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Precision of automated segmentation of the heart

Automated cardiac chamber and great vessel volume segmentation in difficult cases using an open-source full body segmentation model

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Purpose

To evaluate the precision of automated cardiac and great vessel segmentation using the 'Total Segmentator' (TS) by Wasserthal et al in patients with structural abnormalities.

Materials and Methods

This study analyzed 89 CT scans, including a control group of routine clinical cases without cardiac abnormalities and a balanced study groups representing 13 various structural abnormalities. The study group included patients with chest wall and spine deformities (n=5), hypertrophic cardiomyopathies (n=5), left ventricular assist devices (LVAD) (n=5), adults with situs inversus (n=4), adults with transposition of the great arteries (n=4), adults with Fontan circulation (n=5), newborns (age 0; n=5), preschool children (age 1–4; n=5), elementary school children (age 5–9; n=5), and secondary school children (age 10–16; n=5).
Imaging data were retrospectively collected from multiple CT scanners between 2012 and 2024, using a soft tissue kernel and intravenous contrast agents. Total Segmentator was used for automated segmentation of six cardiovascular structures (aorta , left and right atrium, left and right ventricle and pulmonary artery), followed by manual corrections. Segmentation accuracy was assessed using the Dice coefficient, Jaccard index, and Volume Similarity index to evaluate the quality in dependence of pathology and age.

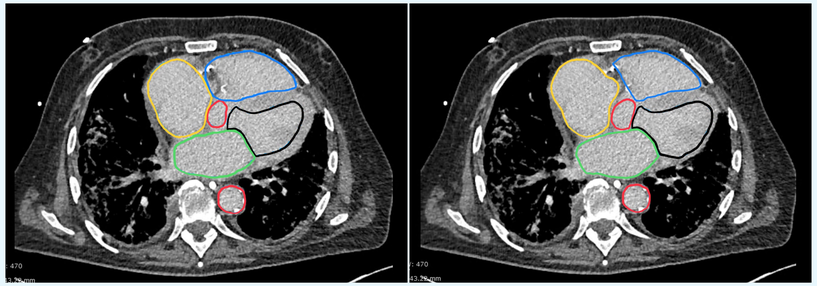
Results

The model demonstrated high performance on the clinical routine group, achieving a Dice coefficient of 0.91. However, its performance on the study group was significantly poorer, with a Dice coefficient of 0.73 ($p \leq 0.05$). In the subgroup analysis spine and chest wall deformities (dice=0.87), aortic (dice=0.87), mitral (dice=0.88) and tricuspid valve replacements (dice=0.88) were segmented with acceptable quality. Patients with left ventricular assist devices were not segmented inferior in total (dice=0.87), but in the left atrium (surface dice=0.20) and the left ventricle (dice=0.69).
Children aged 0 had very poor cardiac chamber (dice=0.32) and the great vessel (dice=0.05) segmentations. The precision of the heart chambers increased with age. In secondary school children the great vessels were segmented significantly poorer while the performance on the cardiac chambers was good, resulting in an overall good performance (total dice=0.88). In adults with congenital heart disease the algorithm performed inferior to the clinical routine collective (transposition of the great arteries: dice=0.46; situs 0.38 in patients with a situs inversus and 0.53 in patients with Fontan circulation.

Conclusion

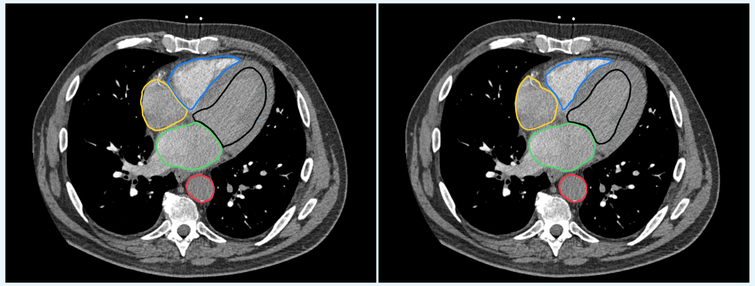
Automated segmentation demonstrated reliable on the major mediastinal cardiovascular structures in routine clinical cases. However, its performance is less effective in patients with cardiac abnormalities and in underaged patients.
Especially underaged patients and adults with congenital heart disease had poor segmentations of all structures and LVAD patients had inferior segmentation of the left heart.
Therefore, manual control of the automated segmentation is mandatory in these cases.

Works well on adult patients without cardiac abnormalities:
Total Dice= 0.91



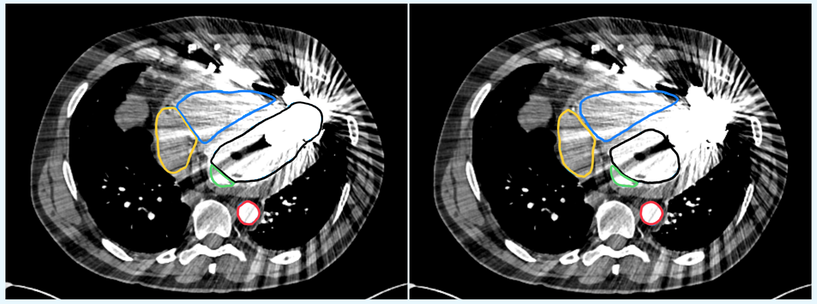
Healthy adult, automatic segmentation | Healthy adult, manual segmentation

Works adequate on adult patient with hypertrophic cardiomyopathy:
Total Dice= 0.88



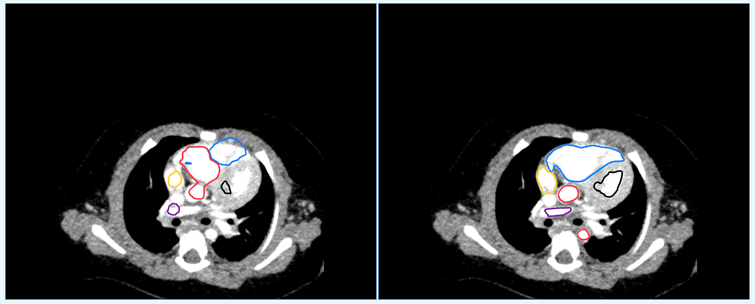
Patient with HCM, automatic segmentation | Patient with HCM, manual segmentation

Works mostly good, despite artefacts on adult patient with LVAD:
Total Dice= 0.87, Left Ventricular Dice=0.69



Patient with LVAD, automatic segmentation | Patient with LVAD, manual segmentation

Works deficient on newborn:
Total Dice= 0.23



Newborn aged 0, automatic segmentation | Newborn aged 0, manual segmentation

Data processing:
- Data management tool Mint Lesion Racoon (Version 3.9.2; Mint Medical GmBH; Heidelberg, Germany)
- Processing tool Satori (Segmentation and Annotation Tool for Radiomics and Deep Learning; Version 1.9.1; Fraunhofer Institute for Digital Medicine MEVIS; Bremen, Germany)
- https://github.com/wasserth/TotalSegmentator

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References:

- Wasserthal, Jakob et al. "TotalSegmentator: Robust Segmentation of 104 Anatomic Structures in CT Images." *Radiology. Artificial intelligence* vol. 5,5 e230024. 5 Jul. 2023, doi:10.1148/ryai.230024
- Heyder, Ralf et al. "Das Netzwerk Universitätsmedizin: Technisch-organisatorische Ansätze für Forschungsdatenplattformen" [The German Network of University Medicine: technical and organizational approaches for research data platforms]. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz* vol. 66,2 (2023): 114-125. doi:10.1007/s00103-022-03649-1
- Bujotzek, Markus Ralf et al. "Real-world federated learning in radiology: hurdles to overcome and benefits to gain." *Journal of the American Medical Informatics Association : JAMIA*, ocae259. 25 Oct. 2024, doi:10.1093/jamia/ocae259