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Case Report

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Intrathecal Autologous Bone Marrow Mononuclear Cell Transplantation in a Case of Adult Autism

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Abstract

Autism is a complex neurodevelopmental disorder with a worldwide prevalence of 1 in 88. With greater understanding of mechanism of action of cellular therapy it is now possible to address the pathogenesis of autism. Recent findings of cellular therapy offering immunomodulatory, angiogenic and paracrine effects make it a lucrative option for treatment of autism. We administered a 33 year old adult patient of autism intrathecally, with autologous bone marrow mononuclear cells (BMMNCs), twice with an interval of six months. On follow up at 3, 6 and 9 months post first intervention, he was re-evaluated clinically and no major or minor side effects were observed. At 6 and 9 months objective outcome measures of Indian Scale for Assessment of Autism (ISAA) and Clinical Global Impression (CGI) were used and they showed significant improvement. At the end of 9 months, on ISAA, the score improved from 94 to 64. The CGI showed improvement by change in severity of illness from 3 (Mildly ill) to 1 (Borderline mentally ill). Global improvement on CGI was scored 2 (much improved) with an efficacy index of 5 (moderate therapeutic effect). PET CT scan was repeated at 6 months which showed a balancing effect in the metabolism of affected areas. The changes observed on the PET CT scan correlated with clinical improvements. MRI remained same at 6 months thereby, indicating that PET CT scan may serve as a better monitoring tool for effects of cellular therapy. In this case study, we hypothesize that cellular therapy has repaired the neural connections and achieved balance in the excitatory and inhibitory neuronal cells by various mechanisms of neuroprotection, neuromodulation and neurorestoration. Cell therapy holds great potential and randomized controlled trials may be conducted to study their long term effects in treating autism.

Keywords: Autism; Cellular therapy; Autologous; Bone marrow mononuclear cells; PET CT

Introduction

Autism is a neurodevelopmental condition with cognitive and neurobehavioral issues leading to impairments in socialization, verbal and non-verbal communication and behavior. The symptoms are noticed at around twelve–eighteen months. However, at times autism is diagnosed at adulthood [1]. The prevalence of autism is estimated to be about 1 in 88 [2]. Adults with autism are deprived of social relationships, employment and a better quality of life [3]. Development of effective interventions is thus required to help the amalgamation of these adult patients into the wider society.

All the present available treatments for autism are targeted towards specific symptoms. Cell therapy as a treatment for autism is currently being explored. Adult stem cells have shown positive benefits in various neurological disorders such as cerebral palsy, stroke, etc [4,5]. Various mechanisms have known to be responsible for the positive effect of cellular therapy which include a combination of trophic factor delivery, neuroplasticity, neuromodulation, neuroprotection, angiogenesis amongst others [6]. With an aim to further study the effect of cell therapy in adult autism, we administered an adult patient of autism with autologous bone marrow mononuclear cells (BMMNCs), twice at an interval of six months. To our knowledge, there is no published case study of cell therapy in adult autism. Thus, this case report provides an insight of application of cell therapy in adult autism.

Case Report

Case presentation

A thirty three years old male was diagnosed with autism at the age of eighteen years. He achieved normal motor milestones except speech.

His speech developed only after the age of three years. At six to eight years of age, hyperactivity developed along with behavioral issues like laughing without reason, hitting others, poor eye contact and running without reason. By the age of fourteen he became more aggressive and started showing temper tantrums and poor social interaction skills. Responses were delayed due to which he required repetitive commands. At the age of eighteen years he was diagnosed as autism. He lacked empathy, had difficulty understanding other person's feelings. There was a failure to establish relationships including sexual relationships. Absence of understanding of making a family. Since the age of eighteen he underwent rehabilitation including behavior therapy, occupational therapy and speech therapy. He was trained to become independent in activities of daily living. Vocational rehabilitation was provided, so he could stitch, make boxes and work on a computer. Presently, his eye contact and social interaction was affected. He stayed aloof and did not maintain peer relationships. Emotional responses were also poor. He used stereotyped and repetitive language. Behavior was aggressive and he threw temper tantrums.

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Pre-intervention assessment

MRI brain showed mild cerebral and cerebellar atrophy. The EEG showed no epileptogenic focus. On Indian Scale for Assessment of Autism (ISAA) he scored 94 (mild autism with 60% disability). On Clinical Global Impression (CGI) scale, severity of illness (CGI-I) was scored 3 which was mildly mentally ill. PET CT scan was performed using the Siemens Biographmct with 64 slice high speed scanner- 3D PET True V wide detector (Siemens-CTI, Knoxville, Tenn., USA), with a resolution of 0.6-mm full width at half maximum (FWHM) and the images of 45-50 contiguous transverse planes with a field of view of 21.6 cm axial PET FOV with True V (Figure 1). The mean standardized uptake values (SUV) are given in the Table 1.

Isolation and administration of autologous bone marrow mononuclear cells

The protocol is based on the inclusion criterion as per the World Medical Associations Helsinki declaration [7]. It has been reviewed and approved by the Institutional committee for Stem cell Research and Therapy (IC-SCRT). The patient's parents were informed about the procedure and a duly filled informed consent form was obtained. 300 mcg of G-CSF injections were administered 48 hours and 24 hours before bone marrow derived mononuclear cell transplantation, to stimulate CD34+ cells and increase their survival and multiplication. Bone marrow (100 ml) was aspirated from the anterior superior iliac crest bone using the bone marrow aspiration needle. Mononuclear cells (MNCs) were obtained from the bone marrow by density gradient separation method. Viable count of the isolated MNCs was taken and was found to be about 98%. The MNCs were checked for CD34+ by FACS analysis. Approximately 56×10^6 MNCs were immediately injected post separation, intrathecally at L4-L5 level using an 18G Touhy needle and epidural catheter. Simultaneously, the patient was administered with one dose of 30 mg/kg methylprednisolone intravenously.

Neurorehabilitation

The patient was also given multidisciplinary therapies which included occupational therapy, psychological therapy, applied behavior analysis, sensory integration and speech therapy. It included Vestibular activities like tandem walking, peg transfers on vestibular board/swiss ball etc, kneel walking, ball throwing in standing etc, therapeutic activities like grouping, sequencing, improving eye hand coordination and visual perceptual skills were included. Social interaction and skills were emphasized during the therapy sessions. During his psychological

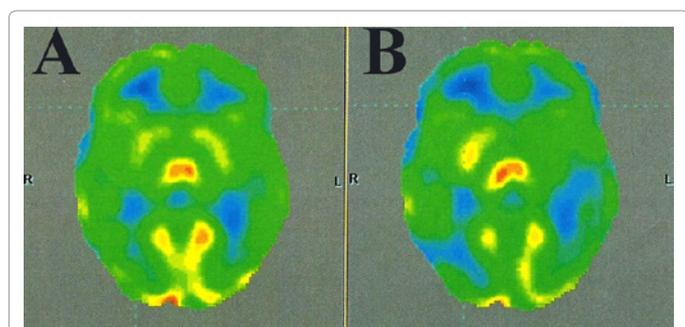


Figure 1: (A) PET CT scan of the patient carried out before cell therapy, (B) PET CT scan of the patient carried out after cell therapy. Comparison of PET CT scans demonstrating improvements after cell therapy i.e., the yellow areas decreased in the post intervention scan as indicated by SUV values in Table 1.

Areas	Mean SUV (PRE)	Mean SUV (POST)	Correlating clinical functional improvements observed in the case
Frontal Lobe Left	6.86	5.85	initiation, planning, anticipation, organization, problem solving, emotions, attention
Frontal Lobe Right	6.92	5.67	
Cingulate and Paracingulate gyri Left	6.72	5.57	Social brain processing
Cingulate and Paracingulate gyri Right	6.62	5.39	
Temporal Left	6.84	5.44	Social Interaction, memory and categorizing objects
Temporal Right	6.95	5.85	
Mesial Temporal Left	4.96	4.01	Social brain processing
Mesial Temporal Right	5.34	4.48	
Middle Cingulate Left	7.23	5.88	emotion processing, learning and memory
Middle Cingulate Right	7.31	5.95	
Amygdala Left	4.7	3.97	emotions, memory, social interaction, behavior
Amygdala Right	4.85	4.18	
Hippocampus Left	4.49	3.77	social interaction
Hippocampus Right	4.58	3.97	
Para hippocampus Left	5.47	4.25	Scene recognition and social context
Para hippocampus Right	6.08	4.97	
Parietal lobe Left	6.69	5.7	integration of sensory information and language
Parietal lobe Right	6.49	5.3	
Posterior cingulate Left	6.71	5.76	emotional and motor tasks
Posterior cingulate Right	5.78	4.24	
Anterior cingulate Left	6.03	5.07	attention, motivation, anticipation of tasks, emotional responses
Anterior cingulate Right	5.69	4.76	
Basal Ganglia Left	7.63	5.71	voluntary movement, coordination
Basal Ganglia Right	7.73	6.7	
Cerebellum Left	6.08	5.4	Coordination, memory, emotions
Cerebellum Right	5.6	4.56	

Table 1: Comparison of pre and post intervention SUV values in 18 FDG PET CT scan and correlation with clinical symptom improvement in the case study.

sessions, cognitive rehabilitation, family counseling and psychological education was emphasized.

Outcome measures used

On follow up at three, six and nine months post first intervention, he was re-evaluated clinically and no major or minor side effects were observed. At six and nine months objective outcome measures of ISAA and CGI were used. PET CT scan was repeated at six months after the intervention.

Results

After the procedure, the patient had no major or minor side effects. There was improvement in eye contact within a week. After three months of follow up, reduction in hyperactivity and reduced repetitive speech was observed. On six months follow up, improvements further continued. Attention span increased along with decrease in temper tantrums. His tongue movements improved and he could eat without spilling due to improved eye-hand coordination. Reduction in the behavioral issues such as self- talking, laughing loudly was also noted. He was reassessed on ISAA scale wherein the score reduced from 94 (Mild autism with 60% disability) to 79 (Mild autism with 50% disability). On ISAA, he improved in language and communication, behavior pattern and sensory aspects (Table 2). On repeating his PET CT scan after six months, it was observed that various areas of brain showed reduction in FDG uptake (Table 1). MRI of the brain

	Sub-components of ISAA	Score Pre treatment	Score at 6 month follow up	Score at 9 month follow up
A.	Social Relationship and Reciprocity	30	30	17
1	Poor Eye contact	5	3	1
2	Lacks social smile	5	5	1
3	Remains aloof	5	5	4
4	Does not reach out to others	2	2	1
5	Unable to take turns in social interaction	4	4	3
6	Does not maintain peer relationships	4	4	2
B.	Speech Language and Communication	14	13	11
1	Engages in stereotyped and repetitive use of language	5	3	2
2	Unable to initiate or sustain conversation with others	3	3	1
3	Unable to grasp pragmatics of communication (real meaning)	5	1	1
C.	Behaviour Patterns	18	13	13
1	Shows hyperactivity and restlessness	4	3	3
2	Exhibits aggressive behavior	5	3	3
3	Throws temper tantrums	5	3	3
D.	Sensory Aspects	12	9	7
1	Stares into space for long periods of time	4	3	2
2	Has unusual vision	4	2	1

Table 2: Table giving details of the improvements in different sub components on ISAA at follow up of 3 months and 18 months.

remained same after six months. With a purpose of sustaining these improvements he underwent a second dose of autologous BMMNCs at six months after the first intervention. Three months after the second cell therapy, (nine months after the first intervention) hyperactivity and aggressive behavior further reduced drastically. Eye contact along with repetitive speech had improved. His problem solving and response time had reduced as he could solve mathematical problems and he could answer faster. His ISAA further reduced to 64 (no autism). On Clinical Global Impression (CGI) scale, his severity of illness (CGI-I) before the first intervention was 3 (mildly ill) while nine months after the therapy it was 2 (borderline mentally ill). The global improvement (CGI-II) was rated 2 (much improved) and efficacy index (CGI-III) was 5 (moderate improvement with no side effects).

Discussion

Autism, a complex neurodevelopmental condition, is caused by atypical brain development beginning during early prenatal or postnatal life. The underlying pathophysiologic mechanism in autism is still being explored. Currently, various mechanisms are postulated for pathogenesis of autism. Evidence suggests that immune dysfunction is associated with impairment in behavior, deficit in social interaction and communication. It involves increased cytokine production which inhibits neurogenesis and leads to neuronal death along with inflammation in brain. There is an increase in brain specific autoantibodies and altered immune cell function [8].

Some studies suggest that the imbalance in inhibition-excitation of neurons has a direct impact on the adult brain plasticity and is the foundation of the pathogenesis of neurodevelopmental disorders like autism [9]. Elevated levels of excitation could be due to increased glutamatergic transmission or suppressed GABAergic inhibition. Suppressed GABAergic inhibition thus could be one of the etiologies of autism [10]. Cortical interneurons make up to 20% of the cells in cortex. These cells modulate the firing activities of the excitatory projection neurons. The dysfunction of cortical interneurons is also believed

to be the underlying pathophysiology of autism [11]. Neuroimmune abnormalities may be reflected as neuroglial activation in the brain [12]. Suzuki et al. [13] in their recent study, have indicated excessive microglial activation in multiple brain regions in young adult subjects with ASD.

Neuroanatomical studies suggest that frontal lobes, mesial temporal lobe (especially amygdala) and cerebellum are also involved in the pathology of autism [14]. In a multicentre study conducted on adult men with autism, it was found that there is a significant increase in gray matter volume in the anterior temporal and dorsolateral prefrontal regions along with significant reduction in the occipital and medial parietal regions as compared to the control group [15]. Brain volume in the frontal lobes is larger, whereas the occipital lobes are smaller in size in individuals with autism [16]. On studying the brain function of language processing in children and adults with autism it was found that left middle temporal, left pars triangularis, left pars opercularis, left medial frontal, and right middle temporal were the most affected. The autism group differed from the control group in the degree of network coordination and the dynamic recruitment of regions in response to stimulus [17]. All the above findings are observed in some patients with autism. In autism, the trajectory of brain development is more disturbed.

Many treatment options have been studied for adults and children with autism such as behavioral and developmental interventions, vocational therapy, pharmacotherapy, etc [18,19]. Vocational therapy and other rehabilitation interventions alone have not shown desirable benefits in adolescents and young adults with autism [20]. Medications are used to treat the comorbid conditions such as anxiety, seizures, depression and not the core symptoms of autism [21]. Since 2006, few drugs have been approved by the FDA. But, adverse events including weight gain, sedation and increased risk of mortality among adults have been recorded with use of these drugs [22].

In neurological disorders, it has been observed that stem cells improve the damaged neuronal function which is also one of the underlying pathogenetic mechanisms of autism [23]. With an aim to study the benefits of stem cells in autism, we transplanted autologous BMMNCs in an adult with autism. Bone marrow cells are safe and are widely available with no ethical or carcinogenic issues involved as compared to embryonic/fetal cells. BMMNCs are a mixed population of differentially matured B-cells, T-cells and monocytes, along with progenitor cells such as hematopoietic stem cells (HSC), mesenchymal stromal cells (MSC), endothelial progenitor cells (EPC) and very small embryonic-like cells (VSEL) [24]. It has been observed that the whole BMMNCs are more effective compared to the fractionated parts [25]. Studies suggest that these cells improve oxygenation, as they reduce the brain hypoperfusion by stimulating angiogenesis. BMMNCs can modulate the immune system by inhibiting the proliferation of CD3+, CD4+, CD8+ T cells and NK cells [26]. The transplanted cells migrate and home onto the damaged areas of the brain and produce factors such as VEGF, BDNF, FGF2, activating the endogenous repair mechanism and contributing to recovery of lost neuronal function [27,28].

The intervention is safe as being autologous; the cells evade the possibility of any reaction. Intrathecal administration of cells is a relatively less invasive procedure. These cells migrate via the CSF to the affected areas in the brain. The transplanted cells home into the damaged sites by crossing the blood brain barrier. It has been seen that various mechanisms including inflammation alters the permeability of the blood brain barrier in autism [29,30]. In this case study, after autologous BMMNC transplantation we observed significant

improvements in social relationship, behavior along with language and communication. On correlating these improvements, it can be assumed that there was improvement in temporal, amygdala and Wernicke's area of the brain.

PET CT scan was used as a monitoring tool. It is a non-invasive and a relatively safe functional neuroimaging technique which examines the association between the metabolic activity in the brain and the mental processes. The 18-FDG dye used for the PET CT scan is an analogue of glucose which provides functional information of the cells based on the glucose uptake [31]. Reduced glucose uptake reflects reduced metabolic activity of those brain cells. The standardized uptake value (SUV) is used as a relative measure of FDG uptake [32]. These values are compared to a normal controlled SUV and a standard deviation (SD) value is calculated which indicates the areas of the brain functioning beyond the normal limits. Hence, the hyperfunctioning areas of the brain will show hypermetabolism and hypofunctioning areas will show hypometabolism. A reduction in hyperfunctioning areas or increase in hypofunctioning areas may reflect as a clinical functional improvement. In our case, on correlating the clinical improvements to the specific areas of the brain we observed a reduction in metabolism of these particular areas after the intervention. Therefore, the reduction in metabolism is a positive indicator of clinical functional improvement (Table 1). Since, the decrease in SUV values corresponds to the clinical improvements, we may hypothesize that the reduction in metabolism has restored the function of neurons. After six months, the PET CT scan recorded changes corresponding with the clinical improvements while the MRI showed no change. Hence, PET CT scan was more sensitive to study the effect of intervention as compared to the MRI.

One of the limitations of this case report is that there is no control to compare the effect of intervention, but we can consider the case as self control due to the age of the patient and his static condition despite of regular rehabilitation pre intervention. Also, for the PET CT scan, the SUV values of the normal adults (control) were not available as it was a computerized program and the values were automatically generated and compared by the software and reported as SD values. The control group values are for normal adult population and there is a need to study and gather baseline values for autism population.

We hypothesize that cellular therapy has stimulated repair processes of the neural connections and achieved balance in the excitatory and inhibitory neuronal cells by various mechanisms of neuroprotection, neuromodulation and neurorestoration. Cell therapy holds a great potential and randomized controlled trial may be conducted to study their long term effects in treating adults with autism.

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