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Design and Construction of Cervix Phantom for Brachytherapy Dose Assessment Procedure for Clinical Application

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ABSTRACT

An important point to consider in a brachytherapy dosimetry study is the design of an appropriate phantom size in calculations or experimental measurements. Perspex sheets of various size and thickness are used to design the cervix phantom. The aim of the study is to design and construct cervix phantom to mimic the pelvic segment of a standard adult human patients undergoing Brachytherapy. This is to allow assessment of dose to cervix and the surrounding tissues during cervix Brachytherapy. The methodology include; first phantom design where physical dimensions of the phantom were determined from a sampling of 30 patients' cases to simulate an average patient size. Secondly, construction of phantom with fabricated cylindrical shape, composed of 6 mm Perspex sheets, and the assembly enclosed with the 4 mm Perspex sheet. The result of the constructed phantom had lateral separation of 34 cm, an anterior and posterior separation of 27 cm; with length of 33 cm. The Perspex pieces were glued to each other with Trichloromethane (chloroform) at room temperature. Chloroform dissolves the Perspex (PMMA), and when applied to the surfaces of the Perspex sheets, the surfaces stick together after the chloroform dries up. In forming the surface of the phantom, the 4 mm Perspex sheet was oven heated to a temperature of 140˚C to make the sheet malleable. One end of the phantom was made thicker than the other end by gluing another 6 mm Perspex sheet such that the thickness of that particular end of the phantom was 12 mm. A hole of diameter 6.5 cm, which was a little bit posterior to the phantom, was created central to the 12 mm end of the phantom. The opening created was covered by 11 x 11 cm2 and 12 mm Perspex slab which was formed by gluing two 6 mm sheets together. A hole of diameter 5 cm was also made central to the cover created, such that the centre of this hole matches that of the hole on the end of the phantom. A 2.4 cm thick ring with internal diameter of 5 cm and external diameter of 6 cm was fabricated from 2.4 cm Perspex slab, which was formed from gluing four pieces of 6 mm Perspex sheets together. The fabricated ring was mounted on the 11 x 11 cm2 cover created such that the internal walls of the ring and that of the hole in the cover matches. The ring was then glued to the cover using the chloroform. The built phantom simulate actual patient anatomy and produce an excellent result to be use for clinical application.

Keywords : Brachytherapy, Cervix Phantom, Rectum, Bladder, Perspex Sheet

I. INTRODUCTION

Phantoms are generally design and constructed to mimic tissue-equivalent materials to be use for preclinical assessment before its clinical procedure are adapted. It generally provide a physical representation of the body's anatomy and attenuation characteristics for radiation dosimetry studies. Of particular interest for this study is the cervix phantoms for measuring dose in brachytherapy average organ doses assessment as well as it nearby tissues including rectum and bladder. Quantifying organ doses in physical phantoms offers a distinct advantage over computational methods because knowledge of the exact photon energy spectrum or

irradiation geometry is not required. In brachytherapy and other therapeutic procedures require simulation where expected treatment input factors are used to simulate the expected outcome. However various factors affect the design and construction of phantoms hence this study will assist treatment planning clinicians in their clinical practice.

The advantages of the local made phantoms compared to commercially available phantoms are that they design and constructed by clinician to more specific require dimensions and are utilize to small as a 5 mm slice thickness, allowing greater options for dosimeter placement when performing internal dose measurements, and the anatomy is precisely known and used to construct the phantom. In addition, each physical phantom has a corresponding segmented computational phantom. This allows the physical phantom to serve as a direct comparison to the computational phantom for the experimental validation of Monte Carlo codes. In turn, the computational phantom can be used to determine point-to-organ dose scaling factors, allowing the calculation of average organ doses from simple point organ dose measurements made in the physical phantom.

II. OBJECTIVES

The aim of the study is to design and construct cervix phantom to mimic the pelvic segment of a standard adult human patients undergoing Brachytherapy. This is to allow assessment of dose to Rectum and Bladder during cervix Brachytherapy.

III. MATERIALS

The materials use include, 4mm and 6mm diameters of Perspex (PMMA) sheets, tape measure, water, Trichloromethane (chloroform)

IV. METHODOLOGY

Perspex sheets of thickness 4mm and 6mm were used to design the cervix phantom. The physical dimensions of the phantom were determined from a sampling of patient cases to simulate an average patient. The phantom with cylindrical shape was fabricated to mimic the pelvic segment of a standard adult human. The ends of the phantom were composed of 6 mm Perspex sheets, and the assembly enclosed with the 4 mm Perspex sheet. The completed phantom had lateral separation of 34 cm, and anterior and posterior separation of 27 cm; with length of 33 cm. The Perspex pieces were glued to each other with Trichloromethane (chloroform) at room temperature. Chloroform dissolves the Perspex (PMMA), and when applied to the surfaces of the Perspex sheets, the surfaces stick together after the chloroform dries up. In forming the surface of the phantom, the 4 mm Perspex sheet was oven heated to a temperature of 140˚C to make the sheet malleable. The Perspex sheets after oven heating was allowed to cool and wrapped around a metallic frame shaped like the ends of the phantom with length little bit longer than the sheet wrapped around it. The Perspex sheet after cooling takes the shape of the frame, which was then glued to the end Perspex pieces of the phantom. One end of the phantom was made thicker than the other end by gluing another 6 mm Perspex sheet such that the thickness of that particular end of the phantom was 12 mm. A hole of diameter 6.5 cm, which was a little bit posterior to the phantom, was created central to the 12 mm end of the phantom. The opening created was covered by 11 x 11 cm^2 and 12 mm Perspex slab which was formed by gluing two 6 mm sheets together. A hole of diameter 5 cm was also made central to the cover created, such that the centre of this hole matches that of the hole on the end of the phantom. A 2.4 cm thick ring with internal diameter of 5 cm and external diameter of 6 cm was fabricated from 2.4 cm Perspex slab, which was formed from gluing four pieces of 6 mm Perspex sheets together. The fabricated ring was mounted on the 11 x 11 cm^2 cover created such that the internal walls of the ring and that of the hole in the cover matches. The ring was then glued to the cover using the chloroform. A tin wall elastic latex rubber tube, which had been segmented into two compartments (vagina and uterus) was pushed over the ring, and secured in place with a special plastic clips. The vagina segment was made bigger than that of the uterus.

V. RESULTS AND DISCUSSIONS

At the point where the vagina segment opens into that of the uterus, a structure was created to mimic the cervix. The cover was then secured in place on the phantom with four plastic bolt and knots as depicted in figure 1; such that the portion of the cover with the ring was inside the phantom. A rubber washer was also provided for the cover to prevent leakage of the content of the phantom.

A smaller opening with cover was also created at the anterior part of the end of the phantom with the vagina orifice. The smaller opening was created to facilitate filling of the phantom with water. Before gluing the surface piece and the end pieces of the phantom together, rectangular holes were created on the surface piece and the thicker end piece of the phantom to accommodate fabricated cuboids to function as the bladder and rectum. Two cuboids when placed in the holes provided for them liked perpendicular to each other, and the vertical separation between the two structures was 7 cm. The two structures were composed of cuboids constructed from 4 mm Perspex sheets. Each cuboid had dimensions of 15.5 x 4.5 x 2.1 cm^3.

The cuboid representing the bladder was placed anterior to the phantom, such that from the edge of the phantom at the end containing the vagina opening to the middle of cuboid was 8 cm. The cuboid representing the rectum was placed posterior to phantom, and was 2.5 cm from the posterior edge of the phantom. Special fiducial marks composed of tin beads of lead were imbedded into various portions of the cuboids to facilitate accurate identification of certain parts of the structures on radiographic film for dosimetry purpose. The cuboids were therefore glued in place with the chloroform.

The geographical arrangement of the cuboids representing the critical structures is shown in figure 2. The completed phantom was subjected to pressure test to identify possible areas of leakage and having those areas amended. Two Perspex slabs were sawn from the 6 mm Perspex sheets to fill the cavity created within each cuboid. During the in-vivo dosimetry procedure, films were sandwiched between the slabs for dose measurements. The slabs were made to protrude a bit from the surface of the phantom to enable easy removal of the slabs from the cavities.

The phantom was built to simulate actual patient anatomy, as shown in the CT images in fig 2. The relative electron density of the Perspex sheets which were used in the fabrication of the phantom had relative electron density (compared to water) of 1.066. The internal structures of the completed phantom filled with water is shown in fig 2 as CT images in the axial and sagittal plane; the b refers to the bladder; r refers to the rectum; v refers to the vaginal; c refers to the cervix; and u refers to the uterus. A special locking device to hold applicators firmly in place during the intracavitary brachytherapy insertion was designed and constructed from 6 mm Perspex sheets and plastic bolts and knots. The locking device was mounted at the entrance of the vagina orifice.

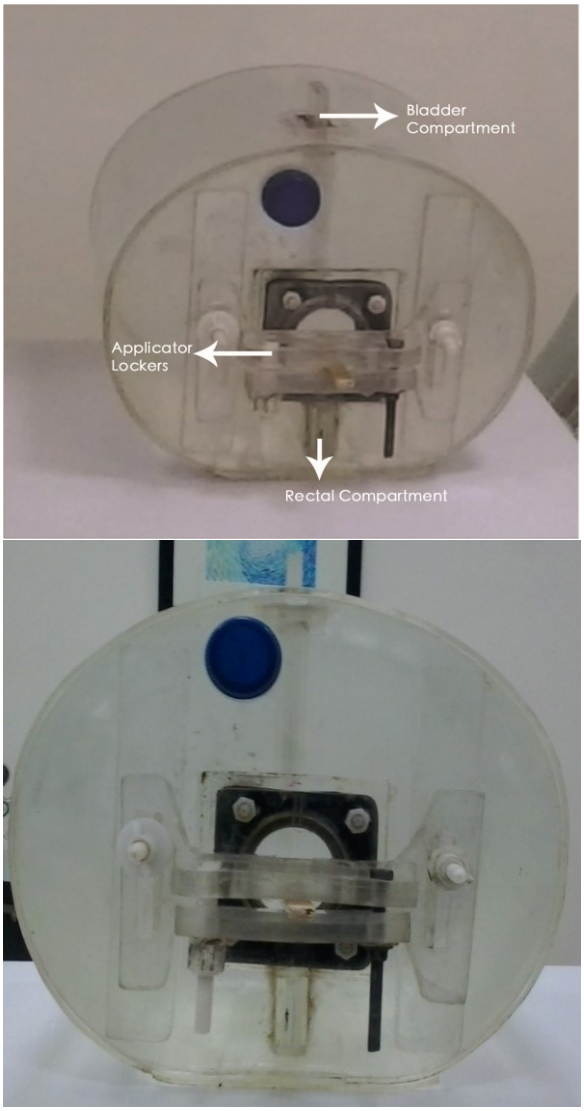
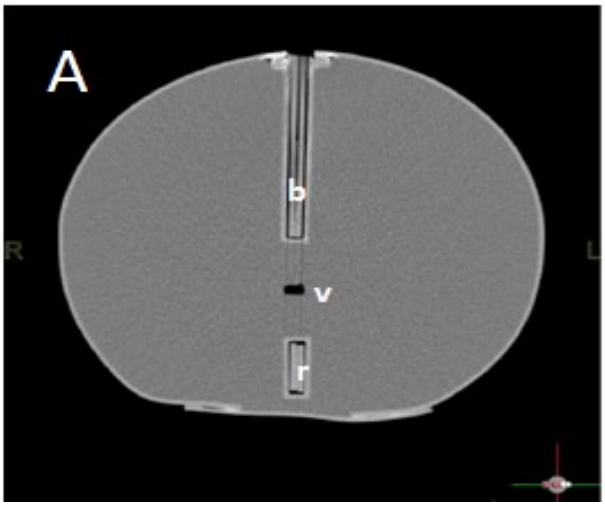


Figure 1: Built Cervix Phantom



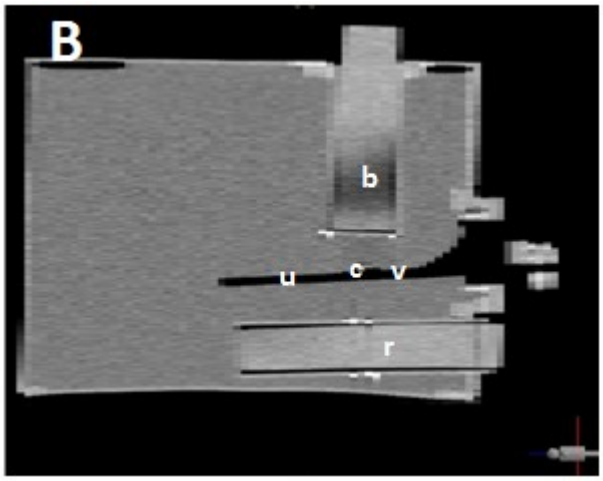


Figure 2 CT images of constructed phantom; A in transverse axial plane and B in sagittal plane.

VI. CONCLUSION

The study discusses the methodology and materials used to design and construct cervix phantoms for use in brachytherapy dosimetry studies. The cervix phantom was built to simulate and mimic actual patient anatomy. The constructed phantom consist of fabricated cylindrical shape, composed of 6 mm Perspex sheets, and the assembly enclosed with the 4 mm Perspex sheet. The completed phantom had lateral separation of 34 cm, and anterior and posterior separation of 27 cm; with length of 33 cm. Two fabricated cuboids to function as the bladder and rectum were also design and constructed. The two structures were composed of cuboids constructed from 4 mm Perspex sheets. Each cuboid had dimensions of 15.5 x 4.5 x 2.1 cm^3.

VII. RECOMMENDATION

A comprehensive and accurate dose assessment phantoms has been developed and recommended for clinical application during brachytherapy of the cervix.

VIII. REFERENCES

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