Clinical Evaluation of an Electromagnetic Tracking System for Cervical Brachytherapy Applicator tracking.

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INTRODUCTION

Cervical cancer is one of the most common cancers that affect women. One of the most effective ways of treating cervical cancer is brachytherapy in combination with external beam radiotherapy and chemotherapy. The dose in cervical brachytherapy is delivered with the use of an applicator that is placed during an operation through the vaginal canal through the cervix into the uterus. The dose is then delivered with the use of an after-loading system. The dose delivery is heavily reliant on the position of the applicator. Although ultrasound is used to provide information about the position of the applicator during the insertion process, in most cases the applicator is not visible on the ultrasound images. Therefore, the placement of the applicator mostly depends on the experience of the clinicians and misplacement of the applicator could result in inaccurate dose delivery, increased levels of toxicity in healthy tissues and perforation of the uterus during the insertion process. Magnetic tracking systems are currently in use in other medical procedures for guidance of needles or for image registration. Such a system is usually provided with ultrasound systems for registration between ultrasound and CT/MRI images. At the time of writing there were no evidence of a magnetic tracking system used for tracking gynaecological applicators during cervical brachytherapy.

AIM

1. **Examine if an electromagnetic tracking system can track the position of the cervical brachytherapy applicator during brachytherapy.**
2. **Measure the accuracy of the applicator and determine if it can be used in vivo to track the applicator during brachytherapy.**

RESULTS

From the results it is shown that overall the five-point registration methodology using the model 800 sensor performed the best overall as it achieved a desirable ≈ 5mm error for the applicator position which can be consider sufficient for the placement of the applicator with a standard deviation of the error at less than 1 mm which suggest the method is very precise.

In comparison the other methods although they have a mean error of ≈ 5mm the standard deviation of the error is greater than 1 mm. In addition the five point methodology seems to be overall better than the three point methodology due to the increased number of points and also by encircling the position of the applicator with another two points that provide variation in the distal direction.

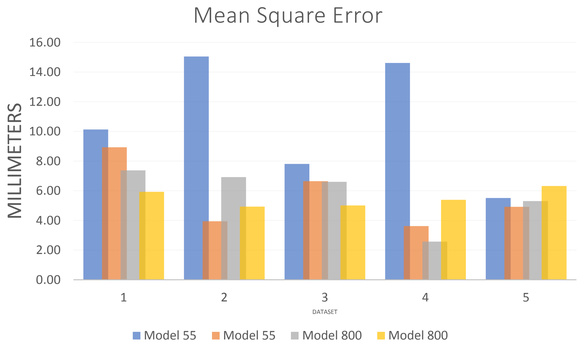

Figure 2. Shows the mean square error of the applicator position in comparison to the CT position of the applicator for the three point methodology (3PM) and the five point methodology (5PM) for each of the captured patient dataset using the different sensors.

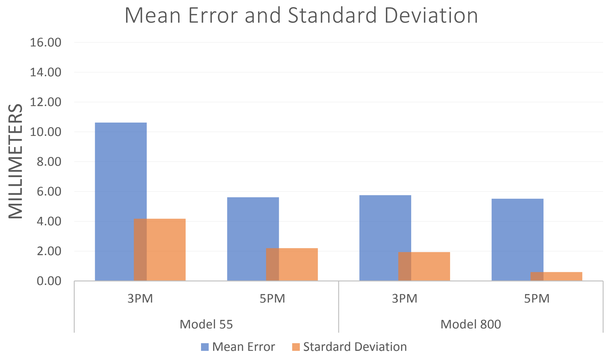

Figure 3. Shows the mean error of the applicator position for each methodology and the standard deviation of the error.

METHOD

The methodology for tracking and evaluating the accuracy of the magnetic tracking system required the following alterations to the standard brachytherapy operation as below.

1. Before the applicator insertion process the patient was given standard skin tattoos that were going to be used to provide reference points that will be used for evaluating the accuracy of the tracking system in regards to measurement of the position of the sensor inside the applicator relative to these skin markers. Skin tattoos show the position the ball bearings will be placed and also be used as a reference between the electromagnetic tracking system and the CT scanner. In addition, the location those markers are placed are in reduced movement regions to minimise the errors caused by tissue movements.

2. The position of the markers and the tandem are to be measure at the end of the insertion process in the operating room.

3. In the scanning room the position of the tandem and the tattoo markers are to be measured before the patients CT scan. When the measurements are done ball bearings are to be placed on top of the tattoo markers in order to provide reference points for the registration between the CT scanner and the electromagnetic tracking system.

Figure 1. Shows the position of the tattoo markers and the ball bearings that were used in the tracking methodologies. The Blue markers were used in the three point methodology (3PM). Then both green and blue markers were used in the five point methodology (5PM)

4. The data from the position of the sensors during the brachytherapy operation were analysed in order to measure the accuracy of the tracking system in relation to the CT scanner which was used as the golden standard since it provides millimeter accuracy. The method involved rigidly registering the marker positions as captured by the electromagnetic tracking system with the positions of the markers as appear in the CT scanner. Then using the rotation and translation matrix determined by registering the marker positions between the two measurements, the position of the sensor inside the applicator was transformed using those matrices

Two methodologies where examined using different type of sensors to measure the external markers sensor 55 and sensor 8000. Their main difference is in the effective tracking distance where 8000 is superior to the model 55 sensor. Also the methodologies differ in the number of markers used in the registration process between the CT and the electromagnetic tracking system.

CONCLUSIONS

The results of the trial shown that the best overall developed methodology (Model 800 – Five point methodology) achieved a ≈5mm error with less than 1 mm standard deviation for the tracking the applicator position which can be consider sufficient in improving the tracking of the applicator during cervical brachytherapy.

The system measures the position of the applicator inside the human body with samples at 100 ms. By comparison the errors in position of the applicator as measured between fractions for several studies Huerta Bahena et al. 1998, Ranjan Datta et al. , Garipagaoglu et al. 2006, Berger et al. 2007, De Leeuw et al. 2009 were greater than 1 cm thus having a system that can track the applicator with better accuracy during brachytherapy can improve the quality of the treatment received by the patient (reduced toxicity, preventing perforations).

In addition improving the registration and the tracking of the five points that are used for registration could potentially reduce the errors significantly as the current methodology relies on measuring the position of the tattoo markers by hand.

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