A time and motion study of stereotactic MR-guided adaptive radiotherapy (SMART) on a 0.35 T MR-Linac

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Introduction

MR-guided stereotactic radiotherapy (MRgRT SABR) allows for reshaping the radiation dose based on daily changes in the shape, size and position of the tumour and surrounding healthy anatomy. This presents a radical change in the radiotherapy workflow and the additional steps can result in treatment times of over an hour for many cases.

Decreasing treatment times is a key driver in the growth of MRgRT SABR. To achieve this and quantify changes, detailed measurement of the time spent on each step is required. Moreover, measuring the effect of new technologies and processes is important in understanding their success.

Timing data

The treatment steps involved in MRgRT are listed in Table 1. Analysis of long file data from the treatment console allows for precise measurement of each of these stages.

Data for over 1000 treatment fractions delivered from December 2019 to June 2021 was available for review. This volume of data is able to give a comprehensive review of the time taken to deliver treatments during this period. Focus was given to the three major sites treated: prostate, pancreas and liver.

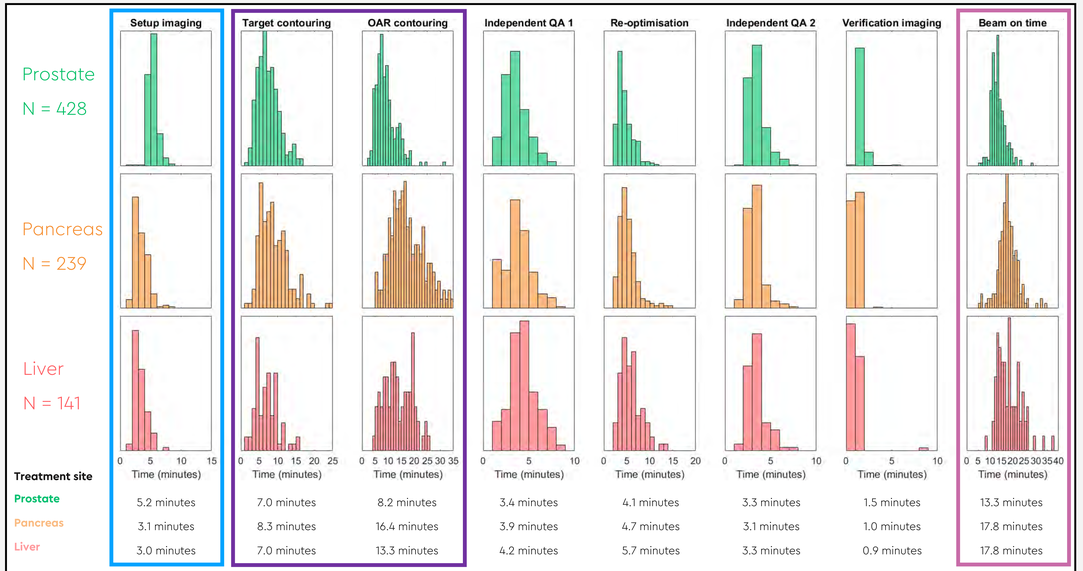
Workflow element	Steps involved
Setup imaging	Low- and high-resolution imaging Image review and matching
Target contouring	Electron density overrides Target review and recontouring
OAR contouring	OAR review and recontouring
Independent QA 1	Tracking structure delineation Physics review
Re-optimisation	Dose re-optimisation, review and sign-off
Independent QA 2	Physics review of dose Independent dose calculation
Verification imaging	Verification of target position Adjustment of tracking parameters
Treatment delivery	Beam on and MLC movement Adjustment of tracking parameters

Table 1: The precise time of user interactions with the treatment machine used to mark specific point in the treatment process. From this data, the elapsed time for each step can be extracted.

Comparison of treatment sites

The overall median treatment time for prostate cases is shorter than for pancreas and liver cases. However, not all workflow steps contribute to this difference. Organ at risk (OAR) contouring and beam on time are longer in pancreas and liver treatments. Whereas beam on time is shorter in prostate cases.

Step imaging: In pancreas and liver cases, 17-25 second breath-hold imaging is used. Whereas higher resolution images are acquired for prostate cases. This noticeably impacts the time of the setup imaging step.



Treatment site	Setup imaging	Target contouring	OAR contouring	Independent QA 1	Re-optimisation	Independent QA 2	Verification imaging	Beam on time
Prostate	5.2 minutes	7.0 minutes	8.2 minutes	3.4 minutes	4.1 minutes	3.3 minutes	1.5 minutes	13.3 minutes
Pancreas	3.1 minutes	8.3 minutes	16.4 minutes	3.9 minutes	4.7 minutes	3.1 minutes	1.0 minutes	17.8 minutes
Liver	3.0 minutes	7.0 minutes	13.3 minutes	4.2 minutes	5.7 minutes	3.3 minutes	0.9 minutes	17.8 minutes

Histogram of time taken for each workflow element, separated based on the treatment site. The table gives median values for each step. The setup imaging, contouring and beam on time steps show variation based on the site being treated.

Contouring: The target contouring step is of similar length for all treatment sites. However, OAR contouring is significantly longer for more complex pancreas and liver cases.

Beam on time: Due to the gated treatment delivery, beam on time is longer in pancreas and liver cases. In extreme cases where patients struggle to repeatedly hold their breath, beam on time can approach 40 minutes.

A key factor in efficient scheduling of treatments is to reduce the case-to-case variation in treatment time. Common variation of over fifteen minutes per fraction is seen for pancreas patients (Table 2).

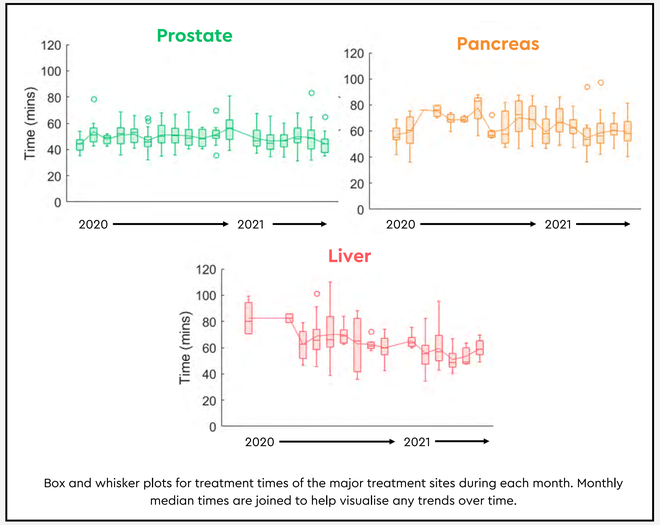
Greatest variation for individual workflow steps is seen in OAR contouring (Table 3) and beam on time. Ensuring regular review and feedback on contouring ensures consistency and reduces variations in workflow timings. High-speed MLCs, patient coaching and improved tracking and gating can reduce variation in this step.

Treatment site	25th percentile	Median	75th percentile
Prostate	42.8 minutes	48.0 minutes	54.3 minutes
Pancreas	52.1 minutes	60.0 minutes	69.2 minutes
Liver	50.4 minutes	58.5 minutes	64.8 minutes

Table 2: 25th percentile, median and 75th percentile times for overall treatment for each site.

Workflow improvements over time

For prostate cases, treatment times have remained consistent since the service started in December 2019. Pancreas and liver treatments show greatest variation in individual fraction timings. For liver cases, changing the way in which OARs are contoured to remove the need to define individual parts of GI-tract has led to more consistent treatment times.



Box and whisker plots for treatment times of the major treatment sites during each month. Monthly median times are joined to help visualise any trends over time.

Contouring time for individual clinicians

The time taken for OAR contouring can be significantly impacted by the attending clinician, with a variation of over 50% observed. This is possibly due to differences in site specialities, experience and confidence.

To decrease the variation seen in contouring time between different clinicians, further training focused on non-specialist areas is planned.

Treatment site	Dr A	Dr B	Dr C	Dr D	Dr E	Dr F	Dr G	Dr G
Prostate contouring time (minutes)	9.08	7.68	6.81	**6.78**	**10.73**	6.99	8.82	8.28
All other sites contouring time (minutes)	16.59	14.07	12.42	**11.06**	**19.45**	12.74	13.78	16.00

Table 3: Median OAR contouring times for eight different clinicians, separated into prostate and all other sites. Fastest and slowest times in each category are highlighted.