

# Automated Video-Based Surrogate Dose Estimation for Patient-Specific Magnetic Drug Targeting Using Time-Resolved Deposition Analysis

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## Abstract

*Background:* The efficacy of medication in MDT is related to the number of loaded magnetic particles at the target site. Accurate quantification of this deposited dose is important for assessing treatment effectiveness and safety, and for enabling patient-specific MDT planning and in silico modelling to emulate in vivo efficacy. Particle deposition is transient under vascular flow: particles first accumulate rapidly, then partially erode. Static or hand-selected frame acquisition does not account for these dynamics, reducing experimental realism and challenging the generation of patient-specific data. *Objective:* To establish an automated, video-based experimental workflow that allows depiction of peak particle deposition and deposited drug dose with high time resolution and accuracy by generating structured datasets for virtual dose estimation, deep learning, and patient-specific MDT planning within digital twin concepts. *Methods:* The integrated medical-informatics pipeline includes a high-resolution multi-angle acquisition system with semi-automatic 3-axis magnetic positioning and synchronised views of a biologically relevant microvasculature structure. Time series of video streams are analysed using computer-vision techniques to segment deposition sites, extract quantitative image-derived data, and inform time-dependent deposition dynamics. These are combined to generate temporal deposition profiles, from which peak deposition is automatically detected. Areas from orthogonal projections of the deposits are integrated under the assumption of a specific geometric reconstruction to estimate 3D deposition volume, and mass (and, by inference, delivered dose) is obtained using calibration data. Annotated video frames, peak-deposition labels, magnet-position parameters, and temporal metadata are converted into structured learning-ready datasets for supervised deep learning and surrogate modelling. *Results:* The platform enables observer-independent, time-dependent estimation of the deposited drug amount and surrogate dose determination under dynamically flowing conditions. *Conclusions:*



The proposed platform supports patient-specific MDT planning, integration into digital twin models, and data-driven optimisation of magnetic drug targeting strategies by converting experimental video data into structured datasets.

**Keywords:** Surrogate Dose Estimation; Medical informatics; Computer vision; Deep Learning (DL); Time-resolved data analysis; Digital twins; Patient-specific therapy.