

# MRI Phantom

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## Function:

The goal of this project is to develop an MRI phantom for the calibration and testing of MRI techniques that quantify fat. This phantom will be used as a quality control mechanism for sites that wish to utilize MRI to quantify fat. Quantities of simulated fat used within the phantom are accurate to within  $\pm 0.3\%$ , and their MR signal will not change over a number of years.

## Client Requirements:

- **Accuracy:** The concentrations of simulated fat within the phantom must be accurate to within  $\pm 0.3\%$ . The method employed to create the simulated fat and water emulsions must yield reproducible results.
- **MRI Constraints:**
  - No magnetic materials can be used for the construction of this device.
  - The phantom must be of appropriate size to fit easily within a standard single channel MRI head coil.
  - The materials and chemicals, such as preservatives or emulsifiers, must not interfere significantly with the fat/water signal.
  - Air-to-sample interfaces must be minimized.
- **Range of Simulated Fat Concentrations:** The phantom must simulate physiological fat concentrations for different organs in the body. Ranges of

samples will need to exist surrounding 5%, 40%, and 90% fat. Concentrations between these target values only need to be sparsely sampled.

- **Shelf Life:** The phantom must have a shelf life of at least three years.

## **Design Requirements:**

### **1. Physical and Operational Characteristics**

a. *Performance requirements:* The concentrations of simulated fat within the phantom must be accurate to within  $\pm 0.3\%$  and be reproducible. These values should not change for the specified lifetime of the phantom. Also, as air is paramagnetic (i.e. interferes with MR imaging), air-to-sample interfaces must be minimized within the phantom.

- I. *Simulated Concentrations:* Concentrations simulated must be physiologically relevant. They must specifically surround the 5% concentration as this is recognized as the diagnostic cutoff for Fatty Liver Disease. Other concentrations should be simulated but are not as important.

b. *Safety:* Materials used in the phantom should be non-toxic, non-caustic, non-allergenic, chemically stable, and non-magnetic.

c. *Life in Service:* The phantom should yield consistent measurements for 3 years. It must withstand standard hospital cleaning procedures such as washing with isopropyl alcohol or similar agents.

d. *Shelf Life:* The conditions of use are not damaging to the phantom so shelf life should be equivalent to life in service.

e. *Operating Environment:* Strong magnetic fields of over 3 T may be used. These should not be damaging to the phantom, negatively affect its performance, or cause the phantom to become potentially harmful.

f. *Ergonomics:* Phantom should be easy to handle and transport by one person.

g. *Size:* Phantom must fit within a standard MRI head coil (27 cm diameter by 42 cm depth).

h. *Weight:* It should weigh less than 20 lbs so that one person can easily handle/transport it.

i. *Materials:* The phantom must consist of non-magnetic materials, and none of its components should interfere with fat quantification. Materials should also be transparent or translucent to allow for the user to easily detect damage to internal phantom components.

- I. *Fat Simulation Materials:* Due to sanitation and degradation concerns, the use of actual fat in this phantom will not be feasible. Instead, other materials displaying similar imaging characteristics need to be used.

## 2. Production Characteristics

- a. *Quantity*: Currently, the client only requires one phantom.
- b. *Target Product Cost*: The phantom prototype should cost less than \$300 to produce. Production on a larger scale would significantly reduce cost.

## 3. Miscellaneous

- a. *Standards and Specifications*: Fat/water solutions must be accurate and reproducible in large quantities. Dimensions for the phantom also must be standardized for potential mass production.
- b. *Customer*: The phantom should be easy to use so that potential customers are not discouraged.
- c. *Patient-related concerns*: The phantom will be used in the same scanner as patients. Therefore, the phantom materials must be non-toxic, non-caustic, non-allergenic, and chemically stable. The phantom must not leave residues upon surfaces it comes into contact with.
- d. *Competition*: Other quality control and research phantoms exist but few deal with fat quantification. Simpler designs can be used as an alternative, however, their accuracy cannot be guaranteed.