3P5-17

A Novel Approach for Intramuscular Lipid Content Estimation with Portable Ultrasonic Measuring Device

ポータブル超音波測定装置による筋肉内脂肪量推定に向けた新手法

Hiroki Takeuchi[1†], Satoki Deguchi[2], Hongxiang Lin[1] , Naoki Tomii[2] ,and Takashi Azuma[2] ([1]Grad. School Eng., The Univ. of Tokyo; [2]Center for Disease Biol. and Integrative Med., The Univ. of Tokyo)

竹内裕貴 [1†]，出口智基 [2]，林宏翔 [1] ，富井直輝 [2] ，東隆 [2] ([1] 東大院　工, [2] 東大院 医 疾患生命工学センター 医療材料・機器工学部門)

1. Introduction

Recent studies show that the proportion of lipids in skeletal muscles, especially in calf muscle correlates with the risk of Type 2 diabetes and sarcopenia [1][2]. Lipids in skeletal muscles are classified into extramyocellular (EMCL) and intramyocellular lipids (IMCL). Non-invasive evaluation of EMCL and IMCL based on a sound speed (SS) estimation using an ultrasound computed tomography (UCT) is anticipated to contribute the risk assessment of these disorders.

We proposed a portable UCT using two parallel linear arrays to interpose the calf without a water tank. In this configuration, although the high resolution was not guaranteed, there was a possibility that the SS change of the calf muscle can be estimated. In this study, we verified the accuracy of average SS estimation using the fastest path, the nearest path using numerical simulation.

Especially in EMCL, there is a possibility that the fastest path does not pass through EMCL which is a region of slow SS, and the accuracy may depend on the structure of EMCL. The purpose of this study is establishing a method to estimate content of EMCL and IMCL not depending on EMCL structures.

2. Materials and Methods

2.1 simulation methods

Radiofrequency (RF) signals were simulated using ultrasound simulation toolbox k-wave (B. E. Treeby, University College London) on MATLAB (The MathWorks Inc., Natick, MA). Wave equations were solved by pseudospectral method. Two parallel linear arrays with 100-elements transducer, 100-elements receivers, distance of 40 mm and apertures of 40 mm were simulated to transmission and reception of ultrasound. The center frequency of transmission was 2 MHz. Its excitation signal was 1 wave of a sinusoid, was convolved it with Hanning window, and was processed by low-pass filter with cutoff frequency of 4 MHz. The sampling frequency was 40 MHz and the time step Δt was 1.9×10^{-8} sec. Calculation area was 50×50 [mm^2], number of calculation grid was 500 for x and y axes respectively, and the grid spacing Δx was 0.1[mm].

the one-dimensional Courant-FriedrichsLewy (CFL) number well known as a number to evaluate stability is defined by

$$\mathrm{CFL} \equiv c_0\Delta t/\Delta x \qquad (1)$$

where c_0 is referential SS i.e. 1580 m/s as SS of skeletal muscle. The CFL number in the simulation was 0.3 and gave stable simulation in k-wave. The first-arrival time was calculated by threshold-method.

hiroki-t@iis.u-tokyo.ac.jp

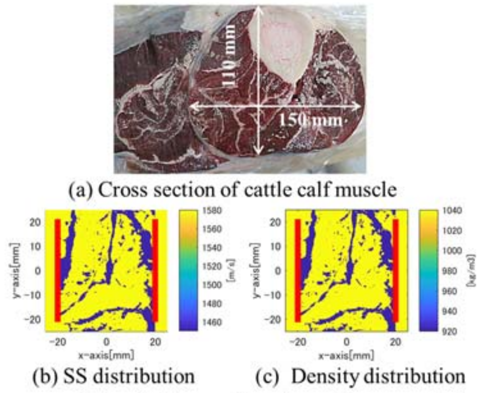

Fig. 1 Example of medium model

2.2 medium models

The medium models (n=25) were made using the image of the cross section of a cattle calf muscle. The image of 50×40 mm^2 was segmented into muscle tissues and EMCL using thresholding technique, Otsu method [3]. The property of muscle and EMCL are shown in **Table 1**.

The example of numerical models was displayed in **Fig. 1**.

	SS [m/s]	Density [kg/m^3]
Muscle	1580	1040
EMCL	1450	920

Table 1 Property of muscle and EMCL

2.3 Average SS estimation methods

Two methods are proposed to estimate SS.

With first method (Method1), average SS (c_{ave}) was obtained by

$$c_{ave} = \frac{1}{n_{tr}} \sum_{i=1}^{n_{tr}} \frac{l_{1,i}}{\min(\boldsymbol{t}_i)} \quad (2)$$

where $l_{1,i}$ is length of the fastest path of i-th element and $\min(\boldsymbol{t}_i)$ is first arrival time from i-th of n_{tr}(=100) elements.

The second method (Method2) is formalized as

$$c_{ave} = \frac{1}{n_{tr}} \sum_{i=1}^{n_{tr}} \frac{l_{2,i}}{\boldsymbol{t}_{i,i}} \quad (3)$$

where $l_{2,i}$ and $\boldsymbol{t}_{i,i}$ is length and arrival time from i-th element to the opposite element respectively.

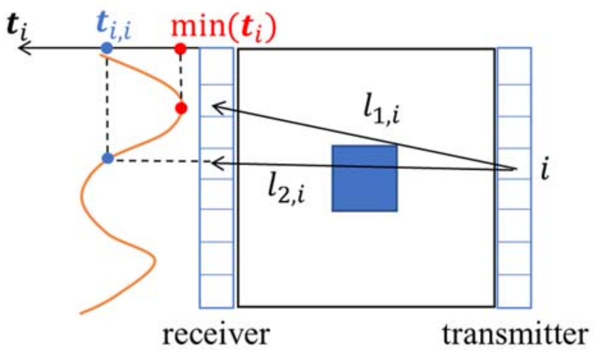

Fig. 2 Illustration of $\min(\boldsymbol{t}_i)$, $\boldsymbol{t}_{i,i}$, $\boldsymbol{l}_{1,i}$, and $\boldsymbol{l}_{2,i}$

3. Results and Discussions

Fig.4 shows the results obtained by Method1 and Method2 respectively. EMCL ratio of each medium model is equal to the area ratio and the black dashed line indicates the average SS calculated from the area ratio as a reference. Correlation coefficients between the average SS and EMCL ratio were -0.89 (Method1) and -0.98 (Method2). Mean square errors between plots of measured average SS versus EMCL ratio and the referential plot were 42.5 (Method1) and 1.0 (Method2).

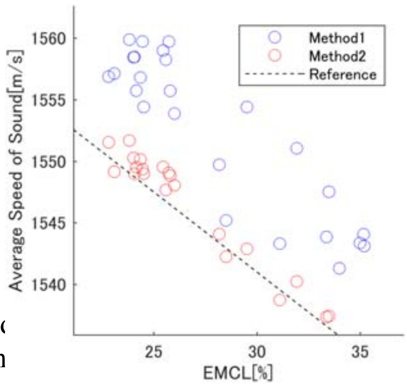

Fig. 3 Method2. Black (obtained from th

The black lines in **Fig.5** indicates an example of fastest paths based on Method1. In Fig.5(b), there is deviation in the endpoints of the paths and the routes appear to avoid EMCLs, whereas in Method2,

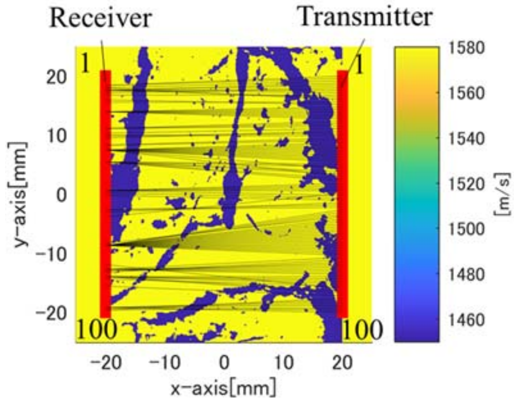

Fig. 5 Example of fastest paths based on Method1.

the routes are fixed and parallel. Therefore, average SS by Method1 tends to be higher and subject to EMCL distribution but EMCL ratio compared to average SS by Method2.

Moreover, it is assumed that linear approximation of the route will cause estimation error of average SS. In method1, the actual detour paths will be longer than assumed linear path, in other words, the estimation error between the average SS by Method1 and referential average SS will increase when actual lengths of fastest paths are employed.

As future work, we intend to experiment with medium models whose size is equal to the size of the human calf and verify which aperture and central frequency of transducer minimize the estimation error. Also, it is needed to determine required accuracy of estimating EMCL ratio to assess the risk of sarcopenia.

4. Conclusions

We considered two methods to estimate EMCL ratio using two different arrival times and paths in simulation. It was turned out that EMCL ratio could be estimated from average SS with an error of approximately 2 %. Experimental results using two linear-arrays of 10 MHz with Verasonics' system will be reported.

References

1. K. F. Petersen and G. I. Shulman: Am. J. Cardiol. **90** (2002) 11-18
2. T. Lang, T. et al.: Osteoporos. Int. **20** (2010) 543-559
3. N. Otsu, IEEE Trans. Syst. Man. Cybern., **9** (1979) 62–66