AI-Driven Reconstruction and Automated Physics Rigging of Deformable Colon Models from CT for Colonoscopy Rehearsal

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BACKGROUND

- There are over 19 million colonoscopies performed in the U.S. annually.
- Current colonoscopy simulators use generic anatomy and limited soft tissue collapse constraining patient-specific rehearsal
- Computed tomography colonography (CTC) is currently the most effective imaging technique for visualizing the 3D anatomy of the colon

Objective: Present an end-to-end pipeline that converts CTC into a deformable three-dimensional (3D) colon model for interactive learning and pre-procedure planning

METHODS

- De-identified CTC volumes (n=14) were segmented to generate a binary lumen mask. A surface mesh was reconstructed (marching cubes) and smoothed/decimated to a simulation-ready resolution.
- A Python-based rigger extracted a centerline and local radius profile, partitioned the mesh into sequential rings, generated a skeletal chain, assigned vertex weights by nearest-surface mapping, and parameterized per-joint masses and hinge-spring constraints to approximate collapse and longitudinal stretch.

RESULTS

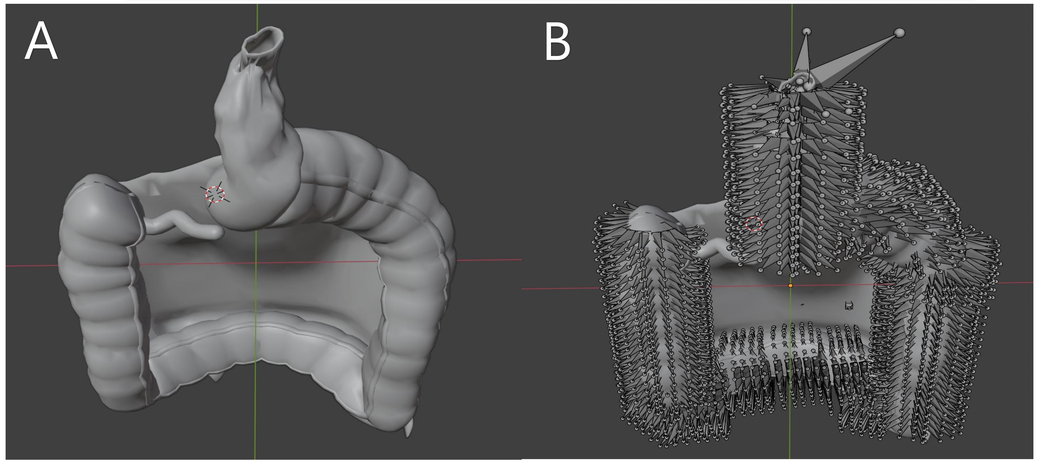

Figure A&B. Output of the pipeline in which the Unity cloth effect was utilized to add 'bones' and 'weights'. Based on Paulo et al. where a tutorial for reconstruction of subject-specific 3D models was published utilizing free and open-source software.

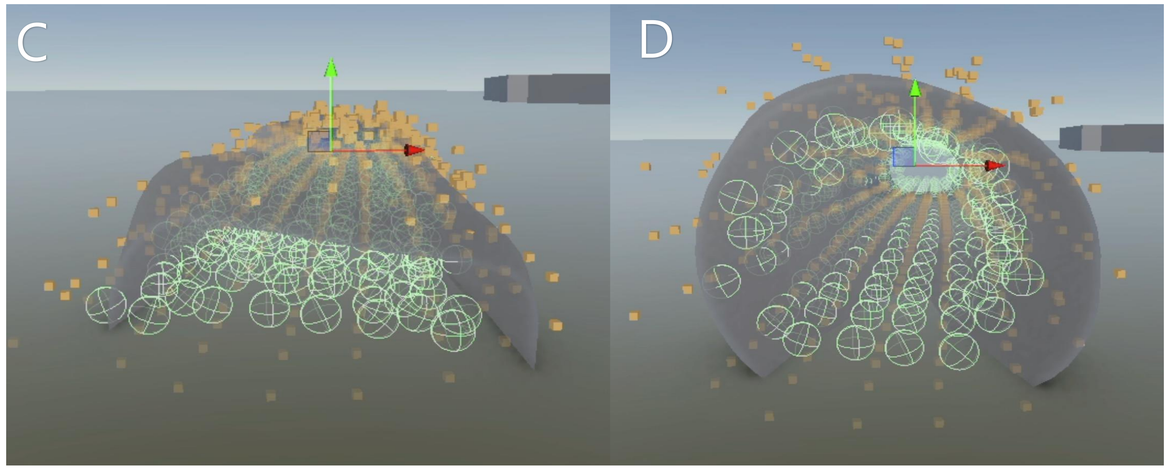

Figure C&D. Physics for colon simulations were created using Blender and Unity where each 'bone' is attached to a series of colliders. Bones have distinct mass and spring constants where reducing it allow collapse (**C**) and increase is insufflation (**D**).

DISCUSSION

- This pipeline produced fully rigged, deformable, patient-specific colon models without manual 3D editing.
- In interactive testing, the model exhibited stable real-time deformation, including segmental luminal collapse under contact loading with recoil after unloading, enabling rehearsal of scope advancement and loop-management maneuvers along the subject-specific anatomy.
- Limitations include the number of CTC utilized for proof-of-concept testing. Next steps include utilization of the publicly available The Cancer Imaging Archive and technical and clinical validation by an expert abdominal radiologist.

CONCLUSIONS

- CTC-derived, AI-segmented colon models can be automatically transformed into deformable simulators using a fully scripted physics rigging workflow. This scalable approach enables rapid creation of patient-specific rehearsal environments and underscores the intersection between radiology as a training overlay for other specialties.