MODELLING THE SPREADING CORTICAL DEPRESSION (SCD) WAVEFRONT

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Spreading Cortical Depression (SCD) is a wave of depolarization that spreads across the cortex at 2-5 mm/min and is followed by a 5-10 minute reduction in EEG activity. It is assumed that SCD is involved in the pathophysiology of migraine. We present a new modeling and visualization technique for the spread of excitation on realistic brain surfaces. The usefulness of the technique is demonstrated on a rat brain which has been segmented from a 3D magnetic resonance image (MRI) data set. With the help of this methodology it is possible to create patient specific models to better understand the mechanisms of SCD.

INTRODUCTION

Leao first discovered Spreading Cortical Depression (SCD) of the EEG in the rabbit brain over 50 years ago[1]. Leao found that reduction of the normal electrical activity of rabbit neocortex could be induced by a variety of external stimuli[1] including KCl application[2]. Leao observed that the depressed activity begins in one hemisphere, at the stimulus site, and spreads slowly in all directions. He also observed vascular changes (pial arterial and venous dilatation) that occurred simultaneously with the onset of spreading electrical depression and followed closely the pattern of that depression[3]. This led him and others to speculate about the possible involvement of SCD in the pathophysiology of migraine[4,5].

Migraine is a moderate to severe headache, lasting from 4 to 72 hours, often accompanied by nausea and hypersensitivity to light and noise. Some sufferers experience an *aura* prior to the attack; in other words, neurological abnormalities such as visual disturbances or partial loss of vision. Both clinical and experimental evidence suggests that the migraine aura results from a transient abnormality that originates locally in the cerebral cortex, and then propagates throughout this brain region. Understanding SCD would lead a significant step forward in migraine research. In this study, the SCD is simulated on a realistic rat brain model.

MODELLING and ASSUMPTIONS

The wave of depolarization of the SCD is modelled by using small dipoles representing small areas of pyramidal cell activities. Each dipole represents a group of cells having a certain surface area. The dipole modelling is explained in a previous study[6]. In that study, theoretical formulations are accomplished while assuming the dipoles represent 0.01 mm^2 of cortical activity, the sulcus is well symmetric and mathematically represented by a closed analytic expression. Besides this, the SCD wavefront is assumed to be 5 mm wide.

In this study, we extend this representation to realistic brain models. A 3D MRI of a rat head was obtained from 256 slices of T1 weighted images. The brain is segmented by using Curry (®Neuroscan, Sterling VA, USA) biomagnetic research software. The surface is discretized with

1804 triangles having 1.0mm average edge length. In addition to realistic brain geometry incorporation, the whole SCD wavefront circle is considered.

It is assumed that the SCD starts at a point *P(x,y,z)* on the cortical surface whose coordinates are obtained from the three dimensional image of the brain. The wavefront then spreads as an circlet around the initial point *P*. The simulated wavefront is represented by discrete dipoles, where each dipole has a unit intensity, direction and travel velocity. The dipoles are oriented perpendicular to the surface. The velocity is constant in strength and tangential to the cortical surface. As a dipole (hence the SCD wavefront) travels, occasionally it passes across an edge of two discrete surface elements (triangles). At these edges, the velocity of a dipole is rotated and the travel is continued.

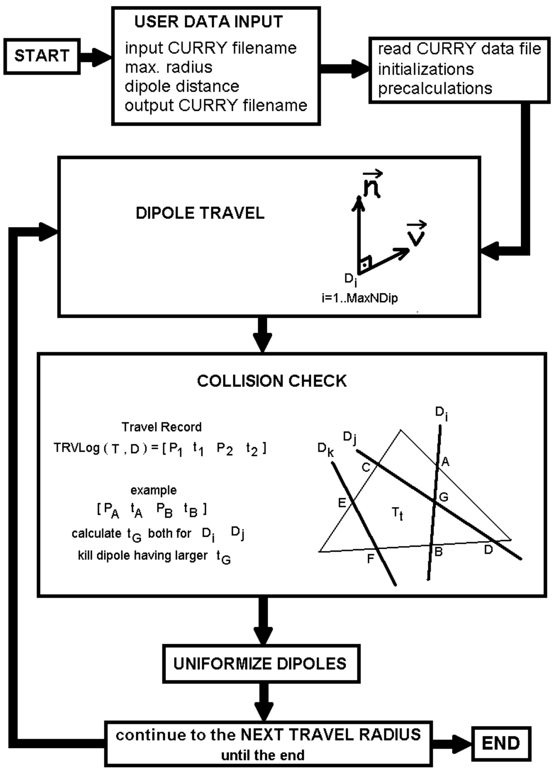


Figure 1 : The flowchart of the simulation

Since the SCD is accompanied with total depolarization and this depolarization period lasts on the order of minutes, it is also assumed that when a part of the wavefront reaches an already depolarized region, this part no longer proceeds further from that point. This is called as *collision*.

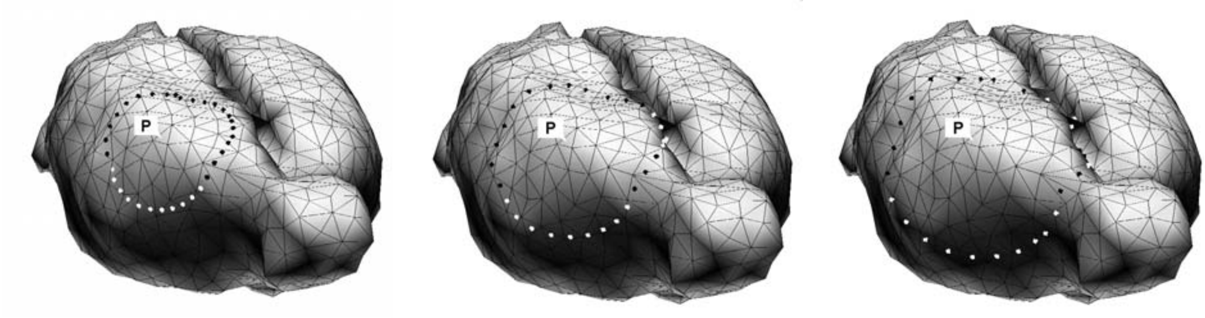
One step of travel is defined for all wavefront dipoles such that they have completed their positional increment equal to their velocity. The velocity, the number of steps, and the interdipole distance are all user defined. At each step, all the dipoles are checked if any collision had occured. If a collision had occured, the latter dipole reaching to the collision point is killed. At the end of each step, the dipoles are redistributed along the perimeter of the wavefront, so that uniform interdipole distance is preserved.

RESULTS

The simulation program is written in Delphi language. It reads the ASCII surface data file output from Curry® and outputs another ASCII file having dipole positions and normals to be read into Curry®. The program flowchart is shown in Figure 1. The results of the program are shown in Figure 2. It is observed that the spreading is well represented on a realistic rat brain model.

CONCLUSION and FUTURE WORK

The simulations are visually representing the spreading cortical depression (SCD) on a realistic brain model. With this methodology, it is possible to create animal specific and patient specific SCD models to better understand the mechanism of SCD. The dipoles which are generated as the outcome of this simulation, can be used to calculate the biomagnetic field distribution around the rat head. Then, this simulated field can be compared with experimental measurements.



(a) (b) (c)

Figure 2 : The results of the SCD simulation. The SCD starts from the point P and spreads up to three different radii (a) 150 mm (b) 200 mm (c) 250 mm. The wavefront is shown by black (on light background) or white (on dark background) dipoles.

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