BME Design Excellence Award: Fetal Radiation Shield

Each year, about 4,000 pregnant women undergo radiation therapy in the United States, with this number growing due to an increase in both cancer diagnoses and average childbearing age. Radiation therapy is often considered when treatment cannot be delayed until after childbirth, especially in young women with either brain or breast cancer. When a woman chooses to undergo radiation therapy while pregnant, steps must be taken to attenuate fetal radiation dose to a minimal level. Photon leakage through the head of the machine and collimators and radiation scattered within the patient from the treatment beams are the main sources a radiation that could potentially harm the fetus. While there is no preventative measure that can be taken to reduce the radiation dose from scatter within the patient, external measures can be taken to reduce radiation from the machine leakage.

Current methods for protecting the fetus from irradiation include repositioning the patient for treatment and stacking lead bricks atop a bridge placed over the patient and treatment couch. The latter method is not favorable due to the safety risk posed to the patient and medical personnel. The University of Michigan's Medical Innovation Center developed an external U-shaped lead shield which included a sophisticated locking system and hydraulic motors. Although the shield was effective at blocking 50% of the peripheral dose (PD) to the fetus, the design was prohibitively costly and led to the bankruptcy of the manufacturing company. As such, there is no commercially-available fetal radiation shield.

The design process of the the current prototype has spanned four semesters and three different design teams. Members from the first design team devised a half-funnel-shaped lead shield, and the second team the following semester designed the support system.The third and current design team has focused on refining the lead shield shape, further specifying the support system components, devising a mechanism for transporting the shield throughout the hospital and working with manufacturers. SolidWorks simulations were used for static and dynamic testing of the shield and support system assembly.

The final design consists of a half-cylinder lead shield encased in A36 steel, secured to the support system by two rectangular casing mounts on each side. The support system consists two rectangular bases on either side of the shield, linear actuators at each corner and one power jack screw at the center of each side. These components permit the raising and lowering of the shield. The actuators and power jack screws are connected to the casing mount on each side. Six four- to six-inch polymer-based caster wheels will allow the shield to be transported through the hospital. The shield is designed to protect the fetus from radiation exposure while not presenting an additional risk to the patient.

Three tests were considered for validating the design: static testing, dynamic testing, and fatigue testing. While only static testing has been done, the results of those tests are promising. The maximum stresses that were identified through SolidWorks testing were well below the materials' yield strengths, which implies that the shield would not fail.

There is a clear clinical need for a safe, readily available fetal radiation shield. Radiation can be extremely dangerous to a developing fetus due to the risk of birth defects and increased likelihood of childhood cancer. The motivation for this project is that a pregnant patient should not have to choose between receiving potentially life-saving treatment and risking harmful radiation exposure to her unborn child. A lead radiation shield will mitigate risk of radiation exposure to the fetus and hopefully make a pregnant patient's decision to undergo treatment easier.