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Dynamic Assessment of High-Resolution MRI with Multi-Planar Reconstruction Increases the Yield of Lesion Detection in Patients with Partial Epilepsy

Sérgio L. M. Santos*,**, Enrico Ghizoni**, Li M. Li**, Fernando Cendes**

Neuroimaging Laboratory, Department of Neurology, Faculdade de Ciências Médicas, UNICAMP.

ABSTRACT

Objective: To investigate the presence and type of lesions associated with partial epilepsies by routine high resolution MRI and multi-planar reconstruction (MPR) and correlate the MRI abnormalities with semiology and EEG findings. **Methods**: We studied 100 consecutive patients followed in the epilepsy clinic of our Hospital with partial epilepsy who underwent MRI investigation. The MRI protocol included 6 mm sagittal T1-weighted, 3-4 mm axial T1 and T2-weighted, 3 mm coronal T1 inversion recovery and T2-weighted images that were printed on a radiographic film for routine analysis. In addition, all patients had a volume T1-gradient echo acquisition with isotropic voxels (1-1.5 mm) for multiplanar reconstruction (MPR). The MRIs were examined in two different occasions: first using only the images printed on films, without volume T1-gradiente echo acquisition and in a second occasion in a computer workstation when all the available images and MPR were analyzed blindly to the clinical information. The clinical and EEG findings were tabulated independently, and results were compared using Chi-square of Fisher exact test when appropriate. **Results:** The patients were divided into 10 groups according to their etiological classification (structural lesions) established by MRI. Mesial temporal sclerosis (MTS) was the largest group (40%). There were 65 women and 35 men. Mean age was 23.9 (± 5.7) years and mean age of onset of recurrent seizures was 9.9 (± 0.8) years. The most frequent risk factors were family history of seizures (23%), head trauma (10%), peri-natal anoxia (5%) and infection (9%). High resolution MRI including thin coronal slices, in addition to a "dynamic" analysis in a workstation with MPR, allowed a significant improvement in lesion detection compared to the traditional analysis with radiographic films (94% versus 80%) ($p < 0.05$). The lesions previously undetected were focal cortical dysplasia and subtle MTS. There was a good concordance between MRI lesions and clinical and EEG findings. **Conclusion:** High resolution MRI including thin coronal slices, in addition to a "dynamic" analysis in a workstation with MPR allowed a significative improvement in lesion detection compared to the traditional analysis with radiographic films (94% versus 80%). Patients with partial epilepsy and "normal" MRI need to be investigated further with thin slices and post-processing techniques using volume acquisitions that allow adequate multi-planar re-slicing.

Key words: Magnetic resonance imaging, partial seizures, partial epilepsy, cortical dysplasia, mesial temporal sclerosis, lesions.

RESUMO

Avaliação dinâmica em epilepsias parciais utilizando imagens por ressonância magnética (RM) de alta resolução de rotina e reconstrução multiplanar (RMP)

Objetivo: Investigar a presença e tipo de lesões em pacientes com epilepsias parciais utilizando imagens por ressonância magnética (RM) de alta resolução de rotina e reconstrução multiplanar (RMP) e correlacionar as anormalidades com semiologia e EEG. **Casuística e métodos**: Estudamos 100 pacientes consecutivos

* Department of Radiology.
** Neuroimaging Laboratory, Department of Neurology, Faculdade de Ciências Médicas, UNICAMP.
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acompanhados no serviço de epilepsia com diagnóstico de epilepsia parcial que foram submetidos ao exame de RM. O protocolo de RM incluiu imagens sagitais ponderadas em T1 de 6 mm, axiais ponderadas em T1 e T2 de 3-4 mm, coronais ponderadas em T1-*inversion recovery* e ponderadas em T2 de 3 mm, que foram impressas em filmes radiográficos para análise de rotina. Além disso, todos exames de RM incluíram aquisição volumétrica (3D) ponderada em T1-*gradiente echo* com voxel isotrópico (1-1.5 mm) para RMP. As RMs foram examinadas em duas ocasiões diferentes: primeiro utilizando apenas imagens impressas em filmes, sem as imagens 3D, e depois em uma estação de trabalho quando todas imagens estavam disponíveis, incluindo RMP, sem conhecimento prévio das informações clínicas ou da análise anterior da RM. Os dados clínicos e de EEG foram tabulados independentemente, e os resultados foram comparados utilizando teste do qui-quadrado ou teste de Fisher quando apropriado. **Resultados:** A casuística incluiu 65 mulheres e 35 homens. A idade media foi de 23.9 (± 5.7) anos e a idade média de início de crises recorrentes foi de 9.9 (± 0.8) anos. Os pacientes foram divididos em 10 grupos de acordo com a classificação do tipo de lesão estrutural estabelecida pela análise de RM em estação de trabalho com RMP. Esclerose mesial temporal (EMT) foi o maior grupo (40%). Os fatores de risco mais freqüentes foram história familiar de crises (23%), trauma de crânio (10%), anóxia perinatal (5%) e infecção (9%). Análise "dinâmica" de RM incluindo cortes coronais finos e RMP em uma estação de trabalho permitiu uma maior detecção de anormalidades em comparação com análise tradicional em filmes radiográficos (94% versus 80%) ($p < 0.05$). As lesões não detectadas na análise com filmes radiográficos foram displasia cortical focal e formas sutis de EMT. Houve uma boa concordância entre anormalidades detectadas pela RM e achados clínicos e de EEG. **Conclusão:** RM incluindo cortes coronais finos e uma análise "dinâmica" em uma estação de trabalho com RMP permitiu um aumento significativo na detecção de lesões em comparação com análise tradicional utilizando filmes radiográficos (94% *versus* 80%). Pacientes com epilepsia parcial e RM "normal" precisam ser investigados com RM incluindo cortes finos e pós-processamento de aquisições volumétricas que permitem RMP.

Unitermos: ressonância magnética, crises parciais, epilepsia parcial, displasia cortical, esclerose mesial temporal, lesões.

INTRODUCTION

Epilepsy is a common health problem, affecting 1 to 2% of the population worldwide[1,2]. Partial epilepsies accompanied with complex partial seizures stand for about 40% of all seizure types seen in adult individuals[1-3], and are often resistant to anti-epileptic drugs (AED) – 40% can develop complete control of seizures with adequate therapy[2-4]. The etiology is multiple, ranging from genetic and environmental conditions such as head traumas and neurocysticercosis[1,5-7].

It is important to define the exact triggering factor of epilepsy and the area(s) where such seizures originate, because these factors are essential for prognosis and therapeutic plan. This has been made possible due to the high resolution of magnetic resonance imaging (MRI)[8].

The objective of this study was to investigate the presence and type of lesions associated with partial epilepsies and to correlate MRI abnormalities with semiology and electroencephalogram (EEG) findings. In addition, we wanted to compare sensibility and specificity between routine high resolution MRI evaluations versus computer assisted multi-planar reconstruction (MPR) in a computer workstation.

PATIENTS AND METHODS

We studied 100 consecutive patients with clinical and EEG diagnosis of partial epilepsy, who underwent MRI investigation between April and September of 1998, in our epilepsy clinic.

We tabulated clinical data and antecedents, including pre and peri-natal history, febrile seizures, family history of seizures, age at onset of seizures, and seizure frequency. Definition of seizures types and epilepsy syndrome were made according to the classification of ILAE[9,10], through detailed anamnese with patients and relatives. Detailed neurologic examination was performed in all patients. EEG were performed using the international 10-20 system of electrodes placement using analogic or digital EEG system with 16 or 32 channels.

The MRI protocol included: 6 mm sagittal T1-weighted, 3-4 mm axial T1 and T2-weighted, 3 mm coronal T1 inversion recovery, 3 mm coronal T2-weighted images, that were printed on a radiographic film for routine analysis. In addition, all patients had a volume T1-gradient echo acquisition with isotropic voxels (1-1.5 mm) (Figure 1).

MRI was examined in two different occasions: First using only the images printed on films and in a second occasion in a computer workstation when all the available images and MPR were analyzed blindly to the clinical information. Results were compared using Chi-square or Fisher's exact test when appropriate. All patients signed an informed consent approved by our local Ethics Committee.

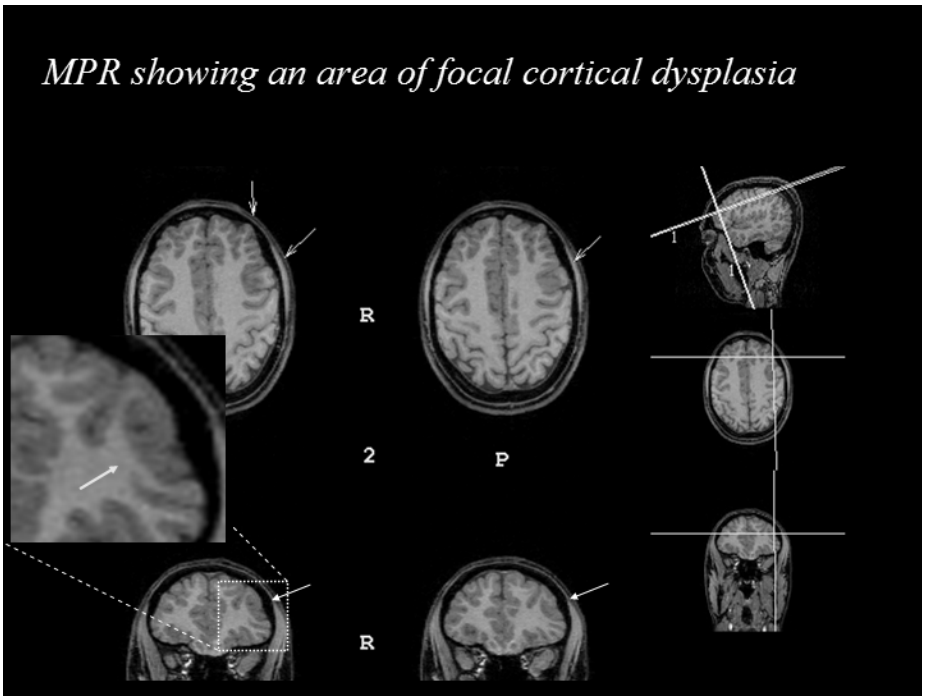

Figure 1. Example of multiplanar reformatting (MPR) showing area of focal cortical dysplasia (arrows).

RESULTS

The mean age was 23.9 (SD = 5.7) years. The mean age of seizures onset was 8.5 (SD = 3.1) years. The risk factors were present in all groups and the most frequent were family history of seizures (23%), head trauma (10%), peri-natal anoxia (5%) and infection (9%). Antecedent of febrile seizures was present in 23% of patients and occurred at a mean age of 2.7 (SD = 1.4) years. Most patients (90%) never had an optimal seizure control and were potential candidates for surgery.

Neurological examination was abnormal in 25% of patients: 18% had a focal motor deficit; 3% had a visual field defect; and 4% had a global cognitive and motor impairment.

Interictal EEG showed epileptiform abnormalities in 85% of patients: 61% in the temporal regions, 9% in extra-temporal regions, and 15% were generalized. The clinical-EEG diagnoses were: temporal lobe epilepsy (TLE) in 81%; extra-temporal epilepsy in 11%, and secondarily generalized epilepsy in 8%.

MRI findings

The analysis of MRI with MPR in a computer working station showed abnormalities in 94% of patients and analyses in conventional films showed abnormalities in 80% ($p < 0.05$). Etiologic diagnosis of structural lesions was possible in 94% of the patients using MPR versus 71% in conventional analysis with film ($p < 0.05$) (Figure 2). The lesions previously undetected were: focal cortical dysplasia (n = 5) (Figure 3), subtle hippocampal atrophy and other abnormalities in the medial temporal region indicating mesial temporal sclerosis [MTS] (n = 9).

Patients were divided in 10 groups according to the type structural lesions established through MRI with MPR (Table 1). Dual pathology (signs of MTS associated with other type of lesions) ([11,12]) was present in 22 patients. The extra-hippocampal lesions were: gliosis in 11; porencephalic cysts in 6, cortical dysgenesis in 4 and cavernoma in one. Most patients with dual pathology presented with ictal semiology of TLE despite of the extra-temporal lesion in the MRI.

Complete concordance between structural lesions on MRI and focal interictal epileptiform findings on EEG was observed in 72% of patients (non epileptiform abnormalities on EEG were not included for this analysis). Ten percent of the patients had normal interictal EEGs and 9% had some discordance between lateralization or localization of interictal EEG epileptiform discharges and localization of the lesion: 4 had left MTS and interictal EEGs predominate on the right temporal lobe; 2 had extensive areas of cortical dysgenesis and 3 had extensive areas of cortical atrophy and gliosis and interictal EEG predominate on the opposite hemisphere.

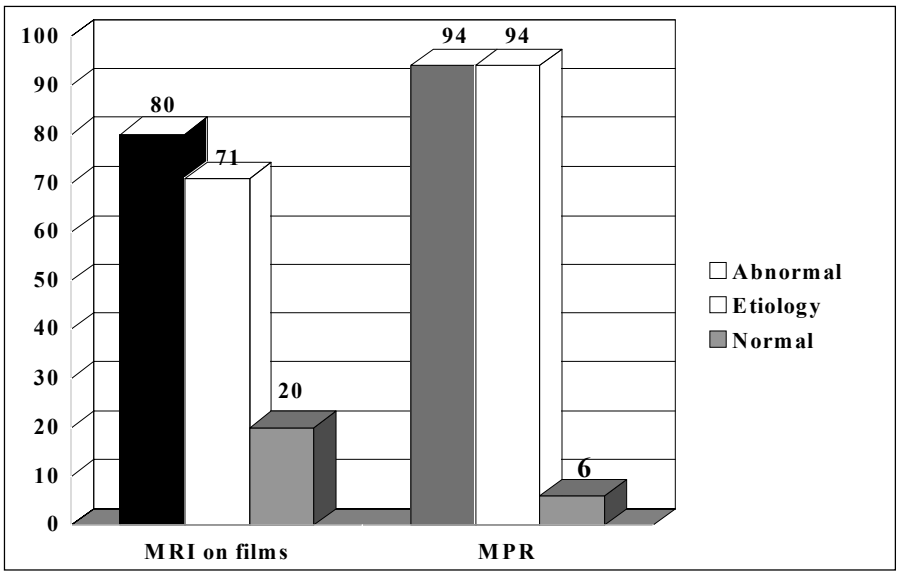

Figure 2. Conventional MRI analysis (using images printed on radiographic films) versus computer assisted analysis including MPR in 100 consecutive patients. Numbers represent the % of overall MRI abnormalities, abnormalities that allowed definition of an etiological diagnosis, and normal MRIs.

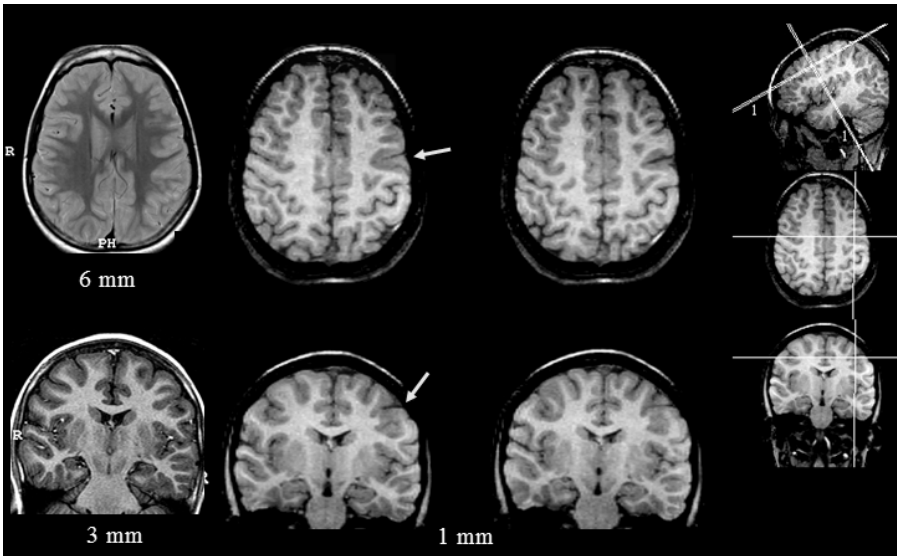

Figure 3. MRI multiplanar reformatting (MPR) showing area of focal cortical dysplasia (arrow) in a 7 years old girl with partial motor seizures starting on her right hand. Conventional MRI with 3 to 6 mm thick slices did not detect the lesion which became apparent in images with 1 mm thick using MPR.

Table 1. Summary of the MRI investigation after multiplanar reconstruction in 100 consecutive patients with partial epilepsies.

1. Mesial Temporal Sclerosis (MTS) (40%)
2. MTS + Atrophy-Gliosis (20%)
3. MTS + Cavitary Lesion (6%)
4. Cortical Dysgenesis (13%)
   a) Proliferation/apoptosis disturbance (6%)
      Taylor Cortical Dysplasia – 5 patients
      Tuberous Sclerosis – 1 patient
   b) Migration Disturbance (5%)
      Heterotopic gray matter – 3 patients
      Pachygyria – 2 patients
   c) Cortical organization disturbance (2%)
      Polymicrogyria
5. Atrophy/Gliosis (7%)
6. Normal MRI (6%)
7. Cerebral Malformation* (3%)
8. Neurocysticercosis (3%)
9. Cavernoma – Vascular Malformation (1%)
10. Ganglioglioma – benign tumor 1(%)

* Other types of cerebral malformation (not including cortical dysgenesis): Large arachnoid cyst associated with hypogenesis of anterior temporal lobe in two; and congenital hydrocephalus associated with hypogenesis of corpus callosum and septum pellucidum agenesis.

DISCUSSION

In recent years, there has been increasing appreciation of the role of structural lesions due to several kinds of injury to the central nervous system. By far the most common example of this is mesial temporal atrophy associated with neuronal loss and gliosis, which was described as MTS[13,14]. The demonstration by MRI of atrophy and signal changes suggesting MTS has streamlined the presurgical evaluation of patients with TLE[8,15]. Other pathologies causing TLE are readily identified on MRI, though again, as the lesions are often small, fine contiguous slices should be used. Volumetric imaging (3D acquisitions) provides information suited to the detection of both hippocampal and neocortical lesions, and is rapidly becoming the MR technique of choice for assessment of partial epilepsies[16-18,18].

In this series of 100 consecutive patients, high resolution MRI including thin coronal slices, in addition

to a "dynamic" analysis in a workstation with MPR, allowed a significant improvement in lesion detection compared to the traditional analysis with radiographic films (94% versus 80%). As a result of an enhanced anatomic display, a significant improvement in the identification and characterization of small cortical lesions located in the hemispheric convexities has been obtained leading to better characterization of the possible underlying etiology of focal seizures[19,20]. This approach for MRI acquisition and analysis is particularly relevant in patients with focal cortical dysplasia. The classical MRI findings of focal cortical dysplasia are: cortical thickening and/or blurring of the gray-white matter junction, often accompanied by variable degrees of focal gyral abnormality, alteration in the width, length, height, shape, orientation and size of gyri and sulci, prolongation of T2 relaxation times in the underlying white matter, and radial signal abnormalities extending from the affected cortical surface towards the ipsilateral ventricle (*transmantle sign*) as illustrated in Figure 4[21-24]. However, these abnormalities may be sometimes quite small and are often "hidden" due to partial volume effect of thick MRI slices as illustrated in Figure 3.

In conclusion, patients with partial epilepsy and "normal" MRI, particularly those with seizures not responding to adequate medical treatment, need to be investigated further with thin slices and post-processing techniques using volume acquisitions that allow adequate multiplanar re-slicing.

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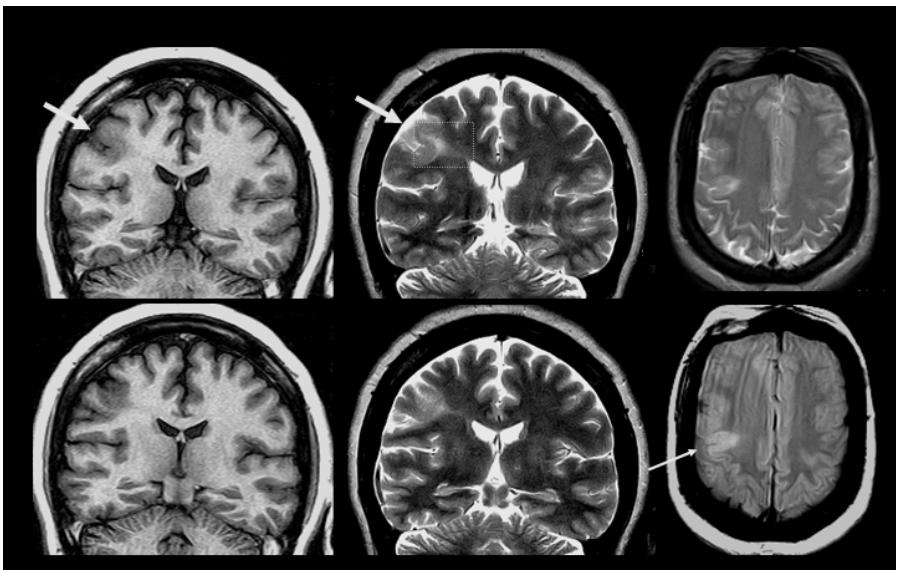

Figure 4. Coronal inversion recovery an T2 weighted, and axial T2 weighted and proton density MRI showing typical findings in focal cortical dysplasia (arrows): Cortical thickening and blurring of the gray-white matter junction, accompanied by focal gyral abnormality, alteration in the width and shape of a gyrus (arrow); prolongation of T2 relaxation time in the underlying white matter and radial signal abnormalities extending from the affected cortical surface towards the ipsilateral ventricle or *transmantle sign* (box).

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Endereço para correspondência:
Fernando Cendes
Departamento de Neurologia
FCM/UNICAMP – Cidade Universitária
CEP 13083-970, Campinas, SP, Brasil
E-mail: fcendes@unicamp.br