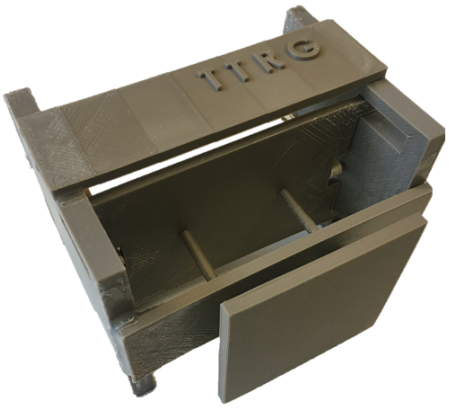
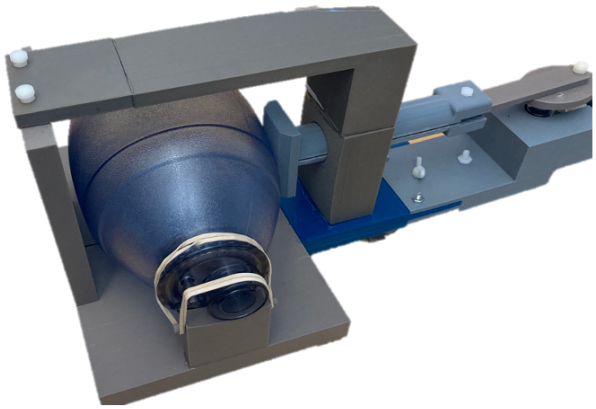
User Manual

Respiratory Motion Simulator





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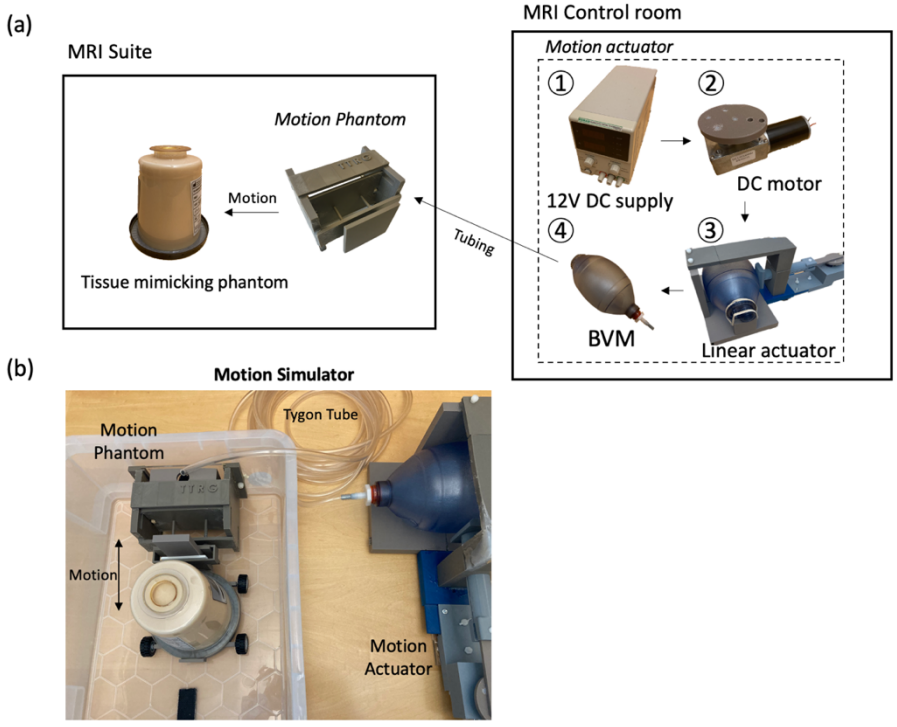
1. Overview of mechanisms

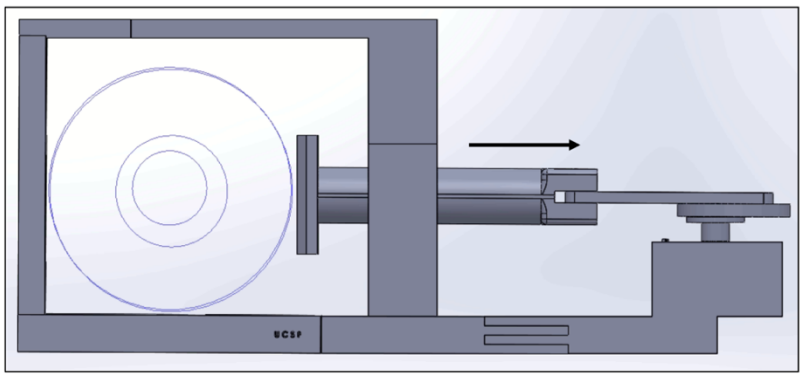
Outside the MRI suite, a DC motor of 16 rpm is connected to a motion actuator, which increases or decreases the pressure inside the BVM. The BVM is coupled via Tygon tubing to the compressible bag in the motion phantom in the MRI scanner. Various levels of inflation or deflation of the BVM cause cyclical motion of tissue-mimicking phantom in the MRI scanner to simulate the shift of abdominal organs due to respiratory motion.



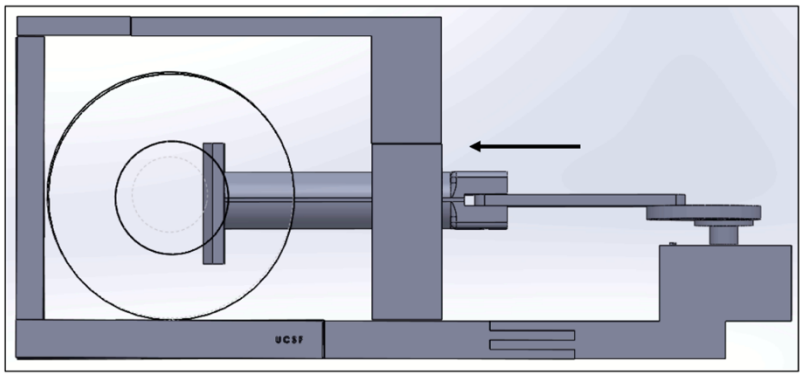
Designed respiratory motion simulator. (a) A schematic diagram and (b) a photo of the phantom and actuator.

Motion actuator mechanisms

Exhalation



Inhalation

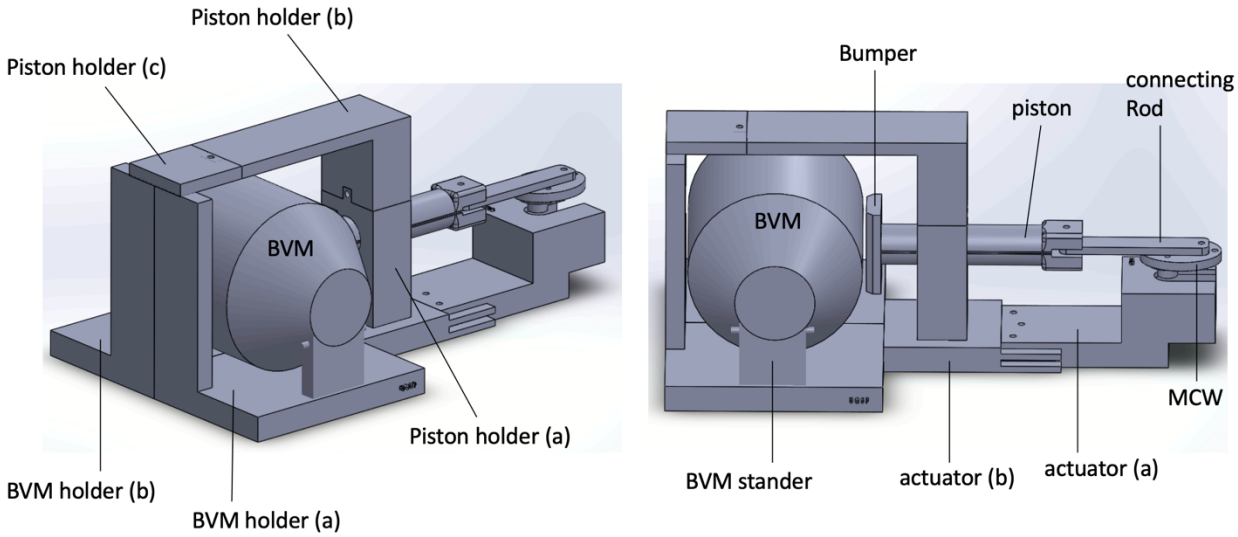


The motion actuator was constructed of a DC motor, 3D-printed linear actuator, and the BVM. The linear actuator was connected to the DC motor to convert the motor rotation into linear motion. The motion of the actuator controlled the level of inflation or deflation of the BVM.

2. List of components

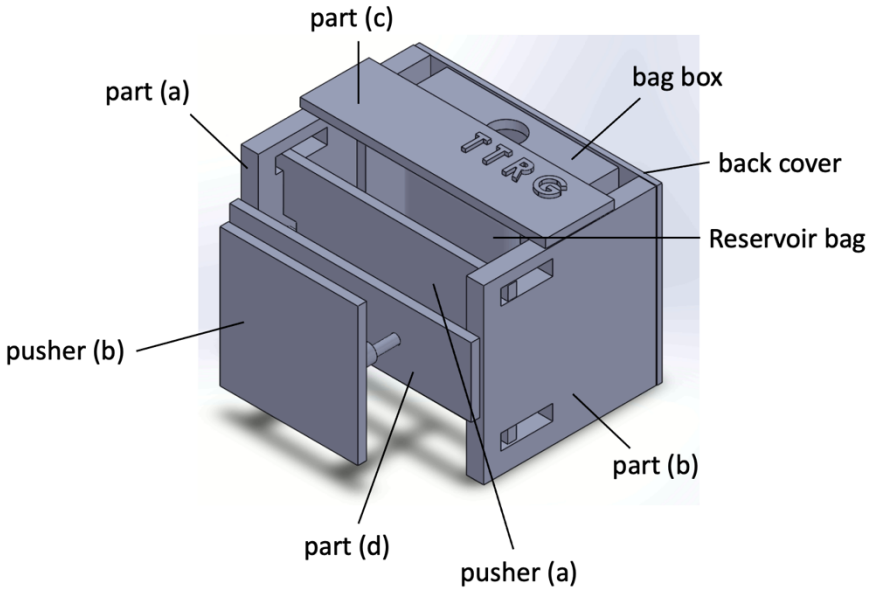
Name	Info
DC Power Supply	Korad Technology KD3005D, DC Linear Power Supply
DC motor	Brand: Bringsmart, 12V-16 rpm, gear motor 70kg·cm
8 mm Flange shaft coupling motor connector	Brand: Magic&shell, Thread size: M4, Material: Metal
Bag Valve Mask (BVM)	Brand: NEcommerce (currently not available) **Package Dimensions:** 25.65 x 17.78 x 11.43 cm; 454 g, volume 1.8 L
Reservoir bag for the BVM	Brand: NEcommerce (currently not available)
Tygon Tubing	Brand: Masterflex, 15ft
3D printer	Zortrax-M200 Plus
3D printing material	Acrylonitrile Butadiene Styrene (ABS)
Epoxy Glue	Brand: Gorilla Glue Epoxy
Motion Actuator	
Motor connector coupling wheel (MCW)	3D-printed
Connecting Rod	3D-printed
Piston	3D-printed
Piston holder (a)	3D-printed
Piston holder (b)	3D-printed
Piston holder (c)	3D-printed
Bumper	3D-printed
Actuator (a)	3D-printed
Actuator (b)	3D-printed
BVM stander	3D-printed
BVM holder (a)	3D-printed
BVM holder (b)	3D-printed
Motion Phantom	
Part (a)	3D-printed
Part (b)	3D-printed
Part (c)	3D-printed
Part (d)	3D-printed
Pusher (a)	3D-printed
Pusher (b)	3D-printed
Back cover	3D-printed
Bag box	3D-printed

Motion actuator components



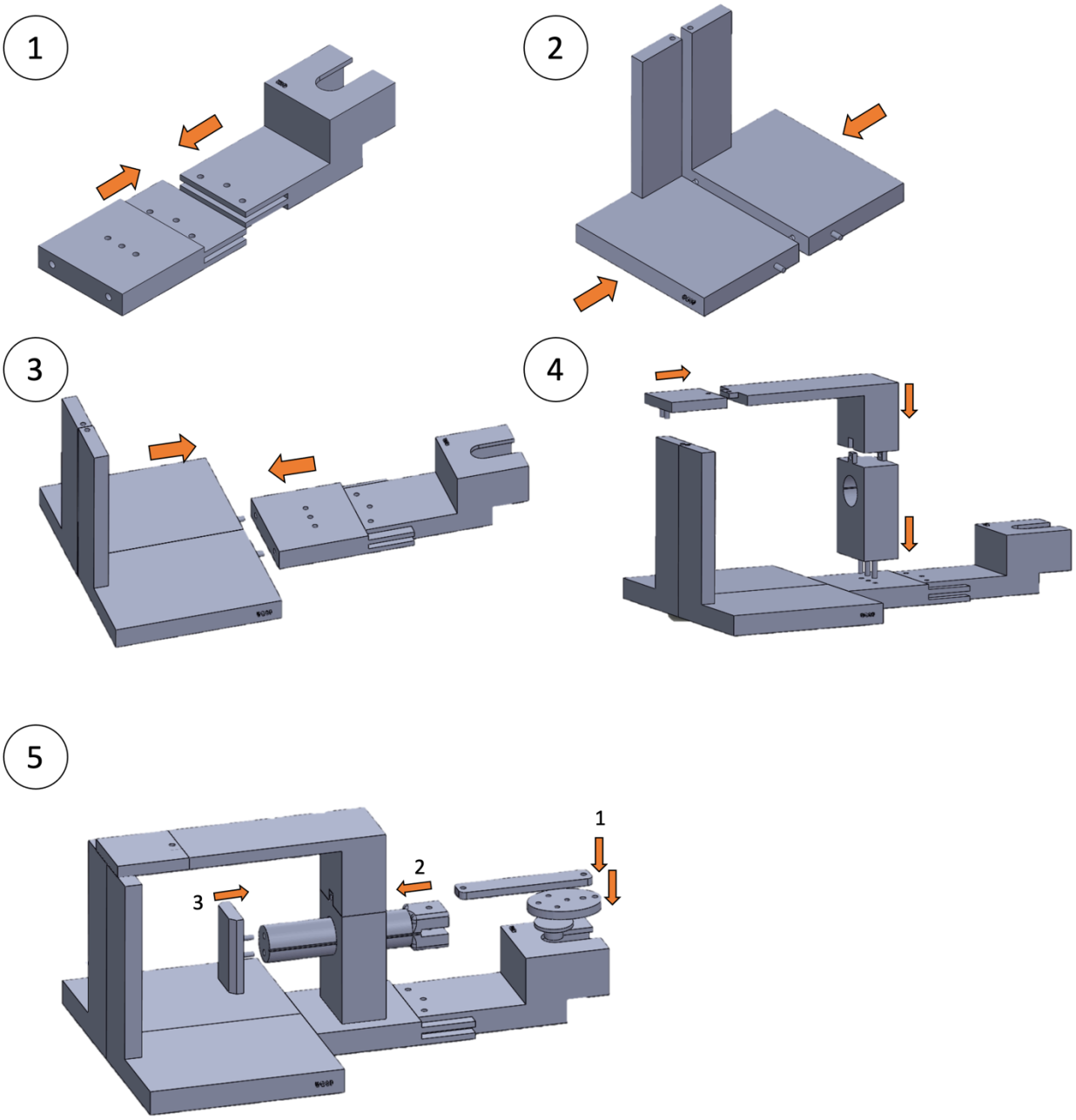
- MCW: Motor Coupling Wheel
- BVM: Bag Valve Mask

Motion Phantom components



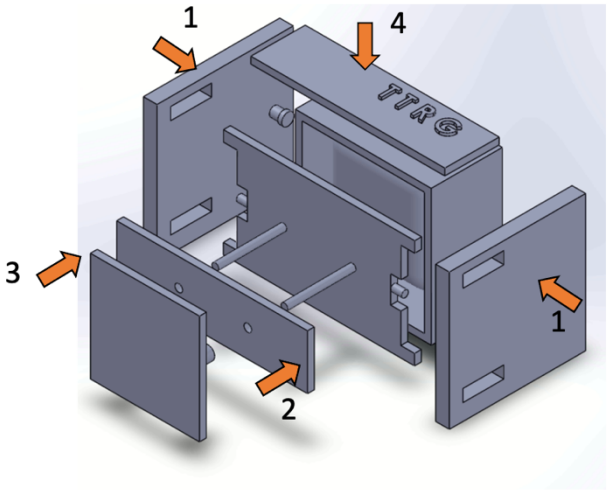
3. Assembly order

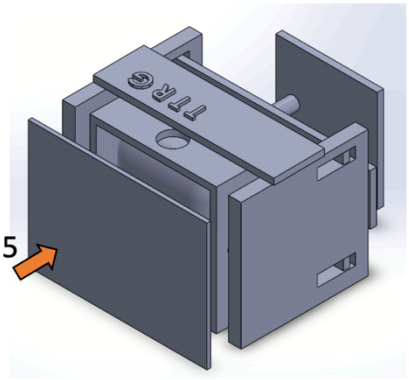
- **Motion Actuator**



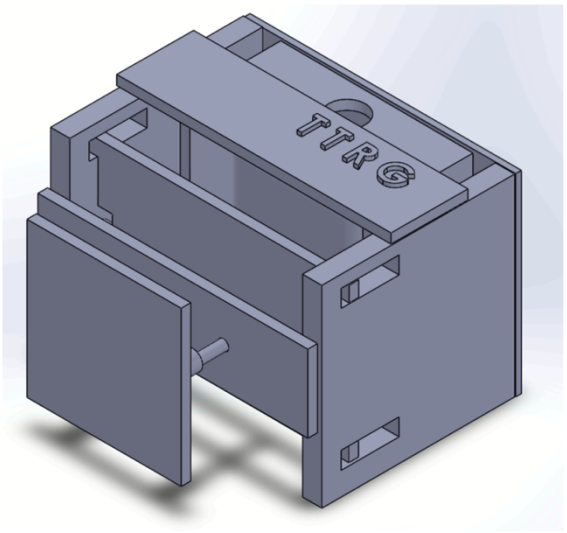
After assembled, bars of 10 mm, 20 mm, and 29 mm need to be used to fix the components. Please print and prepare bars at the steps: Step 1: 3 bars - 20 mm, Step 4: 2 bars - 10 mm, Step 5: 1 bar-29 mm, 1 bar-10 mm
Epoxy gluing needs to fix the components with the bars. Epoxy glue has been chosen due to high bond strength, non-magnetic, and water resistance.

- **Motion Phantom**



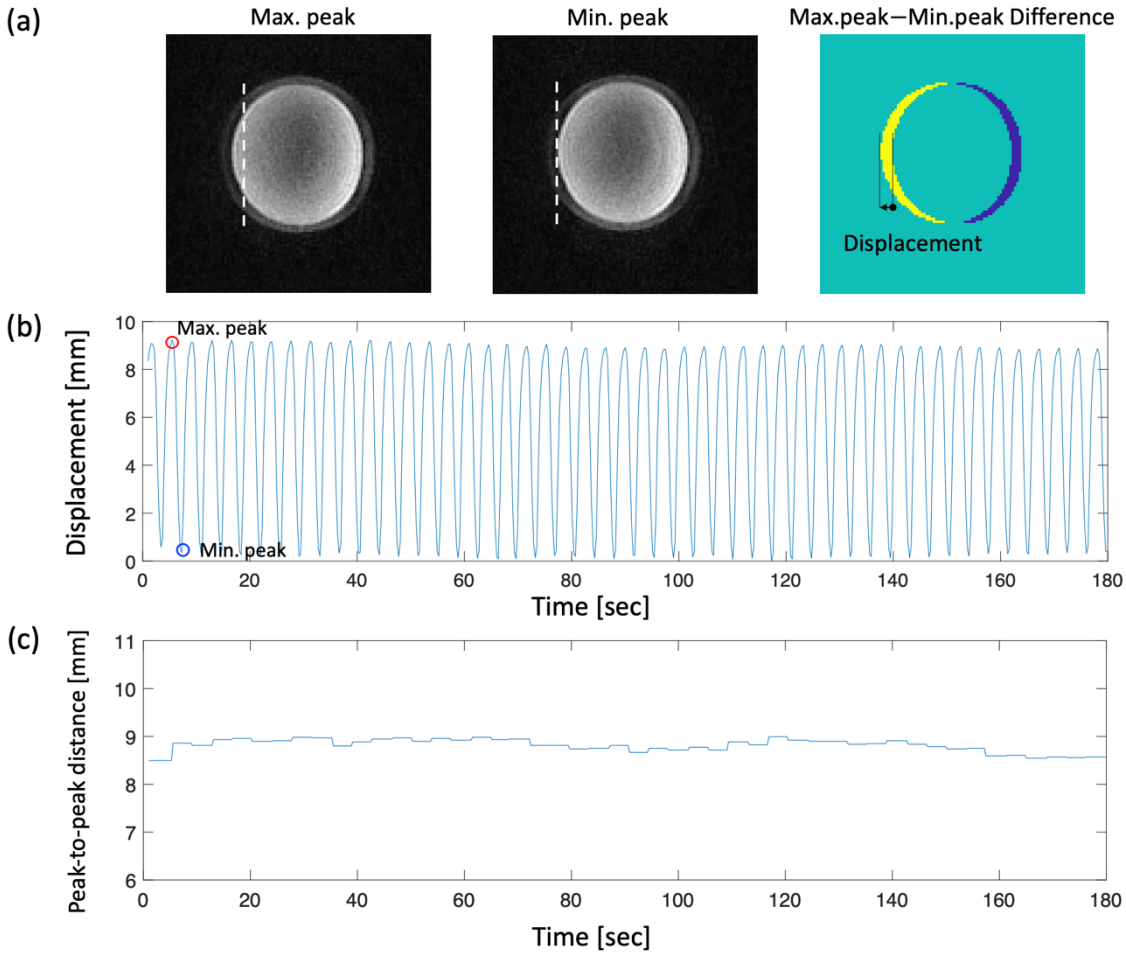


Completed phantom



Epoxy gluing needs to fix the components with the bars. Epoxy glue has been chosen due to high bond strength, non-magnetic, and water resistance.

4. Testing results



Displacements of the phantom with 1.65 L volume of the BVM. MR magnitude images (a, left, center) are shown on the coronal plane and white dashed lines indicate the original position of the phantom. (b) The displacement profile shows consistent and stable motions for 3 mins. Red and blue circles mean the maximum and minimum peaks of the navigator positions, respectively, corresponding to the magnitude images on the top. (c) Distances between the peak-to-peak displacements for 3 mins are plotted to evaluate the consistency of movement.

Table 1. Averaged distance between the peak-to-peak displacements for 3 mins, according to the volume of the BVM.

Volume of BVM (L) /Additional plastic thickness (mm)	Averaged Distance (mm)
1.75 L/10 mm	5.0±0.1
1.7/30 mm	7.0±0.1
1.65/35 mm	8.8±0.1