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ФАНТОМНОЕ МОДЕЛИРОВАНИЕ В МАГНИТНО-РЕЗОНАНСНОЙ ТОМОГРАФИИ: ОБЗОР МАТЕРИАЛОВ ДЛЯ ИМИТАЦИИ ВРЕМЕНИ РЕЛАКСАЦИИ ТКАНЕЙ (ОБЗОР)

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Антропоморфные фантомы необходимы для имитации свойств, геометрии или функций тканей человеческого организма. Материалы, используемые для таких тест-объектов, должны реалистично воспроизводить определенные физические характеристики тканей. В литературных данных отсутствует комплексная информация о классах соединений, которые могут моделировать характеристики биологических тканей, необходимые для реалистичной визуализации при магнитно-резонансном сканировании.

Цель работы — поиск и анализ существующих материалов, имитирующих времена спин-решетчатой (T1) и спин-спиновой (T2) релаксации, для создания МРТ-фантомов.

В статье рассмотрены методики изготовления составов для имитации времен релаксации биологических тканей. Представлены рецептуры, полученные из водных суспензий, гидрогелей, а также приведены примеры реализации композиций в 3D-печати. Показано, что гидрогелевые композиции способны точно воспроизводить релаксационные свойства различных тканей организма в диапазоне времен релаксации от 65 до 1663 мс. Фантомы, изготовленные из агарозы, имеют более низкие затраты на производство, срок их эксплуатации может быть продлен при введении специальных добавок. Отмечено, что агароза является модификатором времени T2 релаксации, даже в композициях с другими типами желирующих агентов. Технология 3D-печати значительно ускоряет процесс фантомного моделирования и позволяет эффективно проектировать сложные геометрические фигуры как из распространенных и доступных материалов (полимолочная кислота, полиметилметакрилат, акрилонитрилбутадиенстирол), так и из специально разработанных многокомпонентных составов. На основе изученных данных авторы подобрали материалы и разработали фантом для контроля параметров количественной МРТ, а также провели его апробацию. Дальнейшая работа по систематизации информации о характеристиках тканеимитирующих материалов позволит оптимизировать работу по проектированию и изготовлению фантомов для конкретных технических и клинических задач.

Ключевые слова: медицинская визуализация, МРТ, фантомы, тканеимитирующие материалы, агарозные гели, 3D-печать, гидрогели, контроль параметров количественной МРТ.

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PHANTOM MODELLING IN MAGNETIC RESONANCE IMAGING: AN OVERVIEW OF MATERIALS FOR SIMULATING TISSUE RELAXATION TIME (REVIEW)

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Anthropomorphic phantoms are required to mimic the properties, geometry, or functions of human body tissues. Materials used for such models should realistically reproduce certain physical characteristics of tissues. The literature lacks comprehensive information on classes of compounds that can model the biological tissue characteristics required for realistic imaging in magnetic resonance scanning.

The purpose of this work is to search for and analyze existing materials simulating the times of spin-lattice (T1) and spin-spin (T2) relaxation to create MRI phantoms.

The article considers the methods of making compositions for simulating the relaxation times of biological tissues. Formulations obtained from aqueous suspensions, hydrogels are presented, as well as examples of realisation of compositions in 3D-printing. Hydrogel compositions have been shown to be capable of accurately reproducing the relaxation properties of various body tissues within the relaxation time range of 65 to 1663 ms. Phantoms made from agarose have lower production costs, their life can be extended with the introduction of special additives. It has been noted that agarose is a modifier of T2 relaxation time, even in compositions with other types of gelling agents. 3D-printing technology significantly speeds up the phantom modeling process and allows you to efficiently design complex geometric figures both from common and affordable materials (polylactic acid, polymethylmethacrylate, acrylonitrile butadiene styrene) and from specially developed multicomponent compositions. Based on the data studied, the authors selected materials and developed a phantom to control the parameters of quantitative MRI, and also tested it. Further work on the systematization of information on the characteristics of tissue equivalent materials will optimize the work on the design and manufacture of phantoms for specific technical and clinical tasks.

Keywords: medical imaging, MRI, phantoms, tissue equivalent materials, agarose gels, 3D-printing, hydrogels, control of quantitative MRI parameters.

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