ²⁸
n	85	154	97	18
% improved	77% (Table 4)	64%	52%	58%
% placebo improved	N/A	27%	31%	14%
% drug improvement over placebo	N/A	37%	21%	44%

Notes: The “% placebo improved” row represents percentage of subjects taking placebo who experienced significant remission of symptoms to the defined threshold of the study or greater. The bottom row is the advantage of the drug over placebo in the study cited.

Abbreviations: AA, amino acid; OCT, organic cation transporter.

Table 10 Retrospective study results, significant improvement in patients (see Table 4) versus reported results in double-blind, placebo-controlled studies of patients taking atomoxetine

	Pilot study results	Atomoxetine studies		
	AA with OCT assay interpretation	Study 1 ²⁹	Study 2 ³⁰	Study 3 ³¹
n	85	618	36	84
% improved	77% (Table 4)	71%	54%	59%
% placebo improved	N/A	28%	40%	31%
% drug improvement over placebo	N/A	43%	14%	28%

Notes: The "% placebo improved" row represents percentage of subjects taking placebo who experienced significant remission of symptoms to the defined threshold of the study or greater. The bottom row is the advantage of the drug over placebo in the study cited.

Abbreviations: AA, amino acid; OCT, organic cation transporter.

It is also suggested that the scrutiny of this retrospective study be expanded to identify more phenotype traits. Incorporation of expanded data fields such as this into further studies would facilitate more indepth comparison with other studies and statistical evaluation of subgroups.

This analysis does provide some initial evidence of the efficacy of amino acids in significantly reducing symptoms associated with ADHD. Tables 9 and 10 reveal the efficacy of this treatment protocol to be potentially superior to results seen with prescription drugs. Future studies are needed to investigate the reliability of these observed effects. If these results can be replicated in controlled studies, then such important issues as cause and effect for the changes in ADHD symptoms, potential mediating variables, and long-term uses can be further investigated and clarified.

Conclusion

Based on the FDA guidelines, the amino acid precursors of serotonin and dopamine, used in this study, are classified as GRAS, meaning no significant safety concerns exist about their use. The next question to ponder is whether the approach is effective. The FDA has not set the bar very high in demonstrating efficacy of prescription drugs. There are numerous examples of drugs being approved that are only 7%–13% more effective than placebo.⁴ Under these conditions, it would appear that the findings of this study have the potential to demonstrate at least that level of efficacy in a prospective study based on Tables 9 and 10.

The purpose of this paper was to document formally the results and findings generated during the course of this retrospective pilot study involving 85 children, and define parameters that allow focus on a future prospective study. It is the goal of this paper to spark interest, research, awareness,

and scrutiny of these findings, and to raise awareness of potential neurotransmitter depletion and neurotoxicity issues relating to ADHD drugs.

Disclosure

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