Predicting successful SBRT voluntary breath-hold candidates at CT simulation

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2020 JULY 12–16 VIRTUAL JOINT AAPM | COMP MEETING

Background:

Stereotactic body radiation therapy (SBRT) treatments [1,2] using SDX (Dyn'r Medical Systems Aix-en-Provence, France) for motion management [3,4] require therapists to manually start and stop radiation delivery while patients perform voluntary breath-holds. The SDX system is a stand-alone unit that does not natively communicate with the treatment machines, so manual intervention is crucial in case of a missed breath-hold (defined as a patient not reaching target lung capacity) or failed breath-hold (defined as unexpected breath-hold releases). In addition, many patients are not good candidates for the SDX system because they cannot maintain consistent breath-holds.

Purpose:

To compare quantitative breath-hold waveform metrics during CT simulation and treatment between patient groups that did and did not have inconsistent breathing during treatment. Our goal is to accurately predict at CT simulation which patients are most likely to have consistent treatment breath-holds.

Methods:

A total of 36 patients under breathing control using SDX were tracked from CT simulation to treatment. Treatment sites included were liver (n=14), pancreas (n=6), mediastinum (n=4), lung (n=10), and kidney (n=2). Minimum, maximum and average number of fractions were 1, 15 and 4.5 respectively. Breathing waveform CSV data files were exported from the SDX system and analyzed using in-house Python scripts. Each treatment fraction includes multiple breath-hold (BH) waveforms and the following BH time and BH capacity metrics were automatically extracted: min, max, mean, standard deviation and range (max - min).

Results - Automated BH Analysis

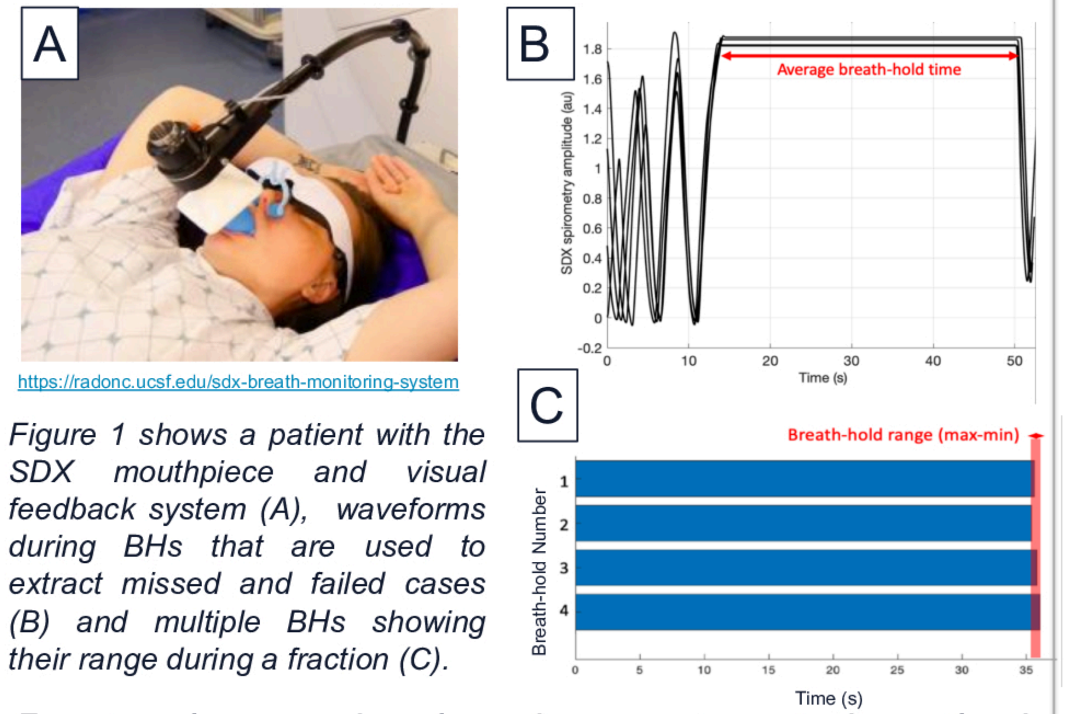

Figure 1 shows a patient with the SDX mouthpiece and visual feedback system (A), waveforms during BHs that are used to extract missed and failed cases (B) and multiple BHs showing their range during a fraction (C).

Previously, we developed an automated method that enables review of SDX treatments by recording patient breathing traces and extracting quantitative metrics of breath-hold quality. This method enables quality assurance checks and identification of patients that may benefit from closer monitoring.

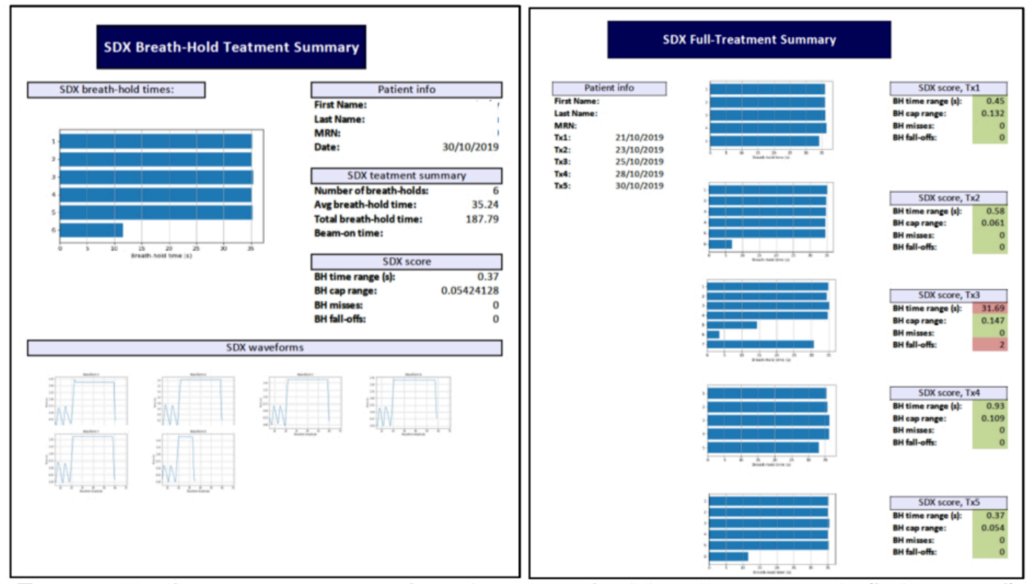

Figure 2 shows an example of an end-of-fraction report (left panel) where the patient had no misses or fails, and an end-of-treatment report (right panel) where the third fraction had 2 failed breath-holds. For each patient, the number of missed and failed breath-holds during simulation and treatment were compared.

Results - Missed and Failed BHs

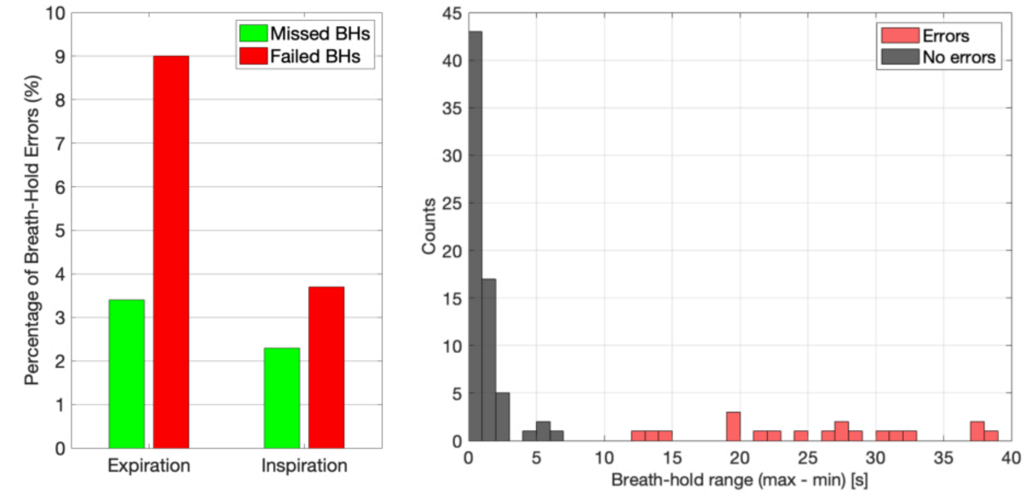

Figure 3 shows percentage of BH errors during expiration and inspiration holds (left) and the count of errors (sum of misses and fails) for different breath-hold time range per fraction showing a split distributions (right).

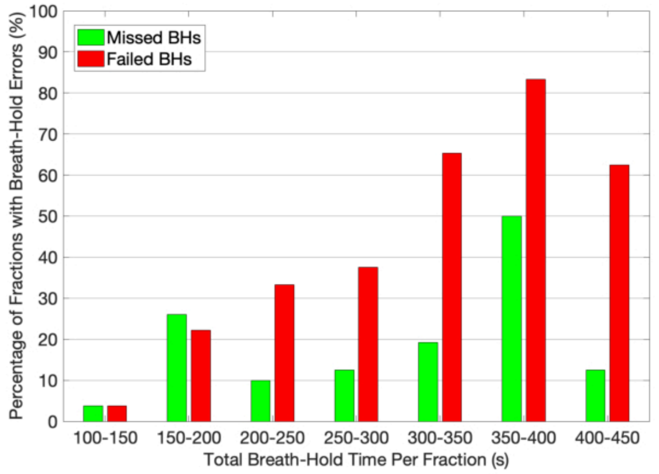

Figure 4 shows the percentage of fractions that had a BH error (missed or fail) as a function of total BH time per fraction of treatment. Missed BH are shown to be independent of total BH time, whereas BH fails increase with longer total BH time.

Breath-Hold Inconsistencies	During CT simulation (number of patients)	During Treatment (number of patients)
At least 1 miss	13	10
At least 1 fail	9	0
At least 1 miss and fail	7	0
At least 1 miss or fail	15	0
At least 1 miss or fail, and BH range > 25s	12	10

Table1 shows a summary of the number of patients that had inconsistent breath-holds during CT simulation and treatments. The bottom row criteria, patients that had at least 1 missed or failed BH and their BH ranges were greater than 25s, accurately identifies all patients at CT simulation that end up having issues in treatment.

Discussion:

We have developed a method of identifying good candidate for breath-hold treatments, or those that would benefit from additional monitoring and breathing training. Errors (missed or failed BH) occurred at some point during treatment in 45.7% of patients, 55.0% of fractions and 8.9% of all BHs for all treatment sites. Inconsistent breath-holds during CT simulation were used to predict further inconsistent breathing during treatment. Patients that had at least 1 missed or failed BH and their BH ranges were greater than 25s, accurately identifies all patients at CT simulation that end up having issues in treatment, resulting in a detection accuracy 100% sensitivity and 80% specificity. Evaluation of motion management techniques between fractions and post-treatment would further strengthen confidence of accurate dose delivery, especially for treatments with manual beam control.

Conclusion:

Inconsistent breath-holds during CT simulation were accurately used to predict further inconsistent breathing during treatment, even though there is a break between simulation and treatment.

References:

1. Wong et. al., "The use of active breathing control (ABC) to reduce margin for breathing motion", Int J Radiat Oncol Biol Phys, 44(4), 1999
2. Bortfeld et al., "Effects of motion on the total dose distribution", Semin Radiat Oncol, 14(1), 2004
3. Keal et al., "The management of respiratory motion in radiation oncology report of AAPM TG 76", Med Phys, 33(10, 2006
4. Brandner "Motion Management Strategies and Technical Issues Associated with Stereotactic Body Radiotherapy of Thoracic and Upper Abdominal Tumors: A Review from NRG Oncology", Med. Phys, 44(6), 2017

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