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PHYSICS CONTRIBUTION

AN ULTRASONIC DEVICE FOR SOURCE TO SKIN SURFACE DISTANCE MEASUREMENT IN PATIENT SETUP

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Purpose: To develop an ultrasound-based source to skin surface distance (SSD) measurement technique and device for patient setup and test its feasibility and accuracy.
Methods and Materials: The ultrasonic SSD measurement device (USD) prototype consists of two main parts: a probe plate with an ultrasonic transducer in the center and a control unit that displays the SSD in millimeters. The probe plate can be slid into the block tray accessory slot of any treatment machine at the time of the SSD measurement. The probe plate contains an ultrasonic transducer as both the source and the detector for measuring the distance between the transducer and the target surfaces on the basis of an echo-detecting technique. The device was calibrated by a mechanical ruler with an accuracy of 0.01 mm and corrected by an offset of 601.7 mm, which is the distance from the radiation source to the ultrasonic transducer surface for the Siemens Primus linear accelerator (Linac). The ultrasound device provided digital readout with an accuracy of ±0.1 mm for a flat surface after calibration. The SSD measurement experiments were done with the USD, an optical distance indicator (ODI), and an AKTINA 53-104 Mechanical Front Pointer (FP) on a Siemens Primus Linac with a full-sized female phantom. Ten measurements were carried out at each gantry angle of 0°, 52°, 85°, 90°, and 227° for anatomic locations of head, thorax, breast, and pelvis, to obtain the average values and standard deviations.
Results: The comparison study with the ODI and FP showed that the USD had an accuracy of less than ±1.0 mm and that USD measurements had the minimum standard deviations among the three methods; therefore, USD gave more consistent and accurate readouts for SSD measurement. When considering the FP as a reference, the USD yields smaller deviations than the ODI for all measured locations (less than ±2 mm). The variation of USD digital readout with a room temperature change of ±2°C is ±0.1 mm, which is sufficiently accurate for SSD measurement.
Conclusions: The USD method has the following advantages. First, it decreases patient setup time by avoiding problems related to the blocking of the device by the patient or by the immobilization device. Second, it is more accurate than the other two methods currently used, as the test data show. Last, the digital readout eliminates the possibility of human reading error associated with the visual scales.

Optical distance indicator (ODI), Source to skin surface distance (SSD), Ultrasonic sensor.

INTRODUCTION

Source to skin surface distance (SSD) is one of the most frequently used reference parameters for patient setup to verify the depth of treatment for each external beam in clinical radiotherapy. The present tool used for this purpose is the optical distance indicator (ODI) mounted inside medical linear accelerators (Linac; Siemens Medical Solutions Concord, CA) (1). It projects a light ruler onto the surface of the patient's body. In some instances, the ODI is blocked by either the patient or by the immobilization devices, making SSD verification difficult and time consuming. The mechanical front pointer (FP) is usually used for machine checking and calibration. Recently, a laser triangulation system was developed for SSD measurement in clinical setups (2). The laser device could be mounted on the head of a radiation treatment machine and a triangulation method used to determine the SSD. However, there still would be a problem with the patient blocking the laser beam. It is also possible that a collision issue could arise from rotating the gantry of the radiation treatment machine around the patient couch. From the standpoint of daily clinical practice, particularly owing to the increasing use of ultra-precise intensity-modulated radiation therapy, new tools for easy and accurate patient setup and SSD measurement are needed. In this article, we report a newly developed ultrasonic

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SSD measurement device (USD), which outputs digital readings in real time and eliminates the human error associated with the misreading of visual scales.

METHODS AND MATERIALS

The USD consists of two main parts: a probe plate with an ultrasonic transducer (LRS3; Format Messtechnik, Karlsruhe, Germany) in the center and a control unit that displays the SSD in millimeters. The probe plate can slide into the block tray accessory slot of any treatment machine at the time of SSD measurement. These parts are connected by a cable, as shown in Fig. 1. The probe plate uses the ultrasonic transducer as both the wave source and the detector and uses an ultrasound echo-detecting technique (time of flight) for measuring the distance between the transducer and the target surfaces. The device was calibrated by a mechanical ruler with an accuracy of 0.01 mm and corrected by an offset of 601.7 mm, which is the distance from the radiation source to the ultrasonic transducer surface for the Siemens Primus Linac (Siemens Medical Solutions). Figure 2 shows the unit slid into place on the tray slot of a Siemens Primus Linac. The calibrated range for SSD measurement was 700–1300 mm. The ultrasound device provided digital readout with an accuracy of ±0.1 mm for a flat surface after calibration. The ultrasound frequency was 50 kHz. The focal area size was approximately 2.0 cm in diameter. The cost of the prototype was less than $3,000.

We conducted SSD measurement experiments with the prototype USD on a Siemens Primus Linac with a full-sized female phantom (PIXY RS-102; Radiology Support Devices, Long Beach, CA), as shown in Fig. 3. The values of SSD were measured with fields at multiple locations of the phantom (head, thorax, breast, and pelvis) by USD, ODI, and FP (AKTINA 53-104 for the Siemens Linac; Aktina Medical, Congers, NY) at gantry angles of 0°, 52°, 85°, 90°, and 227°. Ten measurements were made at each gantry angle for all anatomic locations noted above, then the average values and standard deviations were calculated.

RESULTS

The results of the measurements are listed in Table 1. It is clear from these results that the USD measurements have the minimum standard deviations among the three methods; therefore, the USD gave more consistent and accurate read-

Fig. 2. The ultrasound probe plate in the accessory tray of the Siemens Primus Linac.

outs for SSD measurement. If we consider the FP as a reference, it can be observed in Fig. 4 that the USD yields smaller deviations than the ODI for all measured points (less than ±2 mm). This is because of the ODI's reading resolution and the experimenters' inaccuracy in reading the visual scales.

The USD has a temperature sensor and an electronic correction circuit, which permit it to work efficiently under regular air-conditioned room environments. Our test showed that the variation with room temperature changing by ±2°C is ±0.1 mm, which is sufficiently accurate for SSD measurement.

DISCUSSION

As radiation oncology moves to more precise intensity-modulated radiation therapy techniques, the room for setup errors has significantly diminished. Furthermore, the use of a number of different patient restraining and positioning devices has also impacted on the ability to visually determine the true SSD. This newly developed ultrasound-based SSD device is able to overcome many of these problems. In our experiments, we found that the USD produced the same

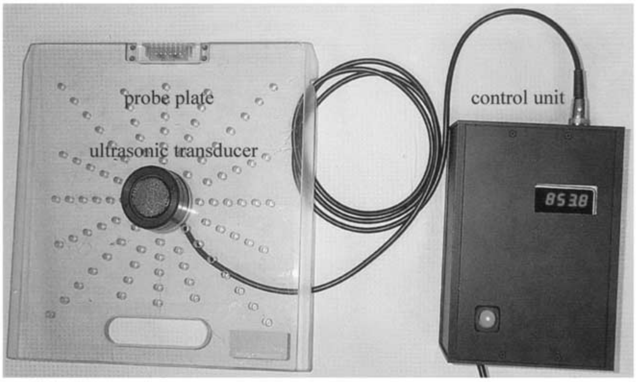

Fig. 1. Prototype of the ultrasonic device (probe plate, ultrasound sensor, and control unit).

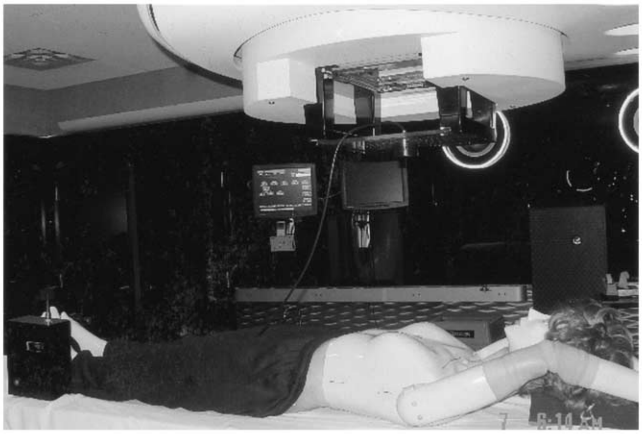

Fig. 3. The ultrasonic device in the Siemens Primus Linac accessory tray and the phantom on the patient couch.

Table 1. SSD measurements and comparisons at different field locations made with the FP, ODI, and USD

		FP (mm)		ODI (mm)		USD (mm)	
Field location	Gantry angle (°)	Average	SD	Average	SD	Average	SD
Head	0	801.5	1.3	797.0	2.1	800.0	0.2
Head	90	787.3	1.5	785.1	1.9	786.2	0.4
Thorax	0	802.2	1.6	805.6	2.5	801.1	0.4
Thorax	90	785.1	1.2	787.2	2.2	784.3	0.5
Breast	52	910.0	2.1	904.5	3.7	911.0	0.9
Breast	227	919.5	2.4	912.7	4.8	918.1	1.0
Pelvis	0	860.0	1.5	856.4	2.9	858.7	0.3
Pelvis	85	812.2	1.7	815.8	2.3	813.4	0.7

Abbreviations: FP = front pointer; ODI = optical distance indicator; SD = standard deviation; SSD = source to skin surface distance; USD = ultrasonic SSD measurement device.

accurate SSD readings whether masks were present or not. It also worked very well with the treatment fields underneath the treatment couch, where reading the ODI scale is very inconvenient.

The USD has the following advantages. First, the ultrasound sensor is mounted on a probe plate that is inside the block tray of the Linac and thus always seated at the center of the radiation beam during an SSD measurement.

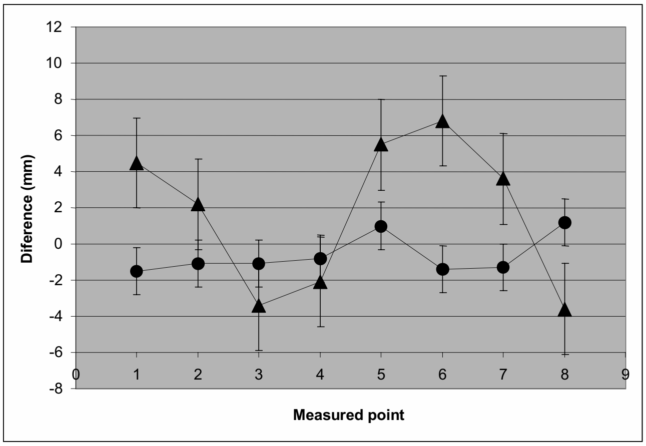

Fig. 4. Deviations in millimeters from the front pointer, as measured by the USD (circle) and by the ODI (triangle). ODI = optical distance indicator; USD = ultrasonic skin surface distance.

This results in a decrease in patient setup time because no problems arise due to the blocking of the device by the patient or by the immobilization device. Second, the USD measurement is more accurate than the other two methods used, as the test data show. Last, the digital readout eliminates the possibility of human reading error associated with the visual scales, particularly in inconvenient locations.

Our experiments show that ultrasound also has very good reflection on the surface of an Alpha Cradle (Smithers Medical Products, Inc. North Canton, OH), so the distance from the source to the Alpha Cradle surface can be measured precisely. For now, the device cannot distinguish the body from the Alpha Cradle.

Of note, when the target surface is significantly oblique (i.e., the normal angle of the target surface is $>30°$), the device does not give out any reading because the reflected sound wave cannot reach the transducer. This shortcoming can be corrected by simply using a paper card on the target area facing the transducer, as therapists usually do in similar situations in current clinical practice.

Overall, we believe the ultrasound device to be easy to use, highly time efficient, and most importantly very accurate for determining SSD. Further improvements in the technical design and integration into the Linac head are currently under way for future clinical applications.

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