Myocardial Target Volume: Defining A Physiologically Relevant Target Structure For Stereotactic Arrhythmia Radiotherapy

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Stereotactic arrhythmia radiotherapy (STAR) has shown promising results as an end-line treatment for catheter ablation-resistant ventricular tachycardia.

To date, studies report dose to traditional planning structures like motion expansion PTV. PTV dose is relevant in oncological applications, as the volume typically encapsulates both tumor and functional tissue. This assumption breaks down in STAR. When an expansion margin is applied to a transmural scar, the resulting PTV contains both functional myocardial tissue and non-functional ventricular blood pool. In STAR, myocardial dose is highly relevant to both treatment efficacy and potential late cardiac effects, while dose to the blood pool might be considered akin to skin flash in traditional 3D planning. The DVH of a STAR PTV obscures which is which.

For STAR, defining a more physiologically relevant target structure for dose reporting is an unmet need.

We propose overall left ventricular (LV) myocardial volume and myocardial target volume (MTV), reported as scar volume / LV myocardial volume [%], as the relevant dose reporting structures.

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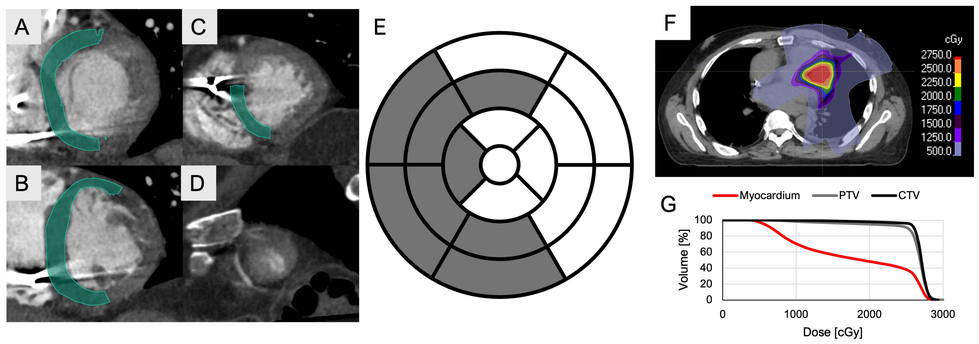
PURPOSE

Stereotactic arrhythmia radiotherapy (STAR) is a promising noninvasive treatment for cardiac arrhythmias. Traditional motion expansion PTVs are well-suited to oncology but little is known about their use for STAR. We propose and evaluate a novel myocardial target volume as the dosimetric endpoint of choice.

METHODS

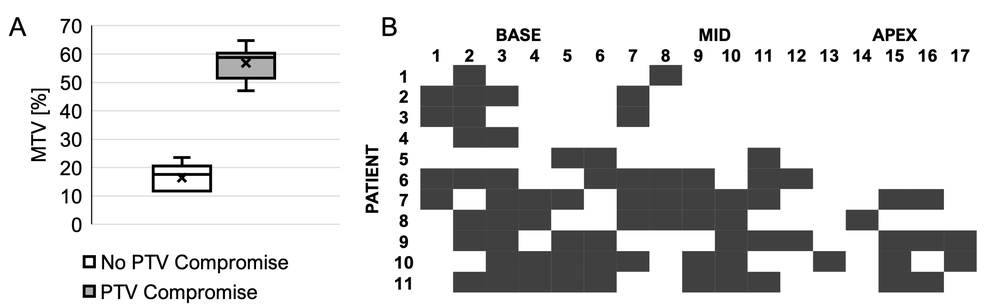
Eleven patients were treated to 2500 cGy x 1 with STAR. Scar volumes were drawn using either a dedicated electrophysiology mapping software (N=8) or on diagnostic images (N=3). Scar was mapped onto the left ventricular (LV) myocardium based on the American Heart Association (AHA) model. Both scar volumes (scar substrate and AHA segmentation) were used to quantify myocardial target volume (MTV) = scar volume / LV myocardial volume [%]. 5 mm PTV margins were applied to physician-drawn scar.

FIGURE 1



STAR planning in a single patient. Left ventricular (LV) myocardial scar extent (green overlay) using scar substrate targeting in basal (A), mid-ventricular (B), and apical (C-D) slices on contrast-enhanced 4DCT; scar extent (gray) on AHA segmentation (E). Clinical treatment plan to 2500 cGy x 1 (F). LV myocardial, PTV and CTV DVH (G), showing myocardial V25 = 37.6%.

FIGURE 2



(A) MTV differed significantly based on whether a compromised PTVeval structure was used to reduce OAR dose: 58.82%1 (54.41, 60.29), N=6 vs17.65% (11.76, 20.59), N=5; p<0.01. (B) Presence of scar (gray) by AHA segment across all 11 patients.

RESULTS

Scar volume averaged 66.1±23.5cc (N=11). In N=9 patients with diagnostic imaging compatible with myocardial contours, MTV comprised 45.2±10.4% of the LV myocardial volume using physician contours and 43.8±19.2% using AHA segmentation (Pearson, R^2 = 0.51). PTV volumes averaged 207.2±91.2 cc (N=11).

Median stomach and esophageal Dmax (D0.03cc) were 279.0 cGy (inter-quartile range 82.0, 914.7 cGy) and 1080.7 cGy (923, 1361.7 cGy) respectively. Dose to critical digestive structures was sensitive to myocardial target volume: stomach and esophageal Dmax both increased with increasing MTV (R^2=0.41 and 0.48).

OAR dose necessarily compromised PTV coverage when scar extended to the LV apex, close to digestive structures: PTV V25 Gy was negatively correlated with the number of LV apical segments in which scar was observed (R^2 = 0.69). MTV was significantly greater in patients where a reduced PTVeval was required for OAR sparing (Mann-Whitney, p<0.01).

SUMMARY

- MTV agreed between scar substrate targeting and AHA segmentation at 45.2±10.4% and 43.8±19.2%.
- Increased MTV drove up dose to digestive structures (D0.03cc); scar in the LV apex drove down PTV coverage (V25). Median MTV was 7.7 times greater when a compromised PTVeval was needed.
- Although trial protocols call for a range of contouring methods, scar substrate targeting and AHA segmentation produce similar MTV estimates and enable complementary retrospective analyses.
- Traditional expansion margin PTVs may obscure clinically relevant dosimetric endpoints in STAR.

CONCLUSIONS

Myocardial target volume generally agreed between segmentation methods and drove dose to critical structures, limiting achievable PTV coverage. STAR-specific target volumes and dosimetry endpoints should be investigated for treatment planning and assessment of efficacy.