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DESIGN OF A MRI COMPATIBLE FARADAY CAGE FOR SYRINGE PUMPS

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ABSTRACT

The goal of this project was to design a MRI compatible Faraday cage for syringe pumps that do not display any artefacts during a MRI scanning procedure. A Faraday cage was fabricated consisting of stainless steel that contained a Medfusion® 3500 syringe pump and a power supply unit. When the syringe pump was running with water flowing at a rate of 3 mL/hour in a 1.6 Gauss magnetic field, artefacts appeared during the MRI scans. Once the syringe pump was placed inside the Faraday cage and ran on its own battery power, no artefacts appeared on any of the MRI scans. The syringe pump was then connected to a power outlet using an extension cord; slight artefacts appeared on the MRI scans. Although the Faraday cage can prevent artefacts from appearing on MRI scans, it is strongly recommended that they run on their own battery power.

INTRODUCTION

One of the challenges that physicians face when working in MRI suites is that infusion and syringe pumps are not MRI compatible. These infusion and syringe pumps contain magnetic metal that can interact with the magnet in a MRI suite. These pumps can act as a projectile and artefacts may appear on the images. An artefact is a feature appearing on an image that is not present in the original object [1]. To overcome this hurdle, anesthesiologists currently have two options. First, they can purchase MRI compatible syringe pumps [2]; however, many clinicians have found them to be not user-friendly and they are more expensive. Second, anesthesiologists have to place these infusion pumps inside the control room and use an extended intravenous tube to reach the patient. Not only is this inconvenient for the clinicians, but if a sudden change is made to the pump, this change will not instantly affect the patient.

The aim of this investigation was to develop a MRI compatible Faraday cage that could contain a syringe pump and a power supply. By designing a Faraday cage, this can prevent artefacts from appearing during MRI scans and the pump can be placed within close proximity to the patient.

METHODOLOGY

A Faraday cage (Figure 1) was designed that consisted of stainless steel and had dimensions of 16.8” (length) x 13” (width) x 6” (height). Along the front panel of the Faraday cage was a stainless steel mesh with dimensions of 9.5” x 6”. Over a 1” x 1” area, the mesh on the Faraday cage consisted of a 10 x 10 grid with 0.1” spacing. The Faraday cage also contained a power supply that was connected to a 110 volt power outlet.

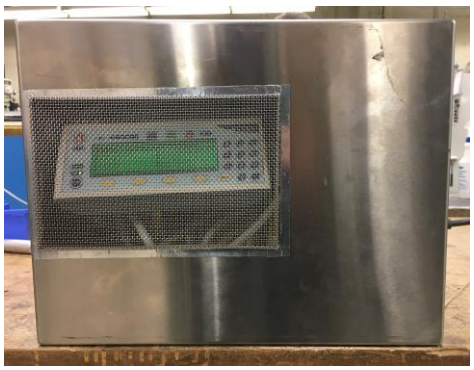

Figure 1. The Faraday cage containing a Medfusion® 3500 syringe pump.

A Siemens Verio MRI imaging system (Siemens Inc., Washington, DC, USA) was used that consisted of a 3 Tesla magnet. Standard imaging flare and turbo-spin echo tests were conducted at a frequency of 123 MHz and the images were assessed for the signal to noise ratio. For the standard imaging flair tests, there was an echo time of 102 ms, a repetition time of 9000 ms, and an inversion time of 2500 ms. Additionally, the field of view was 220 mm x 165 mm and the matrix size was 320 x 180. When conducting the turbo spin echo tests, there was an echo time of 103 ms and a repetition time of 3000 ms. The field of view was also set to 220 mm x 165 mm and the matrix was 488 x 269. For both tests, 24 slices in the transverse direction were obtained in each scan. Each slice was 5 mm thick with a 1 mm gap.

The Faraday cage and a Medfusion® 3500 syringe pump (Medfusion, Inc., Cary, NC, USA) were placed outside the 50 Gauss line and the magnetic field was static. Using a hand-held 4048 Gauss / Tesla magnetometer (F.W. Bell, Orlando, FL, USA), the strength of the electric field was recorded. While the Medfusion® 3500 syringe pump was operating with water at a rate of 3 mL/hour, three conditions were applied:

1. The syringe pump was positioned outside of the 50 Gauss line and was not enclosed by a Faraday cage;
2. The syringe pump and a power supply unit were enclosed inside the Faraday cage and ran on its own battery power. Additionally, the Faraday cage's mesh was facing towards the magnet in the MRI suite;
3. The syringe pump and a power supply unit were enclosed inside the Faraday cage; however, an extension cord was connected between the power supply unit and the 110 volt power outlet. Similar to the previous condition, the Faraday cage's mesh was directed towards the magnet in the MRI suite.

To assess the effect of the syringe pump on image acquisition, a MR phantom was imaged. The phantom consisted of a 1.9 L bottle featuring a solution of distilled H_2O, $NISO_4$ x H_2O (3.75 g per 1000 g of distilled H_2O) and NaCl (5 g per 1000 g of distilled H_2O).

RESULTS

The radiofrequency of the operating Medfusion® 3500 syringe pump was measured to be 123 MHz without the Faraday cage. Using the magnetometer, the Faraday cage with the Medfusion® 3500 syringe pump was positioned in a static magnetic field of 1.6 Gauss.

When the Medfusion® 3500 syringe pump was not enclosed inside the Faraday cage, several artefacts did appear on the MRI scans (Figure 1). This is evident when the signal-to-noise ratio was measured to be 1468 and 1109 for the turbo-spin echo and standard imaging flair tests, respectively (Table 1). Afterwards, the Medfusion® 3500 syringe pump was placed inside the Faraday cage and the pump ran on its own battery power. When MRI scanning commenced, no artefacts were detected on any of the images (Figure 2). Finally, the Medfusion® 3500 syringe pump was placed inside the Faraday cage but an extension cord connected the pump to the power outlet. After performing the MRI scans, there was a slight artefact that appeared just above the phantom (Figure 3). The maximum size of the artifact was 319 and 259 for the turbo spin echo test and the standard imaging flair test, respectively. During all of the testing, the Faraday cage displayed no signs of attraction towards the magnet.

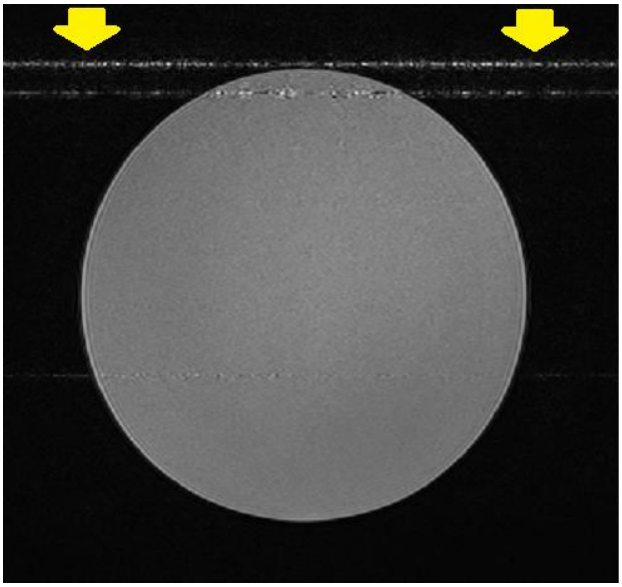

Figure 1. The phantom with multiple artefacts present when the Medfusion® 3500 syringe pump was not enclosed in the Faraday cage.

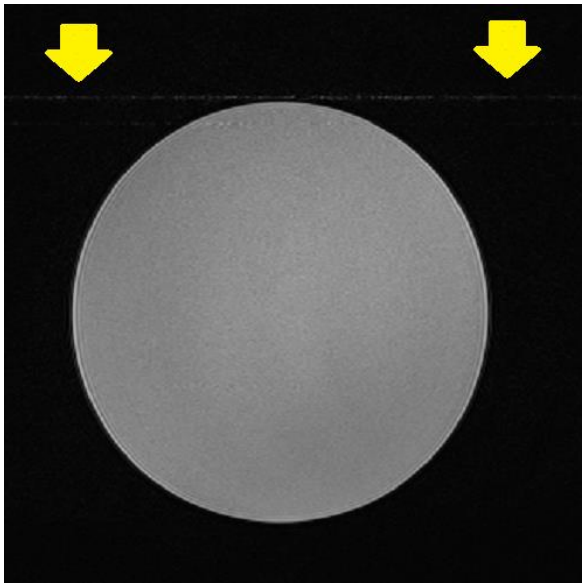

Figure 3. A slight artifact was detected just above the phantom when the Medfusion® 3500 syringe pump was enclosed in the Faraday cage and received power from a wall outlet.

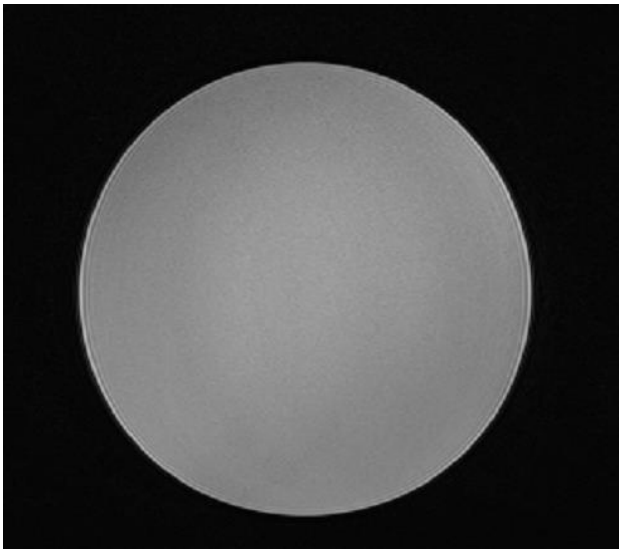

Figure 2. The phantom with no artefacts detected when the Medfusion® 3500 syringe pump was enclosed in the Faraday cage and running on its own battery power.

Table 1. Signal to noise ratio when the Medfusion® 3500 syringe pump was running on its battery power without the Faraday cage.

	Turbo Spin Echo Test	Standard Imaging Flair Test
Background Mean Size	14	15
Background Size Range	1-41	1-53
Artefact Present?	Yes	Yes
Maximum Size	1468	1109
Mean Signal in Phantom	744	862

Table 2. Signal to noise ratio when the Medfusion® 3500 syringe pump was enclosed in the Faraday cage and operating on its own battery power.

	Turbo Spin Echo Test	Standard Imaging Flair Test
Background Mean Size	10.4	10.6
Background Size Range	0-34	0-36
Artefact Present?	No	No
Maximum Size	N/A	N/A
Mean Signal in Phantom	738	853

Table 3. Signal to noise ratio when the Medfusion® 3500 syringe pump was enclosed in the Faraday cage that used an extension cord that was powered by a wall outlet.

	Turbo Spin Echo Test	Standard Imaging Flair Test
Background Mean Size	10.3	9.3
Background Size Range	0-33	0-27
Artefact Present?	Yes	No
Maximum Size	319	259
Mean Signal in Phantom	741	853

In the final test scenario, the use of an extension cord connected to a power ouetlet resulted in artefacts. This can be attributed to the fact that when the extension cord was plugged in, radiofrequency signals are emitted by the cord. Although it is possible that an additional Faraday cage could be built for the power cord, this second Faraday cage would have to cover the distance between the wall power outlet and the Faraday cage that the syringe pump was being stored inside. Setting this up for clinical procedures could be cumbersome and is not practical. In order to prevent artefacts from appearing on the images, we recommend that the syringe pump should run on its own battery power when enclosed inside the Faraday cage.

CONCLUSION

The aim of this project was to design a MRI compatible Faraday cage that could contain a Medfusion® 3500 syringe pump. With the syringe pump enclosed and running on its own battery power, the stainless steel Faraday cage successfully prevented artefacts from appearing on the MRI scans. When an extension cord connected the syringe pump to a power outlet, a slight artefact appeared during the MRI scans. From this investigation, the Faraday cage appears to be effective in preventing artefacts from appearing on the MRI scans as long as it is positioned in a static magnetic field less than 100 Gauss. When the Faraday cage is being applied in practice, it is strongly recommended that the clinician(s) allow the syringe pump to run on its own battery power instead of relying on power from an outlet to prevent any artefacts from appearing on the image.

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