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Agarose gels: Model of artificial brain in neurosurgery

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Introduction: The term artificial brain usually brings to mind a computer model that mimics neuronal activity.

International teams have already worked on a model of agarose gel to explore the cerebral perfusion of drugs (1). Our work had 2 goals: 1- to create a biomechanical brain surrogate used for the development of an invasive neurosurgical robot, devised for future medical applications such as tumor removal and insertion of implant; 2- to determine the physical and mechanical parameters of the gels that will be used for experimental tests (development of robot).

Materials & Methods: Four stages in our work: development of concentrations agarose gels, sensory and texture analysis, homogeneity.

The literature directed us towards manufacturing of gels at 0.8, 0.9, 1, 1.1 and 1.2% (1)

The formulation of gels was a mixture of water, agar-agar and phosphate buffer (K_2HPO_4 $NaHPO_4$ 0.01 M pH 7.1)

Gels, from 0.8 to 1.2 (w/v), offered physical characteristics that imitates the human brain. Nine neurosurgeons, blind of concentrations, gave subjective appreciation of gels according to mechanical criteria (palpation, puncture Cushing trocar, dissection); subsequently, objective geometric criteria and surface were noted for each gel. The production homogeneity was obtained by measuring density and Hounsfield density with a dual energy scanner (General Electric), compared to water, the major constituent of brain and a witness oily industrial manufacturing

A physical quantification was performed by texturometric analysis versus control with a TA NEXYGEN 300 (flat pad).

Texturometry determined hardness, elasticity and adhesion on gels tested versus control. The repeatability was tested.

Results: Selected gels: 0.9, 1, 1.1% mimicking at best the human brain (hardness, compactibility, humidity)

Hounsfield density average: $D_{0.9\%} = 3.9$, $D_{1\%} = 3.2$, $D_{1.1\%} = 5.3$ variation coefficient (CV) < 5.9 $D_{Witness} = -105$ and $D_{water} = 0$

The average density μ (mg/cm³): $\mu_{0.9\%} = 1002$, $\mu_{1\%} = 1004$, $\mu_{1.1\%} = 1007$ (CV < 12.9)

Texturometric average parameters for the 0.9% gel: hardness = 0.6 to 1 kgf (CV = 7), elasticity = 3.6 mm (CV = 5.7), adhesion = 2.6 N (CV = 21)

Discussion, Conclusion: Three gel concentrations were selected using sensory subjective analysis. Gels were homogeneous irrespectively of concentrations. Hounsfield densities of gels were close to water, except for the witness because of its composition (paraffin). The measure of texturometry used the same criteria as in sensory analysis (2). The repeatability of texturometry was satisfactory for all parameters.

This work has allowed us to produce homogeneous gels with general biomechanical characteristics that are close to human brain. Further tests are mandatory to specify the optimal gel concentration.

Inclusions of physical objects simulating different tissues within gels are to be considered in order to provide experimental conditions enabling the simulation of three-dimensional trajectories.

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