Comparison between threshold-based and deep learning-based bone segmentation on whole-body CT images

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INTRODUCTION

Bone segmentation can be used to evaluate metastatic tumor burden in breast cancer.
Metastatic breast cancer lesions are mostly located in the bones [1] and literature shows that tumor response can be assessed by evaluating the size and intensity of bone metastasis on PET scans [2]. Our final goal is to develop a new method to segment automatically bone and bone lesions on PET/CT images. This will allow to calculate a new index to evaluate the tumor response in the context of metastatic breast cancer. Figure 1 presents the first steps : the **bone segmentation**.

$$\frac{Bone\ Lesion\ Volume}{Bone\ Total\ Volume} \times 100 = 15\%$$

Figure 1: First step before bone lesion evaluation

METHODS

Data

Fifty patients were recruited in the prospective EPICURE$_{seinmeta}$ metastatic breast cancer study (NCT03958136). Imaging data were acquired in two sites using different imaging systems. For this work, we only used the collected CT images.

Experiments

This work compares the results of three bone segmentation methods:
1) A **threshold-based** method using combined thresholding and morphological operations.
2) A standard 3D nnU-Net [3] with a cross entropy/Dice loss (**U-Net$_{CE+DCS}$**).
3) A tuned 3D nnU-Net with a Hausdorff distance/Dice loss(**U-Net$_{HD+DCS}$**).

The **Hausdorff distance** (HD) is rarely used as a loss because it is not differentiable. However, it can be approximate by using the **distance transform** to make it differentiable and use it as a loss function [4].
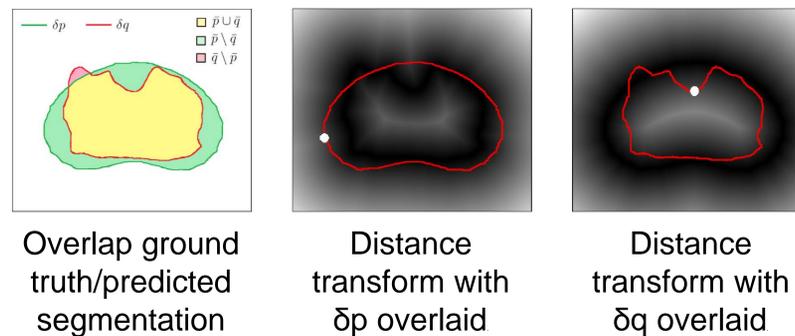

Figure 2: Distance Transforms for HD computation

RESULTS

Table 1: Quantitative evaluation

Methods	Mean Recall	Mean Precision	Mean Dice	Glob. Dice	Mean HD	Max HD
Threshold-based	0,949	0,963	0,955	0,953	103,5	187
U-Net$_{CE+DCS}$	0,988	0,984	0,986	0,986	49,99	131
U-Net$_{HD+DCS}$	0,980	0,975	0,978	0,978	39,59	113

Threshold-based method

Figure 3: Threshold-based segmentation on 4 patients

Visual evaluation

The threshold-based method presents some segmentation errors in the heart or kidneys and under-segmentation in the vertebrates.
The U-Net$_{CE+DCS}$ method sometimes over-segment small volumes distinct from the bone, contrary to the U-Net$_{HD+DCS}$ method.
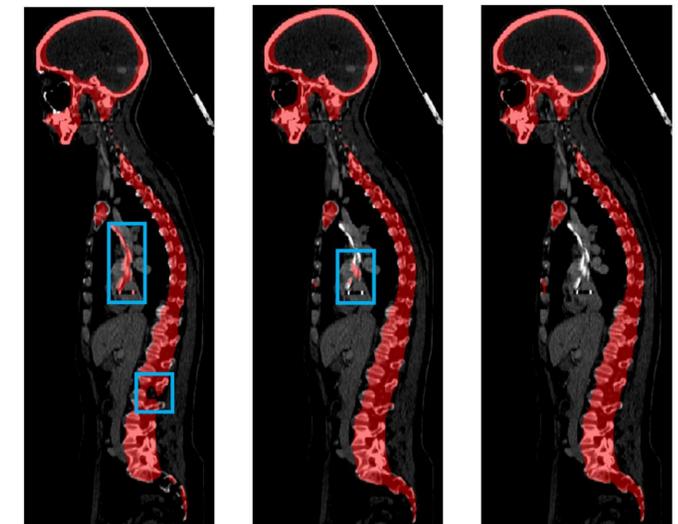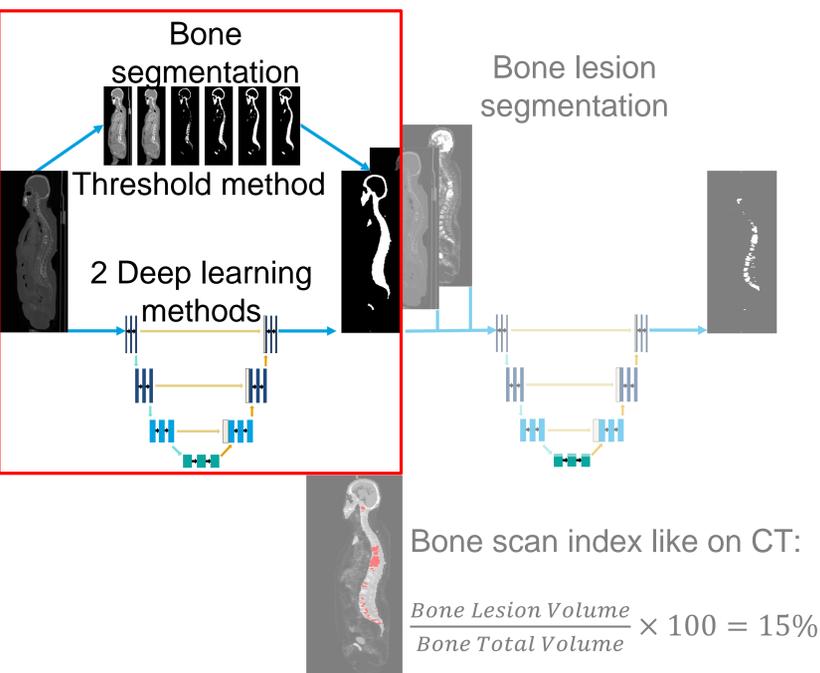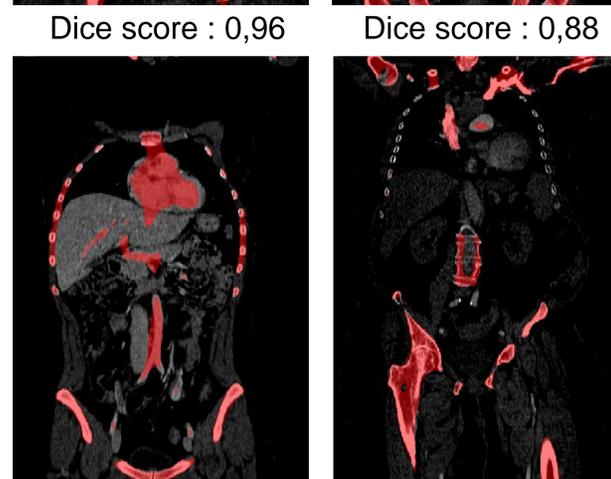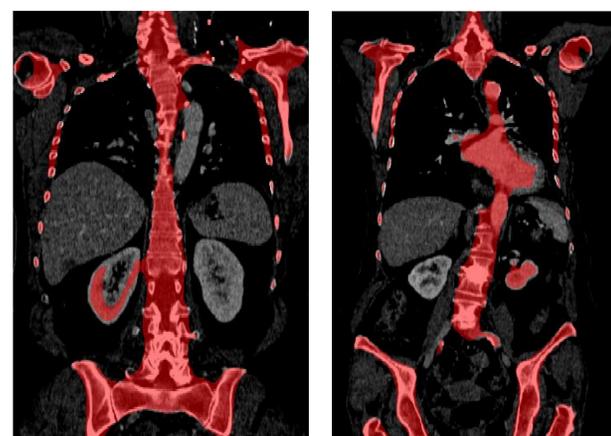

Figure 4: Bone segmentation for the 3 methods

CONCLUSIONS

- **Deep learning methods outperformed than threshold-based method**
- **Hausdorff distance-based loss reduce the false positive segmentation and improve visual results**
- **The dice score is not the best evaluator index to evaluate large volume segmentation like bone.**

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