Evaluation of a method to detect muscle mass reduction from lower extremity CT images

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INTRODUCTION:

Skeletal muscle mass (SMM) is crucial in maintaining the activities of daily living in the elderly. Usually, SMM is quantified using dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA) and is evaluated by the skeletal muscle index (SMI), calculated by dividing the SMM of the appendicular muscles (in grams) by the square of body height (in meters).

To date, the cut-off values to diagnose whole-body muscle loss (i.e., sarcopenia) has been established using SMI. For instance, the 2019 AWGS Consensus set cut-off values of 5.4 kg/m^2 for women and 7.0 kg/m^2 for men in Asians. While the importance of evaluating SMI have been widely recognized, the loss in SMM often remains unevaluated due to the limited availability of the equipment (DXA and BIA). Therefore, it would be clinically meaningful to establish a method to screen for the loss in SMM using medial images obtained during various clinical examinations (i.e., opportunistic screening). In this study, we aimed to 1) develop and validate a method to quantify muscle mass of lower extremities from lower extremity CT images and 2) assess if SMI loss can be predicted from lower extremity CT images where the field of view (FOV) is limited.

METHODS: This study analyzed 183 patients who underwent hip surgery in two institutions (150 women, Institution 1: 119, age: 59.3 ± 16.4 years). For both institutions, a preoperative CT scan was acquired from the pelvic brim to the ankle, and a whole-body DXA was acquired (Institution 1: Hologic, Institution 2: GE Medical). First, each skeletal muscle in the lower extremities was automatically segmented from the CT images using a Bayesian U-net, a deep-learning model for semantic segmentation that we have previously developed and validated. Then, the segmented labels were used to measure the volume and density of each muscle to calculate the muscle mass (in grams) of each muscle. The psoas muscle was excluded as the entire muscle was not included in the FOV. Muscle mass of all lower extremities was summed and was defined as MLE. The relationship between MLE and lower extremity lean mass (LLM) measured using DXA was assessed using Pearson's correlation coefficient for each institution. Then, the SMI was calculated from MLE (defined as SMI_{CT}), and receiver operating characteristic (ROC) curve analysis was performed to clarify the diagnostic performance of the SMI_{CT} in detecting whole-body SMM loss (defined here as SMI < 5.4kg/m^2) obtained from DXA. The area under the curve (AUC), sensitivity, specificity, and cut-off value were calculated. All analyses were performed automatically using MATLAB (R2022a), and $p < 0.05$ was considered statistically significant.

RESULTS: MLE and LLM were 4712 ± 1356 g, 5820 ± 1625 g at institution 1, 4404 ± 1097 g, and 5682 ± 1184 g at institution 2, respectively. A very strong positive correlation was found between MLE and LLM in both institutions ($r = 0.97$ and 0.95, both $p<0.01$) (Figure 1). In the ROC analysis, the AUC for diagnosing whole-body SMM loss using SMI_{CT} was 0.96 in institution 1 with a sensitivity of 90.9%, specificity of 92.8%, and a cut-off value of 3.23kg/m^2. For institution 2, the AUC was 0.96 with a sensitivity of 100%, specificity of 92.6%, and a cut-off value of 2.99kg/m^2 (Figure 2).

DISCUSSION AND CONCLUSION:

In this study, the muscle mass of the lower extremities (i.e., MLE) was measured from CT scans and was compared to the LLM measured by DXA. The very strong correlation found between MLE and LLM ($r > 0.95$) indicated that the MLE quantification method applied in this study could reproduce the measurement of LLM from DXA used to diagnose sarcopenia.

Some previous reports have correlated the MLE with whole-body SMM and indicated the potential for using the MLE in predicting the whole-body SMM. However, limited information has been provided on whether a loss in SMI can be predicted from CT images. Our study revealed the very strong correlations of MLE calculated from CT images between the LLM measured from the DXA of two manufacturers. Further, SMI loss (< 5.4kg/m^2) was accurately predicted with an AUC > 0.95 from the CT images of the lower extremities, indicating its potential use in opportunistic screening for sarcopenia. However, future studies may be necessary as the cut-off values to diagnose SMI loss from SMI_{CT} were different between the institutions that have DXA from different manufacturers.

In conclusion, MLE can be accurately measured from CT images of the lower extremities, and loss of SMI can be accurately predicted from CT images.

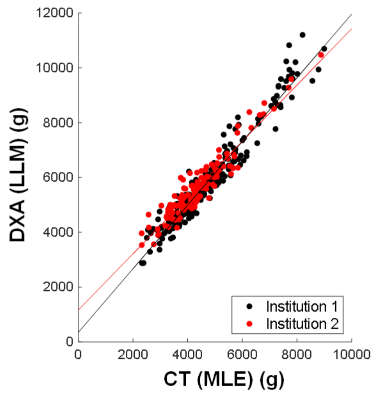

Figure. 1
Correlation of the muscle mass of the lower extremities between CT (MLE) and DXA (LLM).

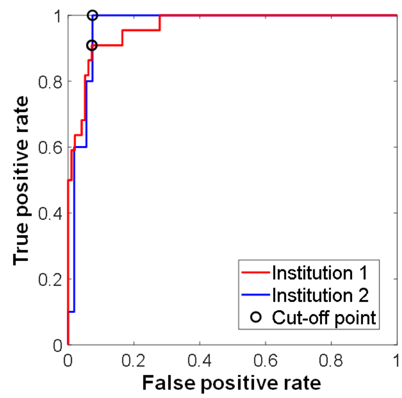

Figure. 2
ROC curve for predicting SMI loss using lower extremity CT images.