Electromagnetic Interference during the Installation of a New Linear Accelerator

Zachary Grelewicz, PhD[1]; Julius Turian, PhD[1]
[1]Rush University Medical Center

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

ABSTRACT

Purpose: The interaction between static magnetic fields and charged particle beams necessitates isolating linacs from the magnetic fields from MRI systems and other sources. In the absence of known sources of strong magnetic fields, it has not typically been observed that magnetic field shielding is necessary for routine installations. We report on the novel problem, and attempts at mitigation, of a linac installation affected by magnetic fields over twice the level of background in the absence of known sources of magnetic fields.
Methods: Prior to magnetic shielding, linac performance was characterized in terms of loss of dose rate vs gantry angle, and a magnetic field survey was performed in the vault. A prototype magnetic shield composed of M36 steel was built to allow for continued testing without demolition of the existing space, and the linac performance measurement and magnetic field survey were repeated.

Results: Prior to shielding, dose rate variation exceeded 10% (tolerance) for 40% of photon energies, and 60% of electron energies. In the area designated for prototype shielding, gauss readings averaged 0.94 G on the ground, 1.12 G at 1 m, and 2.08 G at 2 m (tolerance 1 G). After shielding, dose rate deviations for all energies fell within 10%, and average gauss readings fell to 0.79 G, 0.79 G, and 0.74 G on the ground, at 1 m, and at 2 m, respectively.

Conclusion: Magnetic field mitigation after accelerator installation is possible but can double the construction costs associated with installation of a new machine due to the need to demolish and then refinish a previously prepared space, and the increased difficulty in performing construction around a linear accelerator rather than in an empty room. Some of the additional expenses and delays can be avoided with simple measurements taken prior to installation, during site survey.

CONTACT

Zachary Grelewicz
Rush University Medical Center
zachary_grelewicz@rush.edu

INTRODUCTION

The linear accelerator vault discussed in this presentation was originally built in 1984. The vault housed a Varian Clinac 1800 linear accelerator for 20 years, sat empty for ten years, and then housed a Varian iX accelerator for an additional ten years. In 2024, the iX became inoperative, and a replacement True Beam accelerator was delivered to the same space. During installation, the installation team was unable to obtain stable dose rate vs gantry angle in the absence of steering servos within product specifications (10% deviation acceptable). Figure 1 shows dose rate vs gantry angle for all therapeutic energies. As demonstrated by Figure 1, output deviations exceed 10% for 10X, 10FFF, 9E, 12E, and 16E energies. Several weeks of troubleshooting were unproductive, and the vendor suggested that the problem could be due to magnetic field strength above tolerance in the room.

On the earth's surface, the geomagnetic field generally ranges from 0.25 G to 0.65 G. The product planning guide for Varian Truebeam linear accelerator states that special care must be taken when locating a linear accelerator in the proximity of magnetic field generating equipment such as an MRI, and that the accelerator should be outside of the 1 G field. In most of North America, 1 G is approximately twice the strength of the geomagnetic field. At the time of the case being presented here, there had been no published accounts of linac installations affected by magnetic fields twice the level of background in the absence of known sources of magnetic fields, and the pre-install checklist did not require verification of compliance with magnetic field standards.

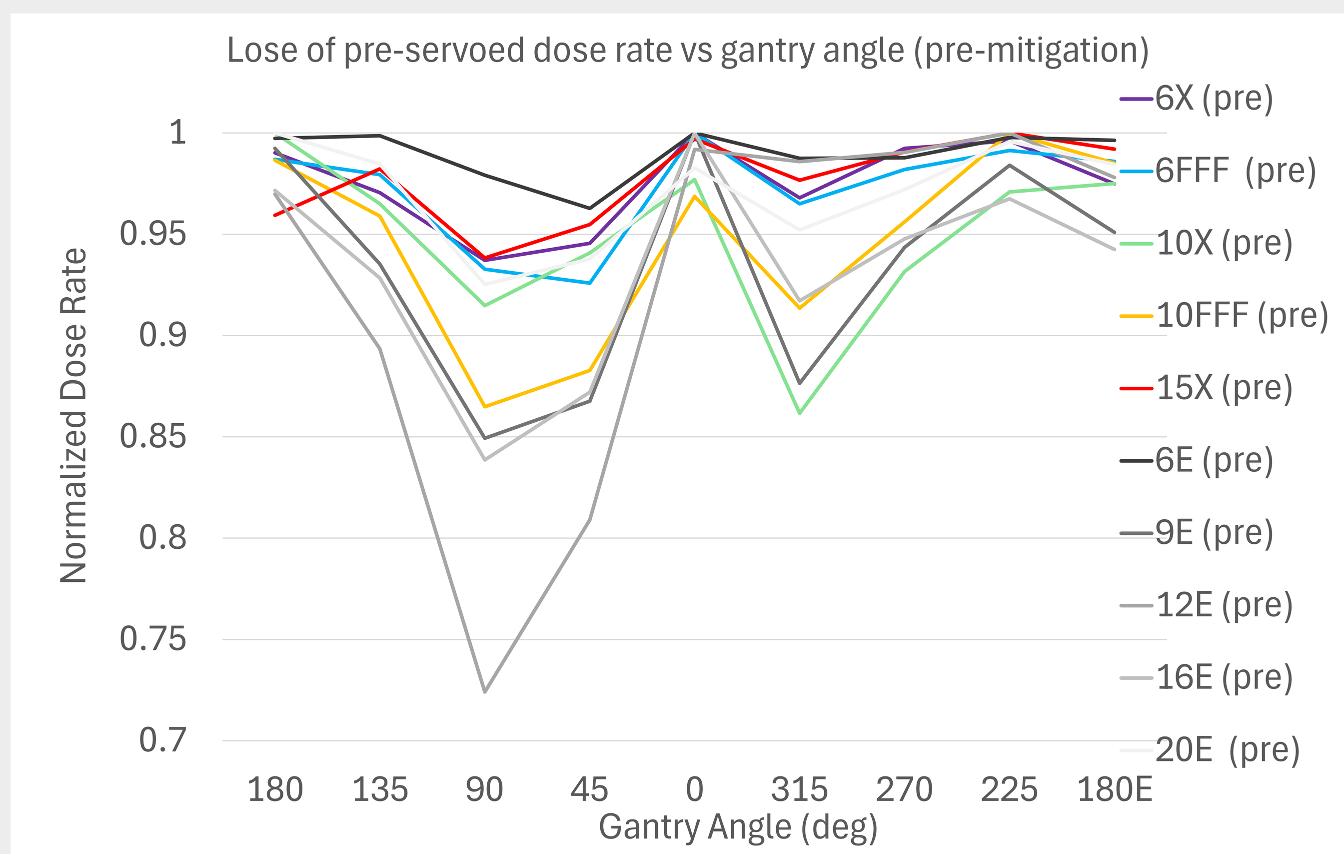

Figure 1: Loss of dose rate as a function of gantry angle for various energies, delivered without any steering or dose rate servos, per installation procedure.

INITIAL SURVEY

In order to determine whether excessive magnetic fields were present in our installation, a third-party vendor was contracted to perform a magnetic field survey. The survey was performed with a Bartington Instruments Spectromag-6, with Mag-03MS1000 Fluxgate magnetometer. A grid of 42 testing points, each with three elevations (ground, 1 m above ground, 2 m above ground) was performed as shown in Figure 2.

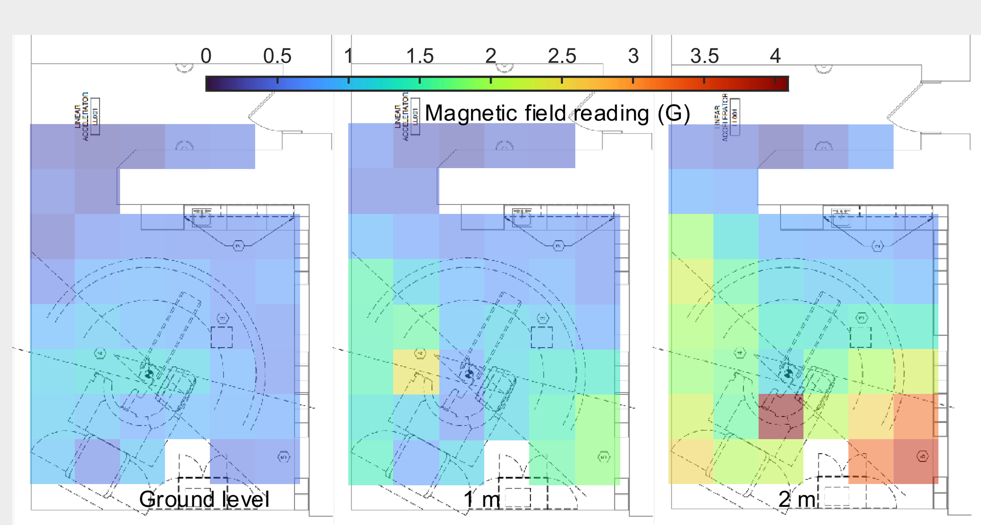

Figure 2: Initial magnetic field survey results at three elevations, demonstrating the need for EMI mitigation.

TEMPORARY ENCLOSURE

After the results of the initial magnetic field survey demonstrated magnetic field lines above background, but before undergoing the expensive process of demolition and reconstruction of the vault space, a preliminary proof of concept temporary shielding enclosure was constructed. An 11'-11" wide, 12'-0" deep, 8'-10" high enclosure was designed to encompass the accelerator on three sides, using M36 steel for shielding. The enclosure used 5 sheets (1/8") on the sides and 10 sheets (1/4") on the top of the structure. The total weight of the steel used for the temporary enclosure is approximately 2470 lbs. Photographs of the temporary enclosure are shown in Figure 3. Magnetic field strength within the area defined by the enclosure was measured and compared to measurements without the enclosure (Table 1). With the temporary enclosure in place, the installation team repeated measurements of dose rate versus gantry angle for all clinical therapeutic energies Table 2).

Figure 3: Photographs of the temporary (prototype) shielding enclosure. Top left: cross sectional view demonstrating layers of steel, plywood, and wooden frame assembly. Top right: Side view. Bottom: Front view.

Readings before enclosure (G)			Readings after enclosure (G)		
Floor	1 m	2 m	Floor	1 m	2 m
0.967	1.11	2.203	1.066	0.97	1.395
0.888	1.131	2.14	1.066	0.574	0.341
1.106	1.139	1.653	0.693	0.644	0.38
0.759	0.612	4.089	0.96	0.855	0.682
1.192	0.732	1.171	0.796	0.571	0.609
1.171	2.452	1.719	0.457	0.659	0.833
0.954	1.08	1.615	0.644	0.78	0.962
0.524	0.733	2.07	0.665	1.273	0.76

Table 1: Comparison of magnetic field readings at points within the space defined by the temporary enclosure, before and after shielding is applied. Readings are generally lower and generally within tolerance after introducing shielding. Better response may require more complete (e.g., complete wall-to-wall) shielding.

Energy	Pre-Shielding	Post-shielding
6x	6%	2.2%
6FFF	7%	2.0%
10X	14%	2.0%
10FFF	14%	2.2%
15X	6%	1.8%
6E	4%	2.5%
9E	15%	4.4%
12E	28%	8.4%
16E	16%	7.2%
20E	7%	3.3%

Table 2: Comparison of dose rate deviation before and after temporary shielding.

DISCUSSION AND CONCLUSIONS

Unexpected magnetic field interference during installation of a TrueBeam linear accelerator has the potential to seriously derail the installation process, even in cases where there is no prior reason to expect magnetic field interference. Magnetic field mitigation after accelerator installation can double construction costs due to the need to partially demolish and then refinish a previously prepared space. Many of the problems experienced in this case report could be avoided with stronger guidance from vendors. Preliminary measurements demonstrate that M36 steel in thicknesses of 1/8" to 1/4"provides adequate isolation for this installation.

Comparing the problems reported in this case report to previously published losses in symmetry and dose rate for older accelerators, initial results suggest that the Truebeam platform may be more sensitive to magnetic field irregularities than older platforms. Further work in this area could include a controlled study of loss of dose rate and symmetry in the Truebeam platform when known magnetic fields are introduced to specific sections of the beam path, for example using Helmholtz coils. If it is demonstrated that the Truebeam platform is in fact more susceptible to magnetic field interference, an additional further work could be investigating methods of shielding the accelerator internally rather than relying on shielding the vault.

REFERENCES

Karzmark CJ, Nunan CS, Tanabe E: Medical Electron Accelerators. McGraw-Hill; 1993.

Johnsen SW: Interference between NMR imaging systems and radiotherapy electron accelerators. Med Phys 11:748, 1984

Kok JGM, Raaymakers BW, Lagendijk JJW, Overweg J, de Graaff CHW, Brown KJ: Installation of the 1.5 T MRI accelerator next to clinical accelerators: impact of the fringe field. Phys. Med. Biol. 54:N409-N415 (2009)

St Aubin J, Steciw S, Fallone BG: Effect of transverse magnetic fields on a simulated in-line 6 MV linac. Phys. Med. Biol. 55:4861-4869 (2010)