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RESEARCH ARTICLE

DESIGN AND STUDY OF IN-HOUSE AUTOMATIC CANCER PATIENT MOVEMENT MONITOR FOR RADIOTHERAPY USING A MICRO SWITCH CONTROLLED CIRCUIT

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ABSTRACT

Accurate patient positioning and monitoring play a vital role in radiotherapy to achieve maximum tumour control and minimal normal tissue complications. The main aim of the present investigation was to fabricate indigenously micro-switch controlled circuit based Automatic Patient's Movement Monitoring Device (APMMD) used with the radiotherapy machine that immediately halts the teletherapy treatment if patient moves claiming accurate field treatment. This device prevents unnecessary radiation exposure to a patient's normal tissue in situations where immobilization devices are not utilized. The APMMD consists of two micro switches, two LED's, two buzzers and two AA batteries and two sensor devices. Patients were placed in between the two sensor devices which are near the treatment area. The movable rod of the sensor should touch the patient's body on both sides. If the patient moves left lateral side, the left inner rod moves inward to the outer rod, and the micro switch is activated, so that the alarm is activated and the LED goes to OFF position automatically. Furthermore, the treatment halts automatically and repositioning of the patient is necessary to continue the treatment. This equipment is utilized for observing the movement of 130 patients with different types of cancer. Our preliminary clinical results indicate that 77 patients were moved from their position during the treatment, whereas the rest received the radiation without movements. This low cost electronic compact device and alarm system can detect patient movements with a sensitivity of about 0.5cm.

INTRODUCTION

The success of radiotherapy treatment is not only to control local tumour growth by delivering a desired dose to the tumour volume but also to minimize the damage to healthy tissue. If there are critical structures around the tumour then more efforts should be taken to safeguard the critical structure from radiation damage (Khan *et al.,* 1998). Patient movements, inaccurate patient positioning and organ motion are the three main reasons for inaccuracy in radiation dose delivery. It is believed that a decrease in 10%-15% in dose delivery will result in decrease in the chance of cure by a factor of 2 or 3 while an increase in dose will similarly increase the chance of irreversible damage (Dutreix 1984).Therefore patient position monitoring is very essential for delivering accurate radiation dose to the planned tumour volume especially in the case of modern treatment technique such as conformal radiotherapy. Reproducibility of target position during and subsequent fractions of radiotherapy treatment plays a critical role in increasing the accuracy of planned treatment (Murphy 2002; Litzenberg and Daeson 2002). Accurate positioning of a patient during the course of external beam radiotherapy is important, especially if the margin around the tumour volume is small. Reduced margins make the treatment set-up more susceptible to displacement errors (Troccax *et al*., 1993). The probability of controlling local disease with radiation therapy depends on the ability to deliver an adequate dose to the entire volume of target cells. Although many factors may contribute to radiotherapy failures, retrospective studies have shown, as one might expect, a strong correlation between local recurrence and inadequate coverage of the defined target volume within the high dose region. Radiobiological and clinical studies suggest that a dose reduction of 7 to 15% to a portion of the tumour can significantly reduce the probability of local tumour control (George *et al*., 2003). This level of accuracy can be achieved only if positioning is precise during the entire course of radiation treatment. As a result, the International Commission on Radiation Units recommends that the accuracy in dose delivery be ±5% (Thesda 1999). Each planned 2D or 3D treatment, as well as the whole conformal therapy, theoretically requires perfect repeatability of the patient's position on the therapy unit together with effective immobilization. In practice,

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however, this is not the case: uncertainties in patient repositioning hinder systematic reproduction of the accuracy which characterizes the treatment plan. Image – guided patient positioning techniques have been introduced to improve the accuracy and efficiency of patient positioning and target localization for high- precision radiotherapy (Hanna *et al.,* 1999; Noel *et al.,* 1997). Sub millimetre accuracy is achieved for conformal radiotherapy using the image guided patient positioning systems. Such a very high positioning accuracy is very difficult to achieve in radiotherapy due to patient movement, organ motion, target localization, etc. Patient movement, improper positioning of patient and organ motion is the major cause for mobilization during the course of the treatment. They play a major role in reproducibility of the target. The patient's anatomy and position during the course of radiation therapy usually vary to some degree from those used for therapy planning purpose. This is mainly due to patient's organ movement (Langen and Jones 2001; Meisong Ding *et al*., 2003). Several approaches have been developed to improve the target localization in radiotherapy like ultrasound imaging, kV X-ray techniques and so on (Senthilkumar and Ramakrishnan 2008; Farid Farahmand *et al.,* 2009). The main reason for patient mispositioning is that, although conventional alignment (laser centring systems) and immobilization (casting techniques) methods offer a suitable trade-off between precision and irradiation set-up speed, their accuracy depends on the operator's skill (Verhey 1995; Robison *et al.,* 2007). Moreover, these methods do not provide immediate quantitative feedback of the accuracy of a specific repositioning and the effective immobility of the patient, and do not produce any quantitative documentation regarding the appropriateness of the treatment. In the present study we have fabricated a patient movement monitoring device with an access to register the information of the radiotherapy patient and to record their positional displacements during the course of the treatment which is developed indigenously. This device is an electronic compact device and can be used with any radiotherapy machine.

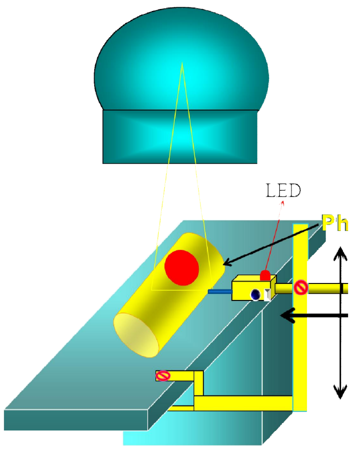

Fig 1. Block diagram of the automatic micro controller switch based patient movement monitoring device

MATERIALS AND METHODS

The whole apparatus was constructed by using acrylic material which is tissue equivalent. The system consists of two micro switches, two LED's, two buzzers and two AA batteries. These devices were fixed in the Radiotherapy machine couch by using magnets and screw. The total length of the sensing device is about 30 cm and also adjustable in up and down directions. We can change the shape of the device as per the treatment machine conveniently. The two sensor devices were placed over the treatment table on both ends of the lateral sides. Patients were placed in between the two sensor device which is near the treatment area. Figure 1 shows the Block diagram of the automatic micro controller switch based patient movement monitoring device. Figure 2 shows the Photograph of the automatic micro controller switch based patient movement monitoring device in the experimental setup with patient.

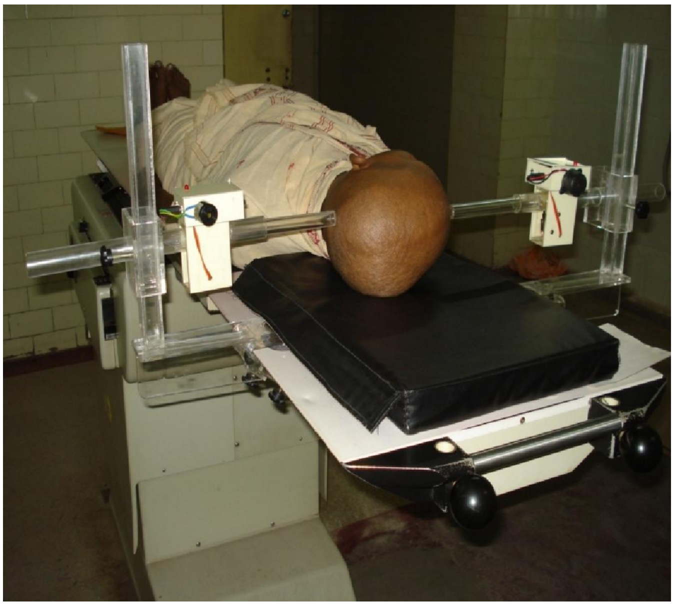

Fig. 2. Photograph of the automatic micro controller switch based patient movement monitoring device in the experimental setup with patient

Table 1. Sensitivity and tolerance limit of the patient movement monitoring device

Fixed threshold level (cm)	Lateral direction	
	Right side(+X)	Left side(-X)
0.25	0.25	0.25
0.50	0.50	0.50
0.75	0.75	0.75
1.00	1.00	1.00
2.00	2.00	2.00
3.00	3.00	3.00
4.00	4.00	4.00
5.00	5.00	5.00

RESULTS AND DISCUSSION

Phantom Study

In order to measure the sensitivity and tolerance limit of the sensor device phantom study has been carried out for +X, –X, +Y, –Y, Z and -Z directions. Any material that simulates a body tissue in terms of its interaction with ionizing radiation is termed as a phantom. Phantom resembles like human body. A tissue equivalent breast phantom made up of Bees wax is used for our studies. The mounting system was placed nearer to the couch and the device was fixed at the edge of the mounting system in such a way that the rod was made to touch the phantom. The mounting system used for APMMD has many degrees of freedom, including adjustments for height, inclination, roll and fixation. The phantom is manually moved

Table 2. Observation of cancer patient's movement during radiotherapy

S.No	Types of cancer	No. of patients observed	No. of patients moved during treatment	Distance moved (mm)	Reasons for patient movement
1	Brain	10	8	9	Pain
2	Paediatric	10	8	12	Child behaviour
3	Head & Neck	20	14	12	Pain/swallow
4	Lung	10	6	8	Cough/sneezing
5	Oesophagus	10	5	8	Cough
6	Spine	10	6	6	Severe Pain
7	Breast	20	10	5	Pain in hand
8	Cervix	20	8	6	Comfortness
9	Bladder	10	6	8	Abdominal movement/pain
10	Rectum	10	6	8	Abdominal movement/pain

to simulate the phantom movement in the lateral direction. When the fixed threshold level was exceeded, the system will indicate the mispositional displacement in two ways. One method of indication is to raise an audible alarm and visual indicator change in colour from Green to Red. The phantom was moved similarly opposite side. The sensitivity of the device measured with the phantom for all directions and the reading were tabulated in the Table1.

Patient study

The APMMD is used with the radiotherapy machine. This equipment is utilized for observing the movement of 130 patients with different types of cancer. Our preliminary clinical results indicate that 77 patients were moved from their position during the treatment, whereas the rest received the radiation without movements as shown in Table 2. The device and alarm system can detect patient movements with a sensitivity of about 0.5cm. The device can prevent the patient's normal tissues from unnecessary radiation exposure and also it is helpful to deliver the radiation to the correct tumor location. Another method to control the motion is using an audible device. The raising sound alerts the radiation technologists. It also enables the technologists to do their work more efficiently. Using this alarming system the patient can be repositioned after interrupting the treatment machine manually.

Conclusion

The outcome of the experimental technology confirms its potential as a tool for detecting the patient movement during the course of the treatment and halting the radiation beam automatically which is caused by organ motion and other patient induced uncertainties. The real time feed back of the fabricated device makes the operator to take countermeasures in case of significant failures by an audible alarm as well as using a visual indicator. The experiment reported specifically aimed not only in detecting the patient movement but also monitors the patient movement continuously and provides a qualitative feedback about the displacements of patient to a sub millimetre level in three dimensions. The results indicate that operator is able to achieve the accuracy by repositioning the patient to the exact treatment position. This study also confirms automated on line patient movement detecting system reduces setup errors without any complications. The device is rigid and does not change with time. By using the threshold provided in the system, it is possible to monitor the patient continuously with certain fixed limits which has made a generous contribution for detection of respiratory motion. Thus errors can be minimized and accurate radiation dose Can be delivered to the patient.

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