Detection of Radiotherapy Setup Errors Using PerFRACTION Software
E. Hsieh\(^1\), K. Hansen\(^2\), M. Kent\(^3\), S. Saini\(^3\), S. Dieterich\(^4\)

\(^1\) Veterinary Medical Teaching Hospital, UC Davis, Davis, CA (2) Surgical and Radiological Sciences, UC Davis, Davis, CA (3) Sun Nuclear Corporation, Melbourne, FL (4) UC Davis Medical Center, Sacramento, CA

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**PURPOSE**
1. To determine if the Sun Nuclear PerFRACTION software can detect setup errors outside the tolerance for intensity-modulated radiation therapy (IMRT) and stereotactic radiosurgery (SRS) in a clinical setting.
2. To assess if PerFRACTION can identify which setup error has been introduced.

**INTRODUCTION**
Advanced radiation therapy techniques such as IMRT and SRS result in a high dose gradient between the tumor and surrounding normal tissue. There is a risk that improper patient setup may shift the high dose gradient into the normal tissues and fail to target the tumor, resulting in increased normal tissue toxicity. (1) Therefore, clinicians must be aware of the dose tolerances for normal tissues and minimize any human or computer errors during treatment planning and patient setup.

There are three common setup errors to consider:
1. Inter-fraction setup error: Variability of patient placement in the immobilization device from one treatment to the next.
2. CT fusion setup error: Uncertainty when the cone-beam computed tomography (CBCT) is used to simulate the CT to let the computer determine the translational and rotational position error after initial setup.
3. Couch shift setup error: Mechanical uncertainty when the computer shifts the treatment table (or couch) to correct the positioning error calculated from the fused CT images.

For IMRT, the accuracy requirement for maximum tolerable setup error in any given direction is 3 mm distance to agreement (DTA). (2) For SRS, it is 1 mm DTA. (3)

Because of the dangers of irradiating normal tissue, IMRT quality assurance (QA) tests are run once before treatment to verify that the planned dose will be delivered as intended. (4) However, some studies have shown that current QA analysis methods may fail to detect unacceptable dose delivery. (5) This potentially faulty standard of care raises the following clinical questions:
1. Gamma analysis: Does the most commonly used QA analysis method accurately assess plan delivery?
2. Patient mobility: Is the current protocol able to detect patient movement during treatment delivery?

The Sun Nuclear PerFRACTION software can hopefully answer these questions and alert radiation oncologists to setup errors by providing IMRT QA analysis during and after treatment. PerFRACTION captures transmitted radiation dose data and compares the relative radiation dose to the planned radiation dose, allowing the clinician to evaluate and correct any setup errors or patient movements that might have occurred.

**MATERIALS & METHODS**
1. 7-field IMRT plans were created for a canine phantom head, made of SolidWater® embedded with a skull, and five frozen canine cadaver heads (3 large and 2 medium breeds) simulating treatment of intranasal tumors (Fig. 1 and 2).
2. The heads were set up using CBCT image guidance, and electronic portal imaging device (EPID) fluence maps were captured for each treatment field and fraction. The first fraction served as a baseline for comparison.
3. Setup errors were then introduced by shifting the linear accelerator couch and thereby each cadaver head in three translational directions with three distances per direction. Each shift was repeated in triplicate.
4. PerFRACTION was used to compare each fraction to the baseline and calculate a pass rate for each data point. A pass rate below 93% with percent difference analysis at 3% and 1% indicated that the software had successfully detected the setup error.
5. Statistical analysis was done using GraphPad Prism 6. Means and standard deviations were calculated. To compare dose pass rates for each shift and beam angle, a 2 way repeated measured ANOVA was done with a Tukey test to adjust for multiple comparisons and look for differences between groups.

**RESULTS**
There are several QA analysis techniques to evaluate a treatment plan, but for this particular study gamma analysis proved to be less sensitive than percent difference (Table 1). A 5 mm left shift was undetected by gamma analysis, and up to a 2 cm shift had to be introduced to elicit a failed delivery at a 5 mm shift using percent difference was detected as a failure.

The affected beam angles varied depending on which translational shift was introduced (Fig. 2). For instance, a ventral shift affected beam angles 25° and 102°, whereas a left shift affected beam angles 25°, 0°, and 153°. The failed beam angles correlated with the direction of translational shift. Values were statistically significant between the 3 mm and 1 mm shifts in all directions for beam angles except 0° in ventral shifts (P < 0.0001, data available upon request).

**CONCLUSIONS**
PerFRACTION successfully detected setup errors outside the tolerance for IMRT (3 mm DTA) and SRS (1 mm DTA). By interpreting which beam angles passed or failed, the user was able to employ PerFRACTION to infer which specific translational setup error was introduced. In addition, PerFRACTION provided more insight into the impact of accurate QA analysis methods and demonstrated that percent difference may be more sensitive in detecting plan failure than gamma analysis.

**FUTURE RESEARCH**
Future studies will further investigate the different QA analysis techniques and their comparability when evaluating various treatment plans. Other studies will repeat this project using 3D analysis instead of 2D analysis to correlate the results and assess the translational shifts using software that can better detect what radiation dose was delivered to a volume of tissue.

**REFERENCES**

**AUTHOR CONTACT:** dahieh@ucdavis.edu, sdieterich@ucdavis.edu