Using EPID in vivo dosimetry to quantify treatment delivery accuracy in canine head and neck tumors

S. Saad[1], K. Hansen[2], 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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SPECIFIC AIMS

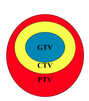
I. Perform real-time dosimetry using PerFRACTION 3D on the planning CT to assess if 95% dose can be delivered to the planned treatment volume in canine patients with head and neck tumors.
II. Compare the dose delivered to critical organs to those in the treatment plan to determine if dose received is at or below 95% of the planning criteria.
III. Validate the PerFRACTION in air system for quality assurance testing of IMRT.

BACKGROUND

Why is positioning important in radiation oncology?
Intensity-modulated radiation therapy (IMRT) creates high radiation dose gradients between tumor and normal tissue. This necessitates positioning precision and accuracy as subtle shifts risk decreasing dose to the tumor tissue or increasing dose to critical organs. Additionally, radiation treatments are delivered over multiple visits, inviting opportunities for errors in patient positioning setup. This is especially critical for head and neck tumors.

What is EPID?
The Electronic Portal Imaging Device (EPID) measures exit fluence (radiation that passes through the patient body), and with information from planning the CT and PerFRACTION™ software, can be used to determine radiation dose delivered to target tissue volumes.

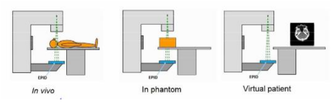
How can EPID benefit radiation treatment?
This study uses EPID to evaluate radiation plan implementation given day-to-day positioning changes. Calculated doses delivered to targets will be compared to planned doses.



Terms
GTV: Gross Tumor Volume, an observable volume
CTV: Clinical Target Volume, GTV + margin for clinical uncertainty
PTV: Planning Target Volume, CTV + margin for uncertainty of setup, patient or organ mobility, and dose delivery

What is QA and why is it performed?
Quality assurance (QA) is performed to verify the machine is capable of delivering the treatment plan. It is traditionally performed by irradiating a phantom with dose detector.

How can EPID benefit QA?
EPID has increased spatial resolution and can decrease setup time.



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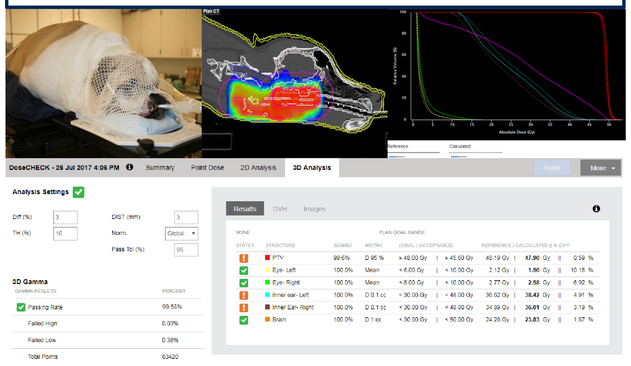
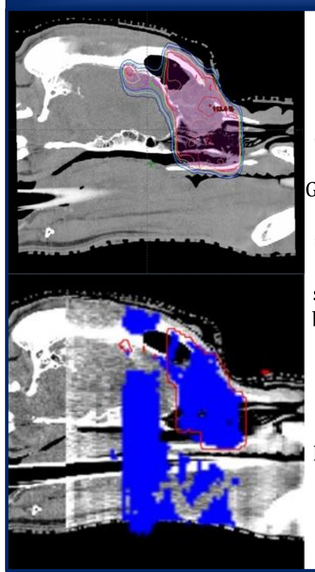
MATERIALS AND METHODS

Specific Aims 1 and 2
I. Varian Eclipse™ software was used to create individual radiation treatment plans using patient CTs.
II. Patients were set-up using positioning tools and CBCT image guidance; EPID fluence maps were captured for each fraction.
III. Radiation treatments were delivered by Varian TrueBeam™ linear accelerator.
IV. Sun Nuclear PerFRACTION software was used to calculate and record radiation dose delivered from exit fluence data.
V. Radiation dose delivered to PTV and critical organs were compared to the values in the planned treatments.

Specific Aim 3
I. Quality assurance (QA) of the treatment plans was initially performed with MapCHECK™ with a Solid Water™ phantom and dose detector prior to implementation of treatment plans.
II. QA with EPID in air was performed.
III. Treatment plans were evaluated for gamma pass rate at 3% 3 mm, following clinical protocol, for both MapCHECK and PerFRACTION in air EPID.



CASE HIGHLIGHT



Patient X, a brachycephalic dog, presented to the radiation oncology service for definitive treatment of a nasal carcinoma encompassing the frontal sinus.

Global positioning was confirmed with CBCT prior to each treatment. However, traditional setup checks failed to notice a slight shift made more dramatic by the sharp contour of the face.

PerFRACTION calculated delivered doses to the left ear were consistently higher than planned doses, while PTV doses were consistently lower but within clinical criteria. In this way, PerFRACTION detected a setup error.

RESULTS

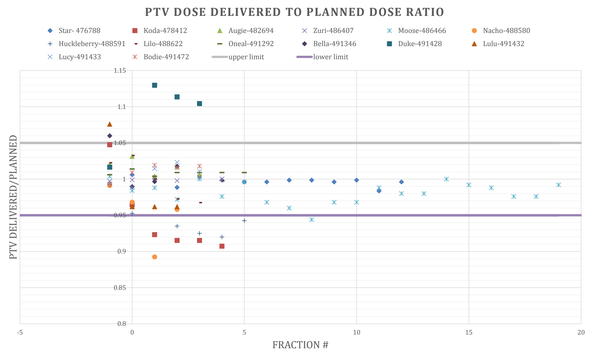


Figure 1. Ratio of Dose Delivered to PTV compared to Planned Dose. This figure shows the ratios of PTV delivered dose to planned dose per fraction for each patient over the course of their treatment. Lines at 0.95 and 1.05 indicate a clinically acceptable 5% margin of error. Fraction -1 shows DoseCheck data, which is a secondary calculation check of the treatment planning software (TPS) Eclipse. Fraction 0 data is generated from in air QA performed with EPID and PerFRACTION. Fractions 1-19 represent data from radiation treatments.

VOLUME	# OF FRACTIONS PASSING CRITERIA	# OF FRACTIONS FAILING CRITERIA	% OF FRACTIONS PASSING CRITERIA
PTV	62	11	85
LEFT EYE	66	7	90
RIGHT EYE	58	14	81
LEFT INNER EAR	28	18	61
RIGHT INNER EAR	42	4	91
BRAIN	60	9	87

Table 1. Fractions Passing and Failing Criteria. This table shows fractions that passed the criteria of delivering a dose at 95% or above of planned target dose to the PTV and fractions that passed the criteria of delivering a dose at 105% or below planned critical organ dose.

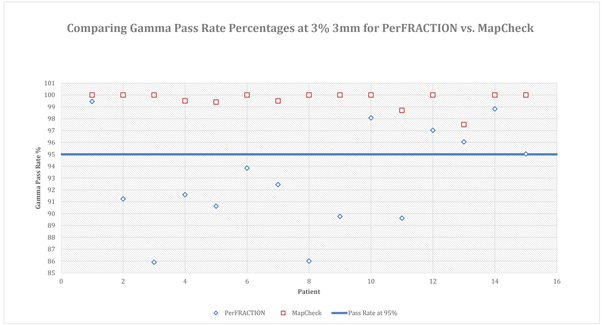


Figure 2. Comparing Gamma Pass Rates at 3% 3 mm for PerFRACTION vs. Mapcheck. Shown are the gamma pass rate percentages for PerFRACTION and MapCHECK per patient treatment plan. The line at 95% indicates the clinically accepted radiation treatment pass rate.

Patient	PerFRACTION in Air EPID		MapCHECK	
	Gamma Pass Rate	Total Points	Gamma Pass Rate	Total Points
476788	99	83481	100	188
478412	91	34087	100	94
482694	86	39043	100	135
486407	92	98304	99.5	192
486466	91	191474	99.4	178
488580	94	96648	100	259
488591	92	879338	99.5	182
488622	86	23979	100	57
491292	90	14575	100	261
491346	98	74325	100	185
491428	90	79387	98.7	150
491432	97	7359	100	26
491433	95	49687	100	193
491472	96	267745	97.5	196
493266	99	69015	100	166

Table 2. Quality Assurance Comparison of PerFRACTION in Air and MapCheck at 3% 3mm Criteria. Gamma Pass Rates are presented for both QA systems as well as total points. The total points are the points for which dose was checked. On the PerFRACTION EPID system points are derived from the patient's planning CT scan. The MapCHECK system points represent the number of physical radiation dose detectors that receive radiation dose out of a total of 445 detectors in the system.

	PerFRACTION in air EPID	MapCHECK
Mean	93.03	99.64
Variance	18.84	0.49
Hypothesized Mean Difference	0	
P(T<=t) two-tail	$4.53x10^{-05}$	
T Critical two-tail	2.14	

Table 3. t-Test: Paired Two Samples for Means Results for PerFRACTION in Air EPID and MapCHECK.

DISCUSSION

Specific aim 1: 85% of fractions delivered met or exceeded 95% dose to planned treatment dose as shown in **Table 1**. Ideally the PTV delivered dose would be at or greater than the planned dose. Radiation treatments were predominantly successful at meeting this criteria despite the effect of positioning changes.

Specific aim 2: The majority of fractions delivered to critical organs were successful at meeting the criteria of being below 105% of dose to planned treatment dose with the exception of the **left inner ear, 61%,** and **right eye, 81%,** as shown in **Table 1**. Ideally the delivered dose to critical organs would be at or below the planned dose to minimize tissue toxicity.

A systematic correction originating between the algorithm difference between DoseCheck and Eclipse has been applied to fractions 1-19 in **Figure 1**. Deviations from planned doses for PTV and critical organs are understood to be due to positioning setup changes. This is seen clearly in the minor fluctuations of dose ratios in **Figure 1.** However, it is of note that the dose delivered to planned for n is consistently lower than fraction 0. Positioning changes will contribute to this decrease, however, other causes include radiation dose attenuation due to the couch, mask, pillows or board that is not accounted for in the treatment planning system.

Specific aim 3: T-tests were performed comparing quality assurance pass rates for both PerFRACTION in air EPID and the traditional method MapCHECK at both dose difference 3% and distance 3 mm with a pass tolerance of 95%. This criteria was chosen as it is used clinically to determine if a radiation plan passes QA. P values were significant $4.53x10^{-05}$ for Paired t- tests, indicating that the tests generated significantly different pass rates as shown in **Table 3.** PerFRACTION appears to be the more specific test, giving a higher failure rate for plans that passed MapCHECK. The difference in failure rate requires further evaluation. It is of note that MapCHECK uses 2d gamma while PerFRACTION uses 3d gamma, which could be contributing to the differences.

CONCLUSIONS

I. PTV: Successfully delivered 95% or greater of planned dose in 85% of fractions.
II. Critical organs: Successfully delivered 105% or less of planned dose to most fractions with the exception of those delivered to the Left Inner Ear and Right Eye.
III. PerFRACTION in air has not been validated as a treatment plan QA method.

REFERENCES

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