Voxel-Based Dosimetry in Y90 Radioembolization for Hepatocellular Carcinoma: A Paradigm Shift in Personalized Treatment Planning

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Purpose

- This educational exhibit aims to evaluate how voxel-based dosimetry influences treatment planning, therapeutic efficacy, and clinical outcomes in Yttrium-90 (Y90) radioembolization for the treatment of hepatocellular carcinoma (HCC), compared to traditional dosimetric approaches.

Materials and Methods

- A targeted literature review was conducted to assess the clinical utility of voxel-based dosimetry in Y90 radioembolization for HCC.
- Sources included clinical studies, retrospective analyses, and dosimetric modeling reports focused on personalized treatment planning.
- Primary outcomes included tumor-absorbed dose, treatment efficacy, and comparisons to conventional dosimetric methods such as body surface area and partition models.
- Emphasis was placed on the role of voxel-based techniques for optimizing patient-specific dosing.

Results

- Traditional dosimetry methods often rely on generalized assumptions that fail to account for patient-specific factors such as liver volume and tumor vascularity, frequently resulting in subtherapeutic dosing or increased toxicity risk.[1]
- In contrast, voxel-based dosimetry enables three-dimensional modelling to calculate patient-specific dosages that outperform traditional methods in dose accuracy and therapeutic precision.[1]
- Compared to region-based approaches, such as the AAPM method, voxel-level planning demonstrated superior precision regarding biological effective dose and absorbed dose.[2]
- Personalized dosing strategies using voxel-based models improve therapeutic outcomes by enhancing tumor targeting and reducing non-target exposure.[3]
- A retrospective data analysis of Y90 treatment for HCC utilizing personalized dosimetry software identified a minimum dose threshold to significantly prolong median time-to-progression and overall survival. This significantly improved disease management profile supports the use of personalized dosimetry, such as voxel-based dosimetry, for optimal treatment planning.[4]
- Further validating the clinical impact of personalized voxel-level dosimetry, a single institutional study found that using voxel-based dosimetry to calculate minimum doses delivered to defined tumor volumes (e.g., 50%, 70%, 95%) was predictive of complete pathological response to treatment.[5]

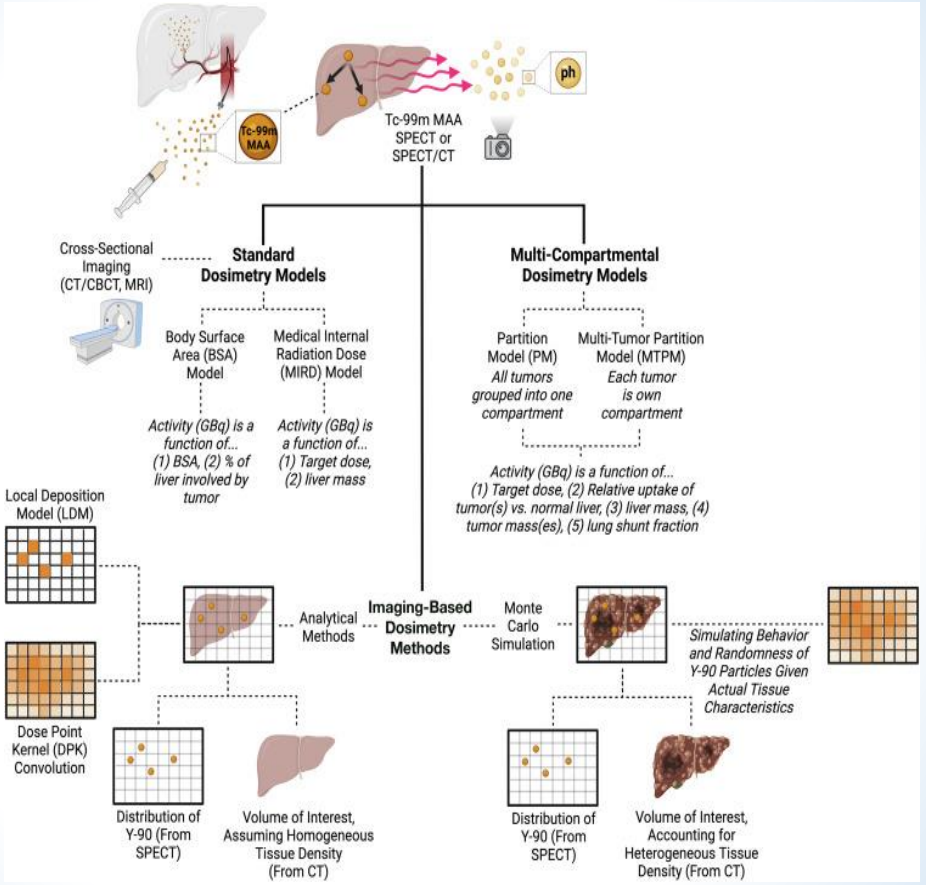

Figure 1:
Figure and caption adapted from Knight et al.
Historical and contemporary dosimetry models. BSA = body surface area; CT = computed tomography; CBCT = cone-beam CT; DPK = dose point kernel; LDM = local deposition model; MAA = macroaggregated albumin; MIRD = medical internal radiation dose; MRI = magnetic resonance imaging; MTPM = multitumor partition model; PM = partition model; SPECT = single photon emission computed tomography; Y-90 = yttrium-90.

Conclusions

- Voxel-based dosimetry enhances treatment precision in Y90 radioembolization by enabling personalized, image-guided dose planning.
- Voxel-based approaches improve tumor targeting, limits healthy tissue exposure, and supports better clinical outcomes.
- Voxel-based dosimetric calculations serve as a reliable tool to predict treatment response and clinical outcomes.

References

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