Comparison of neurophysiological and MRI findings of patients with multiple sclerosis using oligoclonal band technique

Hamit Y Ellidag¹, Esin Eren², Nezahat Erdogan³, Sabiha Ture⁴, Necat Yilmaz¹

¹Central laboratories of Antalya Education and Research Hospital of Ministry of Health, Antalya; ²Antalya Public Health Center of Ministry of Health, Antalya; ³Radiology clinic; ⁴Neurology clinic of Izmir Ataturk Education and Research Hospital of Ministry of Health, Izmir, TURKEY

ABSTRACT

Background: The correlation of oligoclonal bands (OCBs) and intrathecal IgG synthesis are not yet clear in multiple sclerosis (MS). Purpose: In this study, we investigated the OCB situation and IgG index, cranial and cervical magnetic resonance imaging (MRI) findings and also compared visual evoked potentials (VEP) and somatosensory evoked potentials (SEP) in order to better understand the OCB pattern and pathogenesis. Methods: Retrospective study included 40 patients (19 male, 21 female, mean age 29 ± 4.24) with precise MS diagnosis according to McDonald criteria. Result: Sixteen of the patients were OCB negative, and 24 patients were positive. The difference between the OCB situation and number of plaques in cranial and cervical MRI, atrophy, oedema and contrast material retention was insignificant. The different between the OCB situation and VEP and SEP were insignificant. Conclusion: These laboratory findings are all specific, all developing via independent mechanisms and are not related to each other during the silence periods of patients.

doi : 10.5214/ans.0972.7531.200406

Introduction

Multiple sclerosis (MS) is an inflammatory autoimmune disease of the central nervous system (CNS). It is characterized pathologically by acute multifocal demyelination as well as axonal loss and death of oligodendrocyte. The etiology of MS is not completely understood and is widely believed to have genetic susceptibility, which may or may not be triggered by environmental factors.¹ ²

There is no accurate diagnostic test or clinical finding for the diagnosis of MS.³ ⁴ ⁶ The diagnosis of MS is based on neurologic history, and exclusion of other disorders. Different paraclinical tests, such as detection of intrathecal IgG synthesis (present in most patients with MS), evoked potentials, and imaging techniques, are used to support the diagnosis when necessary. The single most consistent laboratory abnormality in patients with MS exclusive of magnetic resonance imaging (MRI) is increased oligoclonal immunoglobulins in cerebrospinal fluid (CSF).⁴ ⁷ Many methods and modifications of different sensitivity and specificity have been described to define oligoclonal bands (OCBs) in CSF.⁷ ⁸ Isoelectrical focusing (IF) is considered reliable modality in defining OCBs.³ ⁸ ¹⁰

The pathogenesis of OCBs and intrathecal IgG synthesis are not yet clear. In this study, we investigated the OCB situation and IgG index, cranial and cervical MRI findings and also compared visual and somatosensory evoked potentials in order to better understand the OCB pattern and pathogenesis of MS.

Methods

Patient selection

Retrospective study included 40 patients (19 male, 21 female, mean age 29 ± 4.24) with precise MS diagnosis according to McDonald criteria,¹ ¹ who consulted Education and Investigation Hospital Neurology Clinics. Sixteen of the MS patients were OCB negative, and 24 were positive. Patients with dubious MS or clinic isole syndrome, or who had a previously diagnosed MS history were excluded from the study.

This study was performed in accordance with the ethical standards set by the Declaration of Helsinki and approved by the local ethics committee.

Biochemical analyses

Serum and CSF samples of all patients included in the study were taken concomitantly. These samples were frozen and kept until the day of analysis, and then CSF albumin, IgG, serum albumin, serum IgG and oligoclonal band examinations were carried out collectively. CSF IgG, CSF albumin, serum IgG and serum albumin were detected by immunoturbidimetric and spectrophotometric methods using commercially available assay kits (Olympus) with an Olympus AU640 instrument.

After these examinations, IgG index was calculated as follows:

\[
\text{IgG Index} = \frac{\text{CSF IgG}}{\text{CSF albumin}} \times \frac{\text{Serum IgG}}{\text{Serum albumin}}
\]

IgG specific oligoclonal bands in serum and CSF were detected using agarose gel isoelectric focusing and immunoblotting techniques (using standard peroxidase method) via Helena Biosciences Europe Electrophoresis instrument. The pH gradients of agarose gels used in this method are between 3 and 10. Two or more bands in CSF is defined as OCB positive.

MRI analysis

MRI examinations are conducted by 1,5 tesla Philips Intera instrument. The MRI findings were evaluated with regard to the number of plaques in cranial and cervical MRI, atrophy, oedema and contrast material retention. Number of the plaques were evaluated as 5–10, 10–20 or more than 20. The localization of the plaques in cranial MRI was not taken into consideration. Also, contrast material retention, atrophy and oedema findings were evaluated as positive or negative.

The applied MS protocol is stated as follow:

Cranial, T2 Axial, T1 Axial, FLAIR Sagittal, T1 Sagittal (Negative contrast).
Cranial, T2 Axial, T1 Axial, FLAIR Sagittal, (Positive contrast, IV Gadolinium) T1 Axial, T1 coronal, T1 Sagittal.

Cervical, T2 Sagittal, T1 Sagittal, T2 Axial, (Positive contrast, IV Gadolinium) T1 Sagittal, T1 Axial.

**Evoked potential analysis**

VEP (Visual Evoked Potentials) and SEP (Somatosensory Evoked Potentials) analyses of all patients were done via Medelec Sapphire 4ME and Nihon Kohden instruments.

**Statistical analysis**

Statistical analysis was carried out using the statistical software version 11.5.1.0 (MedCalc, Mariakerke, Belgium). The direction and significance of association between variables were evaluated by using Chi-square and Fisher’s exact test. P values less than 0.05 was accepted as the significance level.

**Results**

There were no significant differences in age or male/female ratio between OCB (+) and OCB (−) MS patients. IgG index, CSF protein, CSF LDH, EDSS and CSF WBC levels did not differ significantly between OCB (+) and OCB (−) MS patients (Table 1).

**Cranial MRI and OCB**

When the plaque numbers in the MRIs were evaluated, 16 patients had >20 plaques, 18 had 11–20 plaques, and 6 had 5–10 plaques. The relationship between the OCB status and number of plaques in cranial MRI was not significant (p = 0.99). According to the cranial MRI, atrophy was positive in 5 and negative in 35 patients, oedema was negative in all, contrast material retention was positive in 18 and negative in 22 patients. The relationship between these parameters and OCB status are shown in Table 2.

**Cervical MRI and OCB**

When the plaque numbers in cervical MRIs were evaluated, 9 patients had >20 plaques, 14 had 11–20 plaques, and 17 had 5–10 plaques. The relationships between the OCB status and number of plaques in cervical MRI were insignificant (p = 0.74). According to the cervical MRI, atrophy was positive in 13 patients and negative in 27, oedema was negative in

### Table 1: Demographic and laboratory findings obtained from MS patients

| Parameter | OCB (+) | OCB (−) | P     |
|-----------|---------|---------|-------|
| Patients (n = 40) | 24 (60%) | 16 (40%) |       |
| Mean age | 29.64 | 31.75 | 0.61 |
| Gender; Male (19; 47.5%) | 11 | 8 | 0.89 |
| Female (21; 52.5%) | 13 | 8 | 0.89 |
| IgG index | 1.15 (0.8–1.4) | 0.8 (0.5–1.3) | 0.10 |
| CSF protein, g/L | 40.5 (27.6–58.2) | 39.9 (27.5–47.2) | 0.99 |
| CSF LDH, U/L | 18 (11.9–25.9) | 17.9 (14.8–23.5) | 0.96 |
| CSF WBC (cell/HPF) | 0 (0–10) | 0 (0–0.46) | 0.35 |

### Table 2: The relationship between cranial MRI findings and OCB pattern

| Cranial MRI | OCB (+) | OCB (−) | p     |
|-------------|---------|---------|-------|
| Number of plaques |         |         |       |
| 5–10 | 4 (16.6%) | 2 (12.5%) | 0.99 |
| 11–20 | 10 (41.6%) | 8 (50%) |       |
| >20 | 10 (41.6%) | 6 (37.5%) |       |
| Atrophy |         |         |       |
| Positive | 4 (16.6%) | 1 (6.25%) | 0.63 |
| Negative | 20 (83.3%) | 15 (93.75%) |       |
| Oedem | Negative in all patients |         |       |
| Contrast material retention |         |         |       |
| Positive | 12 (50%) | 6 (37.5%) | 0.52 |
| Negative | 12 (50%) | 10 (62.5%) |       |
19 and positive in 21, contrast material retention was positive in 17 and negative in 23 patients. The relationship between these parameters and the OCB situation gave insignificant results (Table 3).

**Neurophysiological findings and OCB**

VEP (Visual Evoked Potentials) and SEP (Somatosensory Evoked Potentials) results of all included patients could be obtained. 23 patients had abnormal VEP, and 17 had normal VEP. Likewise, 15 had abnormal, and 25 patients had normal SEP. The relationship between OCB and VEP/SEP was found to be insignificant (Table 4).

**Discussion**

In this retrospective study, we investigated the correlation between cranial/cervical MRIs, neurophysiological tests and OCB status [OCB (+) or OCB (–)] of clinically definite MS patients. We determined that 40 MS patients who had no significant correlation between age/gender were 24 OCB (+) (60%) and 16 were OCB (–) (40%).

Oligoclonal bands are positive in 85-95% patients with clinically confirmed MS. In a 10-year study period, Rot et al.12 reported 12.8% of the patients had oligoclonal band-negative multiple sclerosis. Zeman et al.5 demonstrated that only 3% of their patients with clinically definite multiple sclerosis were oligoclonal band-negative. However, studies investigating OCB (–) MS were scarce. These studies showed that oligoclonal band-negative MS had a better prognosis than oligoclonal band-positive MS.5,17

Some authors have found that the frequency of OCB (–) patients with MS was high, which is similar to our results. Fukazawa et al.13 showed that 43.9% of Japanese patients had oligoclonal band-negative multiple sclerosis and Nakashima et al.14 showed that this ratio was 41%. These data show that the eastern and far-eastern populations had a higher OCB (–) MS ratio or the findings may be the result of the method used and the subjective interpretation of the result.15 Andlovic et al.16 showed that the novel alkaline phosphatase assay is more sensitive than the standard peroxidase method for detection of OCBs. They compared the two methods and concluded that in patients with clinically isolated syndrome and MS OCB were more often present when analysis was performed by using the novel assay.

To date, there has been no definite association of these oligoclonal bands with any consistent antigens in patients with MS. It is clear that intrathecal antibody synthesis against many different antigens contributes to the IgG oligoclonal bands in CSF, either detected by antigen-driven immunoblots or by quantitative detection with the antibody index. But, to date, there has been no definite association of these specific antigens with the cause of MS. Some particular observations, such as the high frequency (despite low intensity) of intrathecal antibodies against neurotropic viruses in MS need further discussion. It is also clear that many of these antibodies have low affinity.18,19,21 The same pattern consistently seen in an individual over time suggests that a sustained chronic intrathecal immune response may be seen which is unique to each individual. It is also impossible to eliminate the presence of these bands following intensive immunosuppression treatment when a complete immune ablation is needed, such as autologous bone marrow transplantation in MS.20,22,23

Many present studies have emphasized the importance of MRI in the diagnosis and follow-up of MS.24–28 However, studies investigating the relationship between OCB and MRI are limited. In our study we compared the cranial and cervical MRI findings (atrophy, oedema, contrast material retention, number of plaques) of clinically definite MS patients with their OCB conditions and did not get a significant result. Mesaroc et al.29 similarly did not find a significant correlation between OCB (+) and OCB (–) patients with respect to cranial lesion size and atrophy. In the same study, no significant correlation was found between EDSS – a disability scale – and MRI findings of OCB (–) patients, while there was a significant correlation between those of OCB (+) patients. Pou et al. showed good correlation between the clinical features and the morphology and location of the plaques determined in spinal cord MRI.30 On the other hand, Zeman et al.31 found no relationship between OCB (+) and (–) patients with regard to total brain MRI lesions. Fukazawa et al.31 showed no difference between OCB (+) and (–) patients in respect to the size, number, range and width of MRI lesions. The same researchers found no significant correlation between OCB (+) and (–) patients with regard to their MRI findings in another study.13 Heinonen et al.32 found a correlation between the plaque volume in cranial MRI and intrathecal IgG synthesis rate of MS patients.

In early studies, the evoked potentials abnormalities were mostly correlated with the damage and clinical findings of the

---

**Table 3: The relationship between cervical MRI findings and OCB pattern.**

| Cervical MRI | OCB (+) | OCB (–) | P   |
|--------------|---------|---------|-----|
| Number of plaques |         |         |     |
| 5–10         | 10 (41.6%) | 7 (43.75%) | 0.74 |
| 11–20        | 8 (33.3%)  | 6 (37.5%)  |     |
| >20          | 6 (25%)    | 3 (18.75%) |     |
| Atrophy      |           |         | 0.50 |
| Positive     | 9 (37.5%)  | 4 (25%)   |     |
| Negative     | 15 (62.5%) | 12 (75%)  |     |
| Oedema       |           |         | 0.99 |
| Positive     | 13 (54.2%) | 8 (50%)   |     |
| Negative     | 11 (45.8%) | 8 (50%)   |     |
| Contrast material retention |         |         | 0.11 |
| Positive     | 12 (54.6%) | 5 (28%)   |     |
| Negative     | 10 (45.4%) | 13 (72%)  |     |

**Table 4: The relationship between neurophysiological findings and OCB pattern**

| Parameters   | OCB (+) | OCB (–) | P     |
|--------------|---------|---------|-------|
| VEP          |         |         |       |
| Normal       | 10 (41.6%) | 7 (43.75%) | 0.99  |
| Abnormal     | 14 (58.4%) | 9 (56.25%) |     |
| SEP          |         |         |       |
| Normal       | 15 (62.5%) | 10 (62.5%) | 0.99  |
| Abnormal     | 9 (52.5%)  | 6 (52.5%)  |     |
nervous system, while the correlation was poor between the lesions in MRI and the symptoms and findings. In our study, a chi-square test was performed between the evoked potentials and OCB situations of patients, but no significant relationship was found. Meszaros et al. researched the correlation between CSF findings and evoked potentials and found that SEP abnormalities are more frequent in OCB (–) MS patients compared to OCB (–) patients according to the CSF examinations, while no significant difference was present between two groups in respect to VEP abnormalities. Similar to earlier findings another study in ALS patients where the CSF of ALS patients was analysed for OCB stated the presence of IgG in CSF. Out of 259 ALS patients 9 were reported to have presence of IgGs in their CSF as an unusual overlap leading to discussion of common pathway involved in pathophysiology of both ALS and MS.

Such comparative studies between radiology and molecular investigations could be launched in other degenerative disorders as well such as ALS, AMD, AD, PD. Earlier there have been studies involving biomarkers in body fluids such as blood and CSF for advancing the diagnostic criteria for degenerative diseases like ALS, PD and AMD. The purpose for conducting these studies was to ascertain more reliable experiment diagnostic criteria. However in vitro studies may facilitate the research in diagnostic field. Studies involving the analysis of cell culture of stem cells in their niche matching the conditions in diseased entity may help more specifically in understanding the pathophysiology of disease. Recently, the putative role of VEGF in nurturing and proliferating the stem cells through different signalling pathways was studied. Human pigmented ciliary epithelium stem cells were cultured and neurospheres were analysed for the proliferation capacity of PCE in presence of VEGF. An increased NOTCH and JAGG, N Cadherin and Beta Cadenin expression was observed in cells at different time points, thus validating the role of VEGF in proliferation of stem cell. This study provides insight about diseased condition body when the production of VEGF may compensate for dying neurons. This is validated by study reporting increased expression of VEGF in ALS (which is also considered as possible biomarker for ALS diagnosis). In current scenario non invasive techniques such as MRI scanning can be more beneficial with respect to patient centric research.

Furthermore, the information in the literature shows that the OCBs in MS show different properties according to the geographic regions. Many studies are carried out in different countries while no approved systematic study is carried out in our country. Thus, the OCB results of MS patients in this geographic region and the relationships of these results with other diagnostic markers should be investigated in more detailed. However, major limitation of the study is the small number of samples. Therefore, larger studies are needed with more cases and extensive MRI scanning.

The article complies with International Committee of Medical Journal editor’s uniform requirements for manuscript.

Conflict of Interests: None: Source of funding: None

Received Date: 12 October 2013; Revised Date: 28 November 2013; Accepted Date: 28 December 2013

References

1. Exley C, Mamutse G, Korcharzhkina O, et al. Elevated urinary excretion of aluminium and iron in multiple sclerosis. Multiple Sclerosis, 2006; 12: 533–540.
2. Compston A, Coles A. Multiple sclerosis. Lancet 2002; 359: 1221–1231.
3. Rocca MA, Anzalone N, Falini A, Filippi M. Contribution of magnetic resonance imaging to the diagnosis and monitoring of multiple sclerosis. Radiol Med. 2012.
4. Villar LM, Masjuan J, Sadaba MC, et al. Early Differential Diagnosis of Multiple Sclerosis Using a New Oligoclonal Band Test. Arch Neurol. 2005; (62): 574–577.
5. Zeman AZ, Kidd D, McLean BN, et al. A study of oligoclonal band negative multiple sclerosis. J Neurol Neurosurg Psychiatry 1996; 60: 27–30.
6. Reiber H, Thompson EJ, Grimesley G, et al. Quality assurance for cerebrospinal fluid protein analysis: international consensus by an Internet-based group discussion. Clin Chem Lab Med. 2003; 41: 331–337.
7. Correale J, de los Milagros Bassani M. Oligoclonal bands and antibody responses in Multiple Sclerosis. Review. J Neurol 2002; 249: 375–389.
8. Freedman MS, Thompson EJ, Deisenhammer F, et al. Recommended Standard of Cerebrospinal Fluid Analysis in the Diagnosis of Multiple Sclerosis. A Consensus Statement. Arch Neurol., 2005; 62: 865–870.
9. Caudie C, Allauzen O, Bancel J, Later R. Role of isoelectric focusing of cerebrospinal fluid immunoglobulin G in the early biological assessment of multiple sclerosis. Ann Biol Clin 2000; 58: 187–193.
10. McLean BN, Luxtton RW, Thompson EJ. A study of immunoglobulin G in the cerebrospinal fluid of 1007 patients with suspected neurological disease using isoelectric focusing and the Log IgG-Index. A comparison and diagnostic applications. Brain 1990; 113(5): 1269–1289.
11. McDonald WI, Compston A, Edan G, et al. Recommended diagnostic criteria for multiple sclerosis: guidelines from the International Panel on the diagnosis of multiple sclerosis. Ann Neurol 2001; 50: 121–127.
12. Reb J, Mesac A, Pogacnik T. Multiple Sclerosis with Uncommon Cerebrospinal Fluid Findings. Croat Med J. 2003; 44(6): 697–701.
13. Fukazawa T, Kikuchi S, Sasaki H, et al. The significance of oligoclonal bands in multiple sclerosis in Japan: relevance of immunogenetic backgrounds. J Neurol Sci. 1998; 158(2): 129–137.
14. Nakashima I, Fujihara K, Miyazawa H, et al. Relevance of callosal and periventricular MRI lesions to oligoclonal bands in multiple sclerosis. Acta Neurol Scand. 2006; 113(2): 125–131.
15. Lin MW, Suan D, Lenton K, et al. Differentiating patterns of oligoclonal banding in the cerebrospinal fluid improves diagnostic utility for multiple sclerosis. Pathology 2012; 44(3): 248–250.
16. Andricov I, Babic M, Accetto S, et al. A comparison and diagnostic applications. Brain 1990; 113(5): 1269–1289.
17. Reiber H, Thompson EJ, Grimsley G, et al. Quality assurance for cerebrospinal fluid analysis and OCB technique. Authors described this overlap as an unusual overlap leading to discussion of common pathway involved in pathophysiology of both ALS and MS.

In current scenario non invasive techniques such as MRI scanning can be more beneficial with respect to patient centric research.

Furthermore, the information in the literature shows that the OCBs in MS show different properties according to the geographic regions. Many studies are carried out in different countries while no approved systematic study is carried out in our country. Thus, the OCB results of MS patients in this geographic region and the relationships of these results with other diagnostic markers should be investigated in more detailed. However, major limitation of the study is the small number of samples. Therefore, larger studies are needed with more cases and extensive MRI scanning.
23. Mancardi GL, Saccardi R, Filippi M, et al. Italian GITMO-NEURO Inter-group on Autologous Hematopoietic Stem Cell Transplantation for Multiple Sclerosis: autologous hematopoietic stem cell transplantation suppresses Gd-enhanced MRI activity in MS. Neurology. 2001; 57: 62–68.
24. Miller AE, Lublin FD, Coyle PK. Epidemiology and genetics. In: Multiple Sclerosis in Clinical Practise. London-New York. Martin Dunitz Publishing 2003: 31–53.
25. Offenbacher H, Fazekas F, Schmidt R, et al. Assessment of MRI criteria for a diagnosis of MS. Neurology 1993; (43): 905–909.
26. Barkhof F, Filipi M, Miller DH, et al. Comparison of MRI criteria at first presentation to predict conversion to clinically definite multiple sclerosis. Brain 1997; 120: 2059-2069.
27. Grimaud J, Barker GJ, Wang L, et al. Correlation of magnetic resonance imaging parameters with clinical disability in multiple sclerosis: a preliminary study. J Neurology 1999; 246: 961–967.
28. Van Werderveen MAA, Barkof F, Hommes OR, et al. Applicability of semi-automatic segmentation for volumetric analysis of brain lesions. J Med Eng Technol. 1998; 22(4): 173–178.
29. Heinenon T, Dastidar P, Eskola H, et al. Applicability of semi-automatic segmentation for volumetric analysis of brain lesions. J Med Eng Technol. 2003; 13(1-2): 31–35
30. Pou Serradell A, Roquer González J, Perich Alsina X. Acute posterior cord lesions in multiple sclerosis. An MRI study of the clinical course in 20 cases. Rev Neurol (Paru) 2000; 156(12): 1125–1135.
31. Fukazawa T, Miyasaka K, Tashiro K, et al. MRI findings of multiple sclerosis with acute transverse myelopathy. J Neurol Sci. 1992; 110(1-2): 27–31.
32. Heinonen T, Dastidar P, Eskola H, et al. Applicability of semi-automatic segmentation for volumetric analysis of brain lesions. J Med Eng Technol. 2003; 22(4): 173–178.
33. Leocani L, Comi G. Neurophysiological investigations in multiple sclerosis. Curr opin Neurrol 2000; 13: 255–261.
34. Poser C, Brinar V. Diagnostic criteria for multiple sclerosis: an historical review. Clinical Neurology and Neurosurgery 2004; 106: 147–158.
35. Fuhr P, Kappos L. Evoked potentials for evaluation of multiple sclerosis. Clinical Neurophysiology 2001; 112: 2185–2189.
36. Kurokawa T, Kira J, Tobimatsu S. Electrophysiological diagnosis for multiple sclerosis. Nihon Rinsho 2003; 61: 1347–1354.
37. Mesaros S, Drujovic J, Levic Z. Clinical characteristics and neurophysiological findings in patients with multiple sclerosis without oligoclonal Ig G in cerebrospinal fluid. Srp Arh Celok Lek 2003; 13: 122–126.
38. TICOZI N, TILCO Z, MENACCIE NE, et al. Oligoclonal bands in the cerebrospinal fluid of amyotrophic lateral sclerosis patients with disease-associated mutations. J Neurol. 2013; 260(1): 85–92.
39. Troisi F, Sagnelli A, Cirillo G, et al. Amyotrophic Lateral Sclerosis and Multiple Sclerosis Overlap: A Case Report. Case Reports in Medicine 2012; 1: 1–4.
40. Pawan KG, Sudesh P, Suresh S, et al. Vascular endothelial growth factor-A (VEGF-A) and chemokine ligand-2 (CCL2) in amyotrophic lateral sclerosis (ALS) patients. Journal of Neuroinflammation 2011; 8: 47.
41. Pawan KG, Sudesh P, Chandrika A, et al. Vascular endothelial growth factor-A and chemokine ligand (CCL2) genes are upregulated in peripheral blood mononuclear cells in Indian amyotrophic lateral sclerosis patients. Journal of Neuroinflammation 2011; 8: 114.
42. Pawan KG, Sudesh P, Neel KS, et al. Possible Association between Expression of Chemokine Receptor-2 (CCR2) and Amyotrophic Lateral Sclerosis (ALS) Patients of North India. Plos One 2012; 10:1371/journal.pone.0038382.
43. Sharma NK, Prabhakar S, Anand A. Age related macular degeneration – advances and trends. Annals of Neurosciences 2009; 16(2): 62–71.
44. Sharma NK, Gupta A, Prabhakar S et al. Single nucleotide polymorphism and serum levels of VEGFR2 are associated with age related macular degeneration. Curr Neurol Neurosci. 2012; 9(4): 256–65.
45. Anand A, Sharma NK, Gupta A, et al. Single Nucleotide Polymorphisms in MCP-1 and Its Receptor Are Associated with the Risk of Age Related Macular Degeneration. Plos One 2012; DOI: 10.1371/journal.pone.0049905.
46. Vinish M, Anand A, Prabhakar S. Altered oxidative stress levels in Indian Parkinson’s disease patients with PARK2 mutations. Acta Biochimica Polonica 2011; 58.
47. Prabhakar S, Vinish M,巴斯 CR, et al. Occurrence of PARK2 Mutations in a Never-Smoker Population with Parkinson’s Disease in North India. Neuroepidemiology 2010; 35: 152–159.
48. Vinish M, Prabhakar S, Khullar M, et al. Genetic screening reveals high frequency of PARK2 mutations and reduced Parkin expression conferring risk for Parkinsonism in North West India. J Neurol Neurosurg Psychiatry 2010; 81: 166–170.
49. Abburri C, Prabhakar S, Kalra J, et al. Vascular Endothelial Growth Factor (VEGF) Induced Proliferation of Human Fetal Derived Ciliary Epithelium Stem Cells is Mediated by Jagged - N Cadherin Pathway. Current Neurovascular Research 2013; 10(2): 93–102.