IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 9, Issue 6 Ver. II (Nov. - Dec. 2017), PP 15-22
www.iosrjournals.org

Quality assurance for clinical implementation of an Optical Surface monitoring system

Vaibhav Mhatre
Parimal Patwe,Department of Radiation Oncology, Sir HN Reliance foundation hospital, Mumbai

Abstract: *Optical Surface Monitoring system (OSMS) has been recently introduced by Varian for initial patient positioning and real-time monitoring during complex radiotherapy treatment. The purpose of this work was to implement TG 147 with OSMS. Recently we installed OSMS first of its kind in India on linear accelerator, True BEAM STx at our Institute. The OSMS is composed of three-camera ceiling mounted and a Workstation. The following tests were performed to validate the system. a) Calibration b) System reproducibility and drifts c) Static localization displacement accuracy and d) Dynamic radiation gating delivery. The Calibration procedure consists of Daily, Monthly and MV Radiation Isocenter Calibration. The reproducibility of the system was tested by monitoring the Varian gating phantom test pattern for at least 90 minutes. Each recorded pattern was registered to the reference surface to calculate the required couch adjustment. To measure the static localization displacement accuracy of the system and quantify patient shift relative to a reference image, we compared the shift detected by the surface imaging system with known couch transitions in a phantom study. The phantom was set in motion and the radiation beam was held by changing the threshold in the software for different clinical setups to test the dynamic radiation gating capability. The Daily calibration was within ±0.5 mm. The MV radiation isocenter with respect for cameras was less than 0.1 mm in translational axis and less than 0.3° for rotational axis. The reproducibility was 0.3 mm. The static displacement accuracy was 0.25 mm for the translational axis, and less than 0.25 ° for rotational axis. The system was able to hold the beam with a minimum threshold of 1 mm. A quality assurance process has been developed for the clinical implementation of an OSMS following the guidelines of TG 147.*

Keywords: *patient positioning, quality assurance, TG 147.*

Date of Submission: 16-11-2017 Date of acceptance: 30-11-2017

I. Introduction

In radiotherapy, the positioning of the patient is a crucial part of the treatment. The aim is to deliver a high dose to the target while minimizing the dose to the surrounding healthy tissues. Therefore, it is important that the target is positioned correctly for the treatment and that the target definition includes uncertainties like organ movement and positioning errors. In the process to optimize the radiotherapy, the margins of the target should be minimized. This is possible by improving the patient set up and immobilization. Target motion during treatment is a possibility that should be considered, as well as the change of patient geometry caused by weight loss or swelling during a long treatment. The reproducibility of external patient alignment is independent of the internal organ motion that can affect the position of the tumor with respect to the surrounding healthy tissues. Both aspects have to be taken into account as prescribed by the ICRU 62[1].

In order to improve irradiation accuracy, particularly when combined with highly conformal delivery techniques, several different technologies have been developed to image the patient daily and/or track the patient during treatment. Image guided Radiotherapy (IGRT) include kilo voltage (kV) x-rays imaging, in-room computed tomography (CT), kV and MV cone-beam CT, and ultrasound. These Imaging techniques provide the ability to visualize the patient anatomy and correlate the patient settings to the initial planned settings. The daily or frequent use of these systems, however, leads to an additional radiation exposure of normal tissue. The typical treatment of cancer patients consists of 25 to 40 radiotherapy fractions. The extra radiation exposure, resulting from the use of these positioning systems is no longer negligible and becomes more of a concern the more irradiations a patient receives. Other technologies that do not use ionizing radiation have also been developed for the purpose of patient setup and monitoring, with the clear benefit that no additional dose is delivered to the patient from the localization procedure. As an added benefit, infrared, optical, and radiofrequency (RF) based technologies provide real-time feedback and can be used to monitor motion, such as that due to respiration[2].The approach of ALIGNRT and CATALYST use a three-dimensional optical scan of the body surface for verification of the patient's position. This surface scans will be compared with the optimal (e.g., from a reference scan or a surface reconstruction from the planning CT scan) position. Deviations in all dimensions are calculated through body surface comparison, but not for the target volume.

Surface imaging and registration techniques were first described by Li et al. [3].The original Align RT system was introduced by Bert et al. [4], which consisted of two camera pods and was designed to acquire 3-D surface images at couch 0^0.A partial loss of image occurred with their systems due to machine head blockage of the cameras. To improve this add on camera was added to this system. The first study with three cameras was reported by Peng et al. [5] with Elekta accelerators. Fogliata and the group also studied the accuracy of OSMS with Edge accelerators [6].The application and technical performance of the system was analyzed by Schoffel et al. [7] on a phantom and found an accuracy of 0.4 ±0.26 mm translational and 0.3 deg rotational. There are many studies on surface tracking for breast with deep inspiration breath hold techniques using align RT system[8-11].We also evaluated the system for patient monitoring during treatment with the system able to hold the beam when the reference and actual surface are out of the defined thresholds.There are many clinical applications of this system for frameless and almost maskless approach for brain stereotactic treatments as reported previously [12, 13].

Recently Varian medical systems include positioning systems for stereotactic treatments such as calypso for extracranial SRS/SRT and Optical surface monitoring system (OSMS) for frameless, maskless brain SRS.The aim of this study is to come up with a quality assurance program for OSMS, a ''non-radiographic" patient setup verification device. While there have been numerous articles regarding the application of this system for real time monitoring for breast cancer and brain SRS/SRT techniques, only a few articles have studied the quality assurance protocol for OSMS.A monthly QA report was discussed in technical note by Wooten et al.[14] which focuses on quality assurance procedures developed for the static image acquisition mode. Current study presents the acceptance and the commissioning which was performed for this new equipment using phantoms available in the department. The commissioning procedures have been based on the AAPM task group report 147[2]. The main parts of these tests are integration of equipment, measurements of spatial reproducibility and drift and estimation of the localization accuracy along with Dynamic radiation monitoring accuracy.

II. Methods and Materials

The OSMS first of its kind in India was recently installed at our institute on True BEAM STx linear accelerator. The linac is equipped with 120HDMLC, five Photon (6,10,15,6FFF and 10FFF) and five electron energies(6,9,12,15,18), 6 Dimensional couch (Varian, Palo Alto, CA) and the integrated kV and MV imaging system XI (Varian, Palo Alto, CA).The MV QA isocenter calibration phantom was used for this study. This phantom is a portable accessory formed from a solid machined polystyrene cube with a side of 150.0mm with 5x7.5mm diameter alumina ceramic spheres embedded within it. The other four spheres are arranged asymmetrically about the central sphere within the cube. The phantom is placed on a leveling plate that has three leveling feet and bubble level for alignment. The Varian RPM gating phantom was also used to test the dynamic radiation beam hold delivery accuracy.

A. System description:

Optical surface monitoring system (OSMS) is a video-based 3D surface imaging system used to detect and reconstruct the skin surface of a patient in 3D before and during the radiotherapy treatment. It consists of three ceiling camera pods (camera in the following), positioned as shown in Figure1: two laterally to the treatment couch, and the third centrally located at the foot of the couch. A projector unit projects a red light speckle pattern onto the patient. Overall, two image sensors located on either side of the projector acquire the image of the patient and the speckle pattern. A close-range digital speckle photo-grammetry reconstructs the 3D surface. The result is a surface image of the patient that is composed of upto twenty thousand points. With the images from the 3 camera pods, the system reconstructs the 3D surface for all the gantry positions, even in the cases where the linac head is rotated around 45 degrees interposes between one of the cameras and the isocenter, obscuring the image projection for that camera. A reference surface (ROI) is generated by importing the body contour from a treatment planning system based on a CT dataset. Prior to each treatment session, the patient's position is acquired and compared to the Reference surface (ROI) by the system's surface matching software. When aligning surfaces in the ROIs, the system calculates a rigid-body transformation, 3 shifts and 3 rotations, a minimization process involves an iterative least squares estimation that progressively updates the shifts and rotations as a 6D vector until the surface distance is minimal[6].The six shifts are reported as follows: vertical shift, positive in the anterior direction, longitudinal shift, positive in the superior direction, lateral shift, positive in the left direction, rotational shift about the longitudinal axis, rotational shift about the lateral axis and rotational shift of the couch angle. Rotational shift about the longitudinal axis is commonly referred as 'roll', the rotational shift about the lateral axis is commonly referred as 'pitch' and the rotational shift about the couch angle is commonly referred as 'yaw'. A report is generated that includes all six transformations. Real time deltas are displayed on the workstation.

Figure 1: Display of Optical Surface Monitoring system installed on True BEAM STx

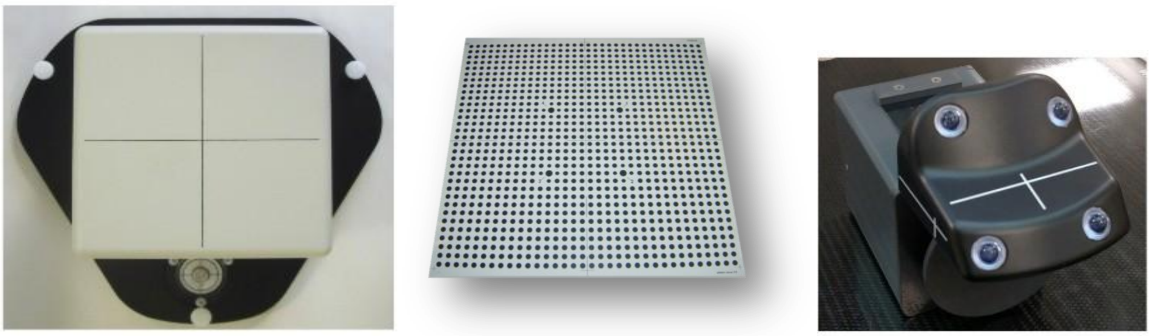
B.Acceptance tests:

Acceptance testing provided by the supplier has been made during installation. A Rigid Test Object was used provided by vendor for acceptance tests.The first test is the Couch data acquisition test which is performed on OSMS workstation for recording position results and the software shall detect MEAN and RMS positional error. The second test involves testing of motion management interface(MMI) in which the system should induce an external beam hold using MMI for predefined thresholds. These tests are useful to become familiar with the equipment operation and its limitations and demonstrate the performance of equipment within the specifications. The commissioning of the system is a procedure where more QA tests will be done before put it into routine clinical use.

C. Commissioning:

The commissioning procedures have been followed based on the AAPM task group report 147.This task group focused on the use of non-radiographic localization equipment's along with comprehensive quality assurance program. The phantoms used for these tests were MV isocenter calibration phantom along with Varian RPM gating phantom for dynamic localization accuracy. A CT scan was acquired using 1mm slice thickness for all the phantoms and image data set was transferred to Eclipse^{TM} (v.13.0)(Varian, Palo Alto, CA)treatment planning system. Following tests were performed as a part of comprehensive QA.

a) System calibration
b) Integration of peripheral equipment
c) Spatial reproducibility and drift
d) Static localization accuracy
e) Dynamic localization accuracy
f) Quality assurance tests



(a) (b) (c)

Figure 2. (a)MV-Isocenter calibration phantom (b) Calibration plate (c) RPM gating phantom

a. System Calibration:

The calibration procedure consists of Daily, Monthly and MV radiation isocenter Calibration. The daily, monthly quality assurance ensures that the cameras are accurately calibrated to treatment isocenter. The monthly calibration should be carried out using calibration plate provided by vendors which is a white slab with a matrix of 32x32 black spots of about 1 cm diameter, 2cm distant(called blobs), 4 of them numbered and larger than others (1.7cm diameter) are positioned on the corners of a square of a side of 10 blobs. The daily QA process also uses a calibration plate and ensures that the cameras have not moved with their respect to each other from their calibrated position. The MV radiation isocenter calibration fine-tunes the calibration so that the OSMS coordinate system is optimally aligned to radiographic isocenter. The phantom is positioned at isocenter and MV images are acquired at gantry 0^0,270^0, 90^0 and 180^0 and the results are analyzed in Isocenter calibration software and the results are stored in the system.

b. Integration of peripheral equipment:

As per the task group 147, we need to check the compatibility of the system with Record and verify system, integration with linear accelerator and the determination of the localization field of view. The OSMS system comes with a separate workstation and it is integrated with True BEAM machine console. The radiation treatment therapy process includes CT simulation, treatment planning, transferring treatment information to record and verify system and treatment delivery. We performed phantom tests to establish the relation between the Eclipse TPS and OSMS system. The phantom was scanned in a different position with head first supine, head first prone as well as feet first supine or any other orientation that may be used clinically. Plans were created, approved and structures were transferred to OSMS workstation. The patient was opened on OSMS system and the isocenter co-ordinates were checked with respect to transferred plans. In addition, we tested the accuracy of the same for multiple isocenter co-ordinates. Patients were moded up on console to check whether there is a proper communication between OSMS and linear accelerator. To determine the localization field of view the phantom was set at isocenter and phantom was moved from isocenter while the monitoring is on to determine the distance from isocenter at which the localization system fails to detect the phantom.

c. Spatial reproducibility and drift:

The cameras can be susceptible to spatial drift. The RPM gating phantom was positioned at the isocenter and the OSMS system was set to monitor the phantom. A reference surface was first captured and continuously monitored to verify the system stability over a period of 90 minutes to ensure that there were no significant measurement drift. The cameras were switched off and on for three times to measure the drift. After the system attains the stability ,the reproducibility was tested. To check the reproducibility, a reference ROI was acquired, the phantom was continuously monitored, acquired surface was registered with the reference surface, and reports were generated every 5 minutes for a period of another 60 minutes.

d. Static localization accuracy:

A process to test the ability of the OSMS system to monitor and track the reference surface was developed. For this test MV Isocenter phantom was monitored and the couch was moved intentionally in vertical, lateral and longitudinal directions by known amounts in the range of 0.0 mm to 30 mm and the shifts were recorded given by OSMS system. The relationship between OSMS coordinate and couch reference was established with this test. In addition to translational, rotational shifts were also checked. Since the True BEAM STx linear accelerator system is equipped with perfect pitch 6D couch, we tested the accuracy of the OSMS system for rotational shifts by introducing a known error in the range of 0.0 to 3 degrees. The difference between the pre-defined applied shifts and OSMS shifts reflect the accuracy of OSMS static localization accuracy for translational and rotational movements.

Figure 3: MV Calibration phantom for static localization

e. Dynamic radiation gating accuracy:

The RPM gating phantom was used for this study. We tested the accuracy of the OSMS system to hold the beam during treatment delivery. For this, the gating phantom was set in motion and monitored. Plans were created on the Eclipse treatment planning system. The OSMS system has different threshold set for different clinical sites to hold the beam when the target is moving out of the pre-defined thresholds. Hence we changed the threshold of the system ranging from 1mm to 10 mm. Plans were exposed and thresholds were changed in order to make sure that the radiation beam is holded for each threshold.

f. Quality assurance tests:

Based on the commissioning tests, a series of tests was defined to check the consistency of the system operation based on the recommendations of the task group 147.The integrity of the data transfer should be tested when any software upgrades are made to the TPS, R&V or OSMS system. The system translational and rotational accuracy can be performed on a monthly basis using phantom. System reproducibility can be established by repeating the system static localization tests after switching the OSMS system 'ON' and 'OFF'. Dynamic tracking accuracy can be performed on monthly basis by monitoring dynamic gating phantom. Finally, daily QA checks using calibration plate should be performed to monitor system localization.

III. Results

(a) System Calibration:

A summary of reports of daily QA checks for OSMS system for a period of three months is presented in figure 4. The system generates a report of daily QA which can be stored on the system. The relative error is here the difference in 3D motion computed by the pair of the camera and is the measure of the inconsistency in movement detection between cameras. The average error was 0.12 ± 0.1 mm. The error of the single camera is the distance from the current calibration plate position to monthly calibration plate position. This error was 0.9 ± 0.8 mm for each camera. The vendor's recommendation for daily QA is 1mm.The average MV Radiation isocenter for a period of 6 months was found to be < 0.1 mm in translational axis and < 0.3 degree for rotational axis.

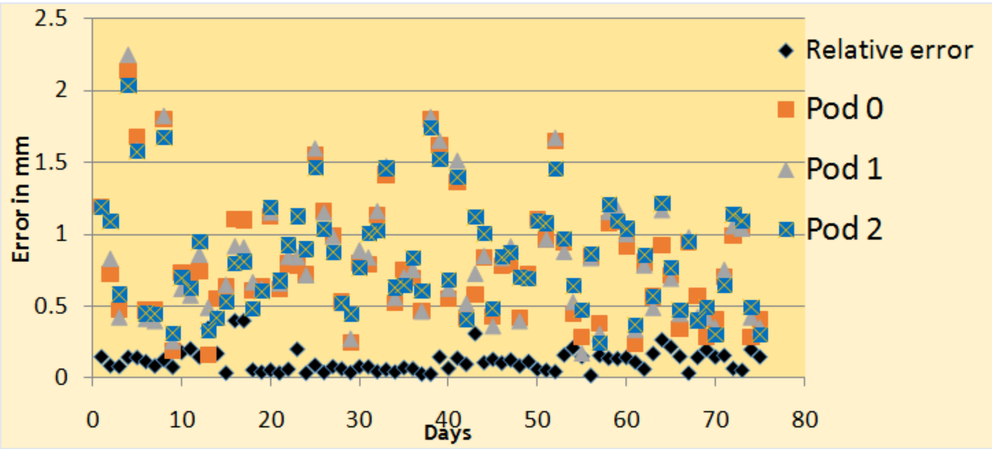


Figure 4: Daily QA record for 3 months

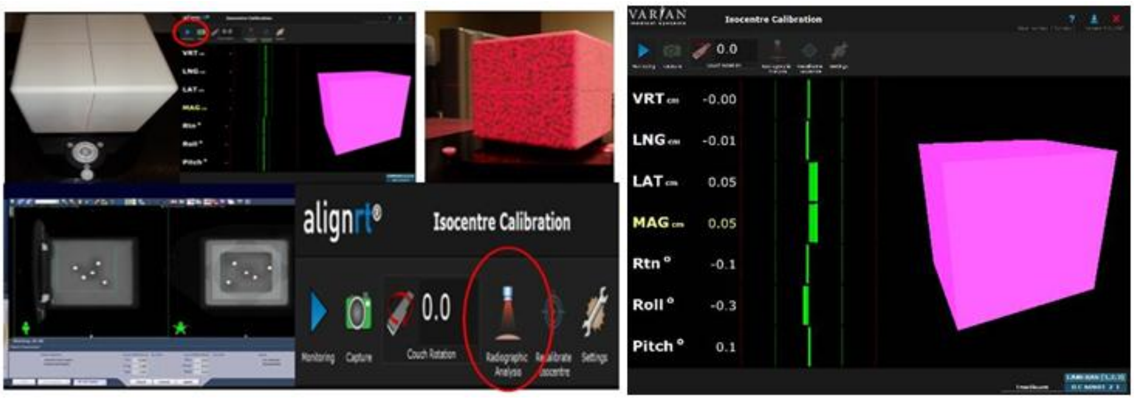


Figure 5: MV Calibration phantom for Isocenter calibration

(b) Integration:
The communication and the integration of the OSMS system with all our equipment were fully functional.
The system reported no error or patient shifts during monitoring indicating correct co-ordinate transformation from the planning system to treatment delivery had been applied. No potential misusage was observed when we import a treatment plan with multiple isocenter. The field of view (FOV) of the OSMS system was 650x1000x350 mm in the lateral, longitudinal and vertical directions respectively.

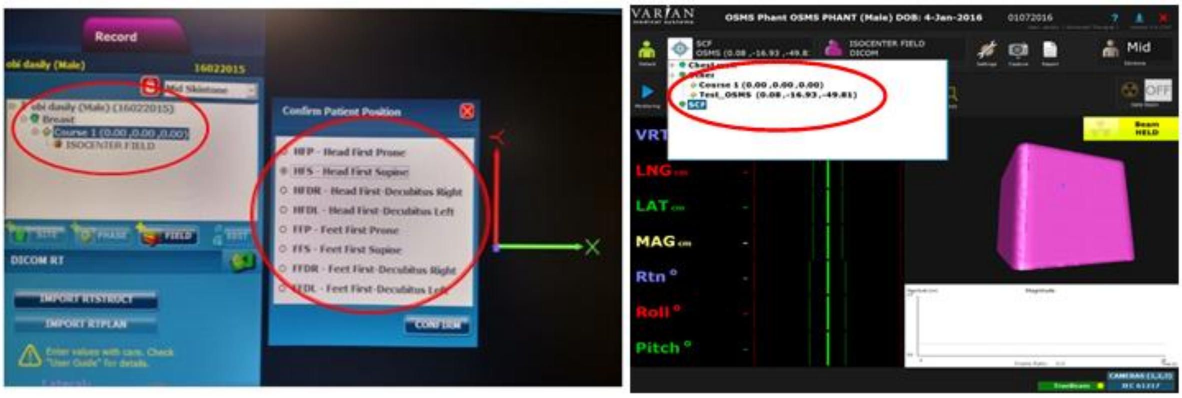


Fig 6: Plan transfer details of patient position and isocentre coordinates

(c) System reproducibility and Stability:
For thermal equilibrium and system drift, a thermal drift of 0.7 mm was noted. A 20 min warm-up time is recommended if the system has been shut off an extended period (>24 hours) before the QA procedure to eliminate any thermal drift. The reproducibility was found to be 0.3±0.08 mm.

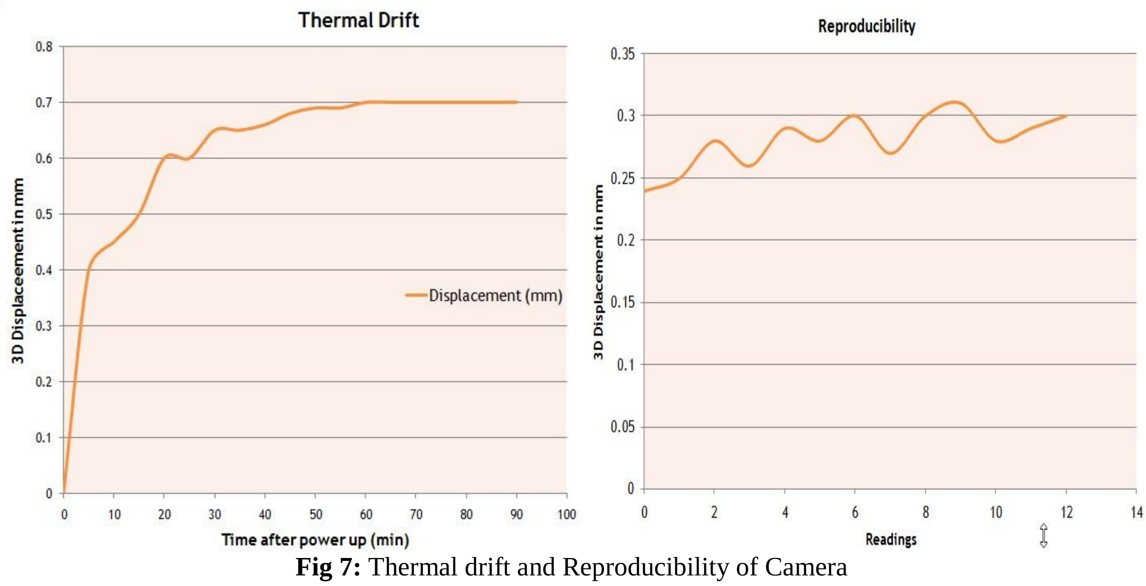


Fig 7: Thermal drift and Reproducibility of Camera

(d) Static localization accuracy:
For the static localization accuracy, system agreement with couch shifts was within 0.26 ±0.08 mm. For static rotational accuracy, system agreement with a high precision rotational stage was within 0.25 ± 0.07 degree.

Table 1 shows the data for the same.

Vertical(cm)			Longitudinal(cm)			Lateral(cm)			Yaw(deg)			Roll(deg)			Pitch(deg)		
6D	OSMS	Diff	6D	OSMS	Diff	6D	OSMS	Diff	6D	OSMS	Diff	6D	OSMS	Diff	6D	OSMS	Diff
-3	-2.9	0.1	-3	-2.8	0.2	-3	-2.8	0.2	-3	-2.8	0.2	-3	-2.75	0.25	-3	-2.9	0.1
-2.5	-2.4	0.1	-2.5	-2.35	0.15	-2.5	-2.35	0.15	-2.5	-2.3	0.2	-2.5	-2.3	0.2	-2.5	-2.4	0.1
-2	-1.9	0.1	-2	-1.8	0.2	-2	-1.85	0.15	-2	-1.85	0.15	-2	-1.8	0.2	-2	-1.85	0.15
-1.5	-1.35	0.2	-1.5	-1.3	0.2	-1.5	-1.3	0.2	-1.5	-1.35	0.15	-1.5	-1.3	0.2	-1.5	-1.35	0.033
-1	-0.9	0.1	-1	-0.8	0.2	-1	-0.85	0.15	-1	-0.85	0.15	-1	-0.8	0.2	-1	-0.9	0.1
-0.5	-0.4	0.1	-0.5	-0.4	0.1	-0.5	-0.35	0.15	-0.5	-0.3	0.2	-0.5	-0.3	0.2	-0.5	-0.45	0.067
0	0.1	0.1	0	0.05	0.05	0	0.1	0.1	0	0.1	0.1	0	0.1	0.1	0	0.1	0.1
0.5	0.45	0.05	0.5	0.35	0.15	0.5	0.45	0.05	0.5	0.4	0.1	0.5	0.3	0.2	0.5	0.35	0.15
1	0.85	0.15	1	0.8	0.2	1	0.8	0.2	1	0.9	0.1	1	0.8	0.2	1	0.9	0.1
1.5	1.3	0.2	1.5	1.35	0.15	1.5	1.35	0.15	1.5	1.35	0.15	1.5	1.3	0.2	1.5	1.4	0.1
2	1.8	0.2	2	1.8	0.2	2	1.8	0.2	2	1.8	0.2	2	1.8	0.2	2	1.9	0.1
2.5	2.35	0.15	2.5	2.3	0.2	2.5	2.35	0.15	2.5	2.3	0.2	2.5	2.3	0.2	2.5	2.4	0.1
3	2.8	0.2	3	2.8	0.2	3	2.8	0.2	3	2.8	0.2	3	2.8	0.2	3	2.9	0.1
Mean		0.13			0.169			0.1577			0.1615			0.196			0.1
SD ±		0.05			0.046			0.0449			0.0416			0.032			0.02969

Table 1: OSMS versus 6D couch static accuracy

(e) Dynamic radiation gating delivery:

We tested the accuracy of OSMS system to hold the radiation beam at different thresholds. The system is able to hold the radiation beam with a minimum threshold of 1mm . Figure 8 shows the

Figure 8: Dynamic Radiation gating delivery with threshold values to hold the beam.

(f) Quality assurance tests:

Table 2: Summary of all QA tests and their frequency of testing.

Daily QA	Monthly QA	Annual QA
1. The Calibration Plate should be used to make sure that the position of camera is not disturbed	1. The agreement between the localization system isocenter and the treatment isocenter should be evaluated. 2. Motion tracking should be tested by moving the phantom a known amount (e.g. 5cm) and checking that the localization system indicates the correct shift within 2mm	1.Camera stability 2. Compare actual and predicted shifts over a range of distances. 3. 4D/motion phantom to test accuracy of beam gating. 4. Test data transfer for at least two patients/device configurations

IV. Discussion

In the present, the system reported a drift of less than 1mm and the reproducibility of the system was within 0.3 mm. Our results are comparable to the results obtained by Bert et al. [4]. This indicates that the system is very stable over large periods. Also, the camera pod to pod variation was less than 1mm, which indicates the alignment of the cameras with respect to isocenter remains stable. Peng et al [5]] measured the static accuracy with the Align RT system on Elekta accelerators with a mean vector of 0.2 ± 0.3 mm and rotational difference of 1.3 degree, which is also similar to our results.

Our work was mainly evaluated on the phantoms, to test the accuracy of OSMS system recently installed on True BEAM STx linac system. The static localization accuracy of the system was found to be on an average 0.26 ± 0.08 mm for translational and 0.25 deg rotational, which were comparable to a previous study by Mancosu et al [6] of the order 0.6±0.3 mm and 0.3 degree. In addition, an advantage of OSMS system is the fact that no ionizing radiation is used and real time monitoring is done during patient treatment. The efficient surface detection and matching is achievable with improved patient comfort and without compromising the accuracy of treatment delivery as shown by previous studies [15, 16]. More investigations are needed to determine the correlation and accuracy between internal patient anatomy and superficial positioning in real cases.

V. Conclusion

The OSMS system was thoroughly evaluated at our institution and we found that it could be used for localization and monitoring during radiation therapy to an accuracy of within 0.5 mm. A comprehensive QA program was developed to maintain accuracy of the system and to ensure accurate operation. This localization and positioning system is expected to become an important component within our radiation therapy process, so a quality assurance of this system is essential. Moreover, this study allows us to refine and to adapt our clinical procedure. The results are well within clinical required accuracy (<1 mm). Present work was limited to only phantom based measurements and no patient data was included. By making use o OSMS, future study can done to detect the patient positioning inaccuracies during actual treatment.

References

[1] ICRU. Prescribing, recording and reporting photon beam therapy (supplement to ICRU Report 50). ICRU Report 62. Bethesada, MD: ICRU; 1999.

[2] Willoughby, T., Lehmann, J., Bencomo, J.A., Jani, S.K., Santanam, L., Sethi, A., Solberg, T.D., Tomé, W.A., Waldron, T.J.: Quality assurance for nonradiographic radiotherapy localization and positioning systems: report of Task Group 147. Med. Phys. 39(4), 1728–1747 (2012).

[3] Li, S., Liu, D., Yin, G., Zhuang, P. and Geng, J. (2006), Real-time 3D-surface-guided head refixation useful for fractionated stereotactic radiotherapy. Med. Phys., 33: 492–503. doi:10.1118/1.2150778

[4] Bert, C.; Metheany, K.G.; Doppke, K.; et al. A phantom evaluation of a stereovision surface imaging system for radiotherapy patient setup. Med. Phys. 32:2753–62; 2005.

[5] J L Peng, D Kahler, J G. Li, et al. Characterization of a real-time surface image-guided stereotactic positioning system. Medical Physics, 37(10); pp. 5421-5433; October 2010.

[6] Mancosu P, Fogliata A, Stravato A, Tomatis S, Cozzi L, Scorsetti M. Accuracy evaluation of the optical surface monitoring system on EDGE linear accelerator in a phantom study. Med Dosim. 2016;41:173–9.

[7] P.J. Schöffel, W. Harms, G. Sroka-Perez, W. Schlegel and C.P. Karger.Accuracy of a commercial optical 3D surface imaging system for realignment of patients for radiotherapy of the thorax. Physics in Medicine and Biology; 52: 3949-3963; June 2007.

[8] L. Cerviño, C. Yashar, S. Jiang, Improvement of the stability and reproducibility of Deep-Inspiration Breath Hold for left breast irradiation using video-based visual coaching and 3D surface imaging, Med. Phys., Volume 35, Issue 6, 2703, June, 2008

[9] Y. Lyatskaya, R. Cormack, J. Bellon, Validation of Align RT System for Breast Radiation Therapy with Deep Inspiration Breath Hold (DIBH) Technique, Med. Phys., Volume 38, 3564, 2011,

[10] Cerviño, L.I.; Gupta, S.; Rose, M.A.; et al. Using surface imaging and visual coaching to improve the reproducibility and stability of deep-inspiration breath hold for left-breast-cancer radiotherapy. Phys. Med. Biol. 54:6853–65; 2009

[11] X. Tang, T. M. Zagar, E. Blair, Clinical experience with 3-dimensional surface matching-based deep inspiration breath hold for left-sided breast cancer radiation therapy, Practical Radiation Oncology, June, 2013

[12] Nath, S.K.; Lawson, J.D.; Wang, J.Z.; et al. Optically-guided frameless linac-based radiosurgery for brain metastases: clinical experience. J. Neurooncol. 97:67–72; 2010.

[13] L. Cerviño, T. Pawlicki, J. Lawson, S. Jiang, Frame-less and mask-less cranial stereotactic radiosurgery: a feasibility study, Phys. Med. Biol., Volume 55, 1863-1873, 2010,

[14] Wooten, H., Klein, Eric, Gokhroo, Garima, AND Santanam, Lakshmi. "A monthly quality assurance procedure for 3D surface imaging" *Journal of Applied Clinical Medical Physics* [Online], Volume 12 Number 1 (21 December 2010)

[15] Breneman, J.C.; Steinmetz,R.; Smith,A.; et al. Frameless image-guided intra- cranial stereotactic radiosurgery: clinical outcomes for brain metastases. Int. J. Radiat. Oncol.Biol.Phys. 74:702–6; 2009.

[16] Ohtakara, K.;Hayashi,S.;Tanaka,H.; et al. Clinical comparisonofpositional accuracy and stability between dedicated versus conventional masks for immobilization in cranial stereotactic radiotherapy using 6-degree-of- freedom image guidance system-integrated platform. Radiother.Oncol. 102:198–205; 2012.,

IOSR Journal of Applied Physics (IOSR-JAP) (IOSR-JAP) is UGC approved Journal with Sl. No. 5010, Journal no. 49054.

Vaibhav Mhatre Quality assurance for clinical implementation of an Optical Surface monitoring system." IOSR Journal of Applied Physics (IOSR-JAP) , vol. 9, no. 6, 2017, pp. 15-22.