Some Unique Radiation Safety Related Challenges with Installation of a MR-Linac

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INTRODUCTION

- Compared to conventional Linacs, there are some unique radiation safety related challenges during installation and commissioning of a MR-Linac.
- The purpose of this work is to review these challenges and provide solutions based on our experience at Sunnybrook.

Figure 1. Photo of a newly installed MR-Linac (Unity, Elekta) at Sunnybrook

CHALLENGE #1: SPECIAL REQUIREMENTS ON RADIATION SAFETY SYSTEMS

- MR-Linac room should be shielded for both radiation and magnetic fields. The RF shielding (a Faraday cage) was placed inside the radiation shielding AFTER the machine had been delivered and installed.
- In order to maintain the shielding integrity of the Faraday cage there are very limited locations where EPO (Emergency Power Off) and LPO (Last Person Out) buttons can be installed inside the room, typically at the doors or cable openings (figures 1.1-2)
- The Linac portion of the machine was installed and tested first. During the first beam-on, the radiation safety systems for the Linac were made operational but the buttons were not mounted on the wall since the Faraday cage was not completed during the testing.
- During commissioning the safety systems were tested both with and without the MR in operation, as required by CNSC.

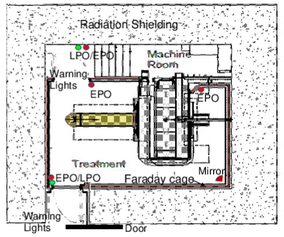

Figure 1.1 Schematic diagram (not to scale) showing locations of the radiation safety systems.

Figure 1.2 Photo showing EPO at one of the Faraday cage doors

CHALLENGE #2: GANTRY/MAGNET TOO BIG FOR NORMAL DELIVERY

- The gantry of an Elekta MR-Linac is much bigger than that of a conventional Linac (figure 2.1) and there is also a big magnet that must be delivered in one piece.
- We had to remove part of the existing roof (~ 2.5 m x2.7 m) of the MR-Linac room for the delivery (figures 2.2-2.3). Once the delivery was completed, a new concrete roof (figure 2.4) was built on top of the existing roof to cover the opening.

Figure 2.1 Photo of the MR-Linac gantry

Figure 2.2 Part of the existing roof removed for the delivery

Figure 2.3 Delivery of the magnet through the roof opening

Figure 2.4 Photo of the roof outside after a new roof was built on top of the existing roof to cover the opening

CHALLENGE #3 X-RAY TARGET ROTATING BELOW FLOOR LEVEL

- For a conventional Linac, the x-ray target stays above the floor level when the gantry rotates. As a result, there is no direct line of sight from the x-ray target through an air gap under a conventional shielding door (figure 3.1(a)).
- However, for a MR-Linac, the x-ray target can go below the floor level when the gantry rotates. For a room without a maze, there is potentially a direct line of sight form the x-ray target through the air gap under a conventional shielding door (figure 3.1(b)), which could result in a serious radiation leakage issue.
- We built a new shielding door that goes below the floor level for our MR-Linac room (with no maze) to avoid this problem (figure 3.1(c)). In our design, the door goes below the floor by about 3 inches (i.e., the floor under the door was cut by about 3 inches deep to allow the door go below the floor level).
- To fill in the gap in the floor when the door is open, a "gap filler" is attached to the door. The gap filter is pulled in to fill in the gap in the floor when the door is open and be push to the side when the door is closed (see figure 3.2).

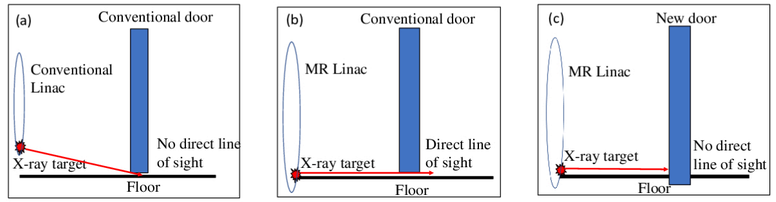

Figure 3.1 Schematic diagram showing (a) no direct line of sight from the rotating x-ray target through the door gap for a conventional Linac; (b) a direct line of sight form the rotating x-ray target of a MR-Linac through an air gap under a conventional door ; (c) no direct line of sight when using a new door that goes below the floor level for a MR-Linac.

Figure 3.2 Photo of a new door for our MR-Linac room with no maze.

CHALLENGE #4: CONVENTIONAL RADIATION SURVEY METERS NOT WORKING IN STRONG MAGNETIC FIELDS

- Most conventional radiation survey meters use photomultiplier tube (PMT) technology, which does not work properly in magnetic fields of large than 10 Gauss.[1]
- This is not an issue for areas *outside* the MR-Linac room since the five gauss line is usually contained within the room.
- However, this does cause a problem for radiation survey *inside* the room since it has been reported that neutrons can be produced from a MR-Linac[2] and neutron activation measurements are therefore required.
- Fortunately, there was a few week long window in commissioning, during which the Linac was running but no magnetic field was turned on. Measurements of neutron activation inside the room were done during this time window using conventional survey meters.

CHALLENGE #5: PERSONAL RADIATION DOSIMETERS NOT MR SAFE

- In many cancer centres, nuclear energy workers are required to wear personal radiation dosimeters when working with radiation.
- Most current personal radiation dosimeters, however, are not MR-safe. There is also a concern on the dose accuracy of personal dosimeters in the presence of a strong magnetic field.
- We modified an existing personal dosimeter (by removing a metal clip) to make it MR-safe (figure 5.1).[3]

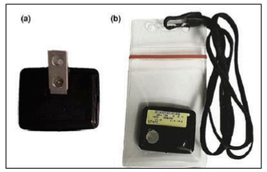

Figure 5.1: (a) Back of a standard radiation protection badge (Mirion Technologies Inc., Irvine, US); (b) modified version stripped of the metal holder clip. [3]

- We investigated potential effect of magnetic field on dosimeter readings, i.e., optically stimulated luminescent dosimeter (OSLD) readings. We found that the effect of magnetic field on OSLD sensitivity was negligible.[3]

CONCLUSIONS

- There are some unique radiation safety related challenges during installation and commissioning of a MR-Linac.
- These challenges have been identified with solutions provided

ACKNOWLEDGEMENTS

The installation and commissioning of the MR-Linac at Sunnybrook involved many people and in this work I only discussed some radiation safety related issues from the RSO's perspective. I thank my colleagues for collaborating on the overall project and providing some of the photos shown here.

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