Automated construction of patient-specific computational models using convolutional neural networks for conceptus dose estimation in pregnant patients

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INTRODUCTION

CT examinations for pregnant patients

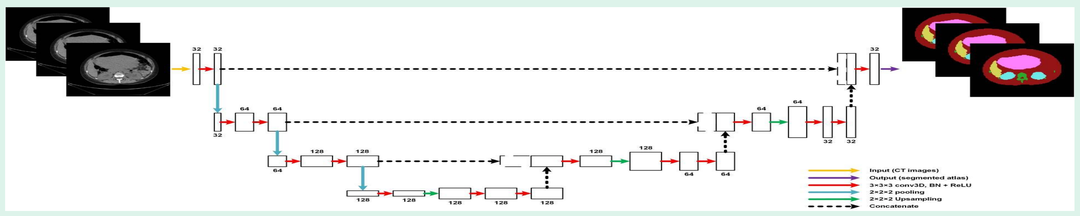
- ✓ One of the most frequently asked questions associated with the clinical use of radiologic imaging is the management of radiation dose for patients presenting with high radiosensitivity, including pregnant female and pediatric patients. Radiologic imaging should be avoided in pregnant females; however, in some specific situations, CT scanning becomes unavoidable.
- ✓ Under these circumstances, the radiation risks to the fetus is a significant concern. At fetal doses greater than 50 mGy [1-3], the potential hazard effects include embryonic death, intra-uterine growth limitation, average intelligence quotient (IQ) loss, mental retardation, organ malformation, and small head size. Stochastic effects might also occur at fetal doses below 50 mGy.
- ✓ The accurate estimation of conceptus dose plays a key role in managing safety and quality in CT imaging procedures for pregnant patients, keeping in mind the current international recommendations in terms of good practice and diagnostic reference levels [4-5].

Objectives

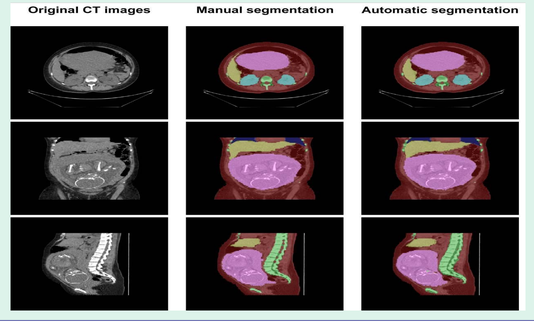
The aim of this work is to develop a deep-learning based methodology for automated construction of patient-specific computational phantoms using actual patient CT images to enable patient-specific radiation dose calculations.

METHODS

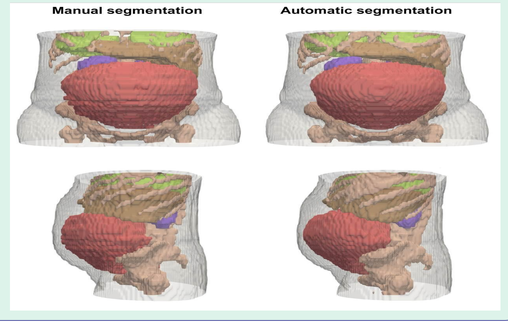
Proposed convolutional neural networks model



CNN-based image segmentation



3D computational models



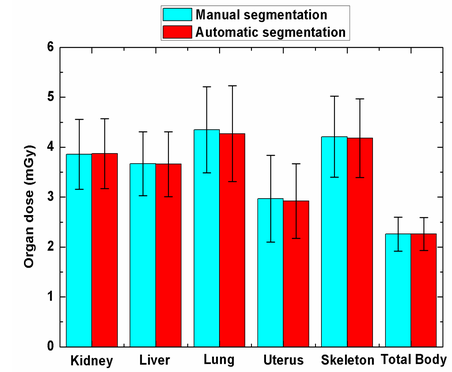
RESULTS

Summary of image segmentation metrics

Organs	Jaccard similarity coefficient	Dice similarity coefficient	Sensitivity	Positive Predictive Value	Volume difference	Hausdorff distance
Body	0.96±0.01	0.98±0.01	0.97±0.01	0.98±0.01	-1.29%±1.17%	25.24±18.03 mm
Skeleton	0.87±0.02	0.93±0.01	0.94±0.02	0.92±0.03	2.96%±4.14%	50.07±18.75 mm
Lung	0.93±0.03	0.96±0.01	0.97±0.02	0.96±0.02	0.92%±2.41%	15.49±11.21 mm
Liver	0.90±0.01	0.95±0.01	0.96±0.01	0.94±0.02	2.36%±2.82%	24.08±14.88 mm
Kidney	0.85±0.03	0.92±0.02	0.90±0.03	0.94±0.02	-4.90%±4.72%	10.71±2.42 mm
Uterus	0.88±0.06	0.94±0.04	0.94±0.05	0.93±0.03	1.49%±4.19%	16.10±8.16 mm

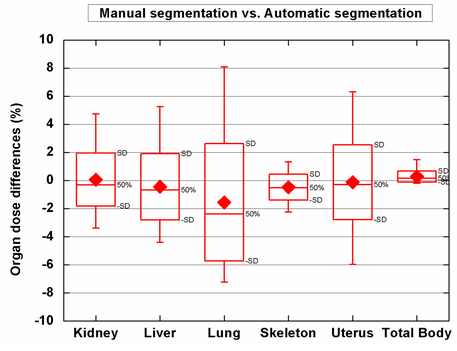
The Jaccard similarity coefficient (JSC) for the different segmented organs varies between 0.85 and 0.96 with an average of 0.90 ± 0.04; while the Dice similarity coefficient (DSC) varies between 0.92 and 0.98 with an average of 0.94 ± 0.02. For the segmented uterus among patients, JSC, DSC, sensitivity, positive predictive value (PPV), volume difference and Hausdorff distance (HD) are 0.88 ± 0.06, 0.94 ± 0.04, 0.94 ± 0.05, 0.93 ± 0.03, 1.49% ± 4.19% and 16.1 mm ± 8.16 mm, respectively.

The relative absorbed dose differences for the total body among the 32 patients ranges from -0.21% to 1.48% with an average of 0.28% ± 0.39% whereas the dose differences for the skeleton vary between -2.26% and 1.33% with an average of -0.48% ± 0.91%. The dose difference for the uterus ranges from -5.98% to 6.31% with an average of -0.12% ± 2.62%.



CONCLUSION

- ✓ Patient-specific computational models can be created using an automated deep learning-based segmentation algorithm.
- ✓ The proposed automated computational modeling approach can be useful for retrospective evaluation of the radiation dose to patients (e.g. unknown pregnancy) for the decision making process for high dose procedures in clinical setting and in research studies involving retrospective data analysis.



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