Measurement of temperature dependence of sound velocity for biological tissues

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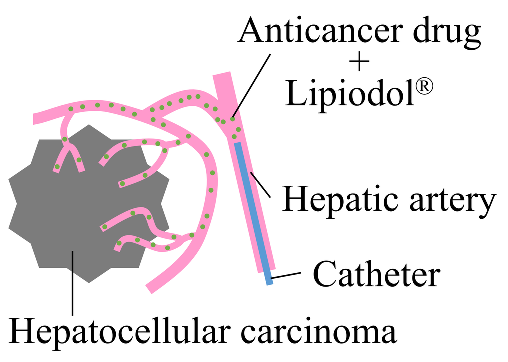
Introduction

Background

TACE (Transcatheter arterial chemoembolization)

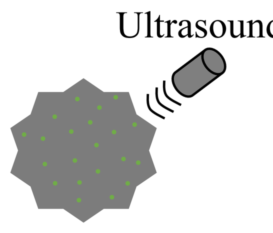
A emulsion of anticancer drug and Lipiodol® is injected into the blood vessels, and an embolic material is injected to clog blood vessels. It is important to monitor the Lipiodol® deposited inside tumors.



Focus on the thermal characteristics of Lipiodol® and the tissue characterization using rate of sound velocity change due to ultrasonic heating[2].

Purpose

Evaluation *in vivo* of densely deposition of Lipiodol® inside tumors by ultrasound.



$$\frac{\partial T}{\partial t} = \frac{\partial c}{\partial t} \cdot \left(\frac{\partial c}{\partial T}\right)^{-1}$$

$\partial T/\partial t$	Rate of temperature rise
$\partial c/\partial t$	Rate of sound velocity change
$\partial c/\partial T$	Temperature coefficient of sound velocity

Increase the temperature of Lipiodol® that deposit inside tumors by ultrasound exposure and measure the rate of sound velocity change due to temperature rise.

Temperature coefficient of sound velocity is required to calculation temperature rise value.

Ultrasound exposure ➡ Sound velocity change ➡ Evaluation of deposition

Aims

- Proposal of the method for measurement of temperature coefficient of sound velocity.
- Measurement of temperature coefficients of sound velocity for Lipiodol® and rat liver cancer.

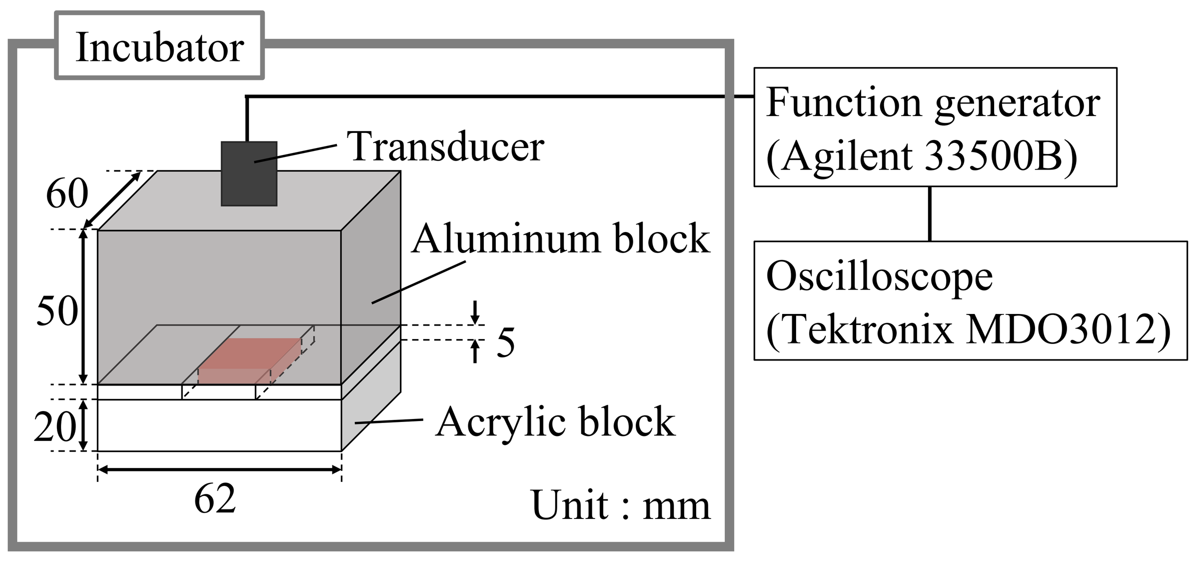
Material and Method

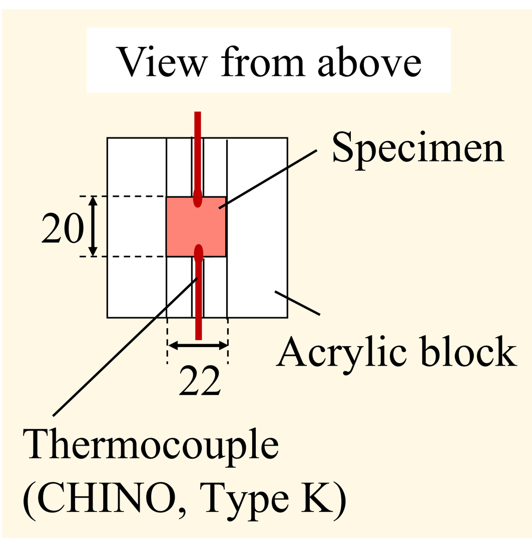
Ultrasonic pulse echo method was used for a measurement of sound velocity.

The sound velocity is calculated from the propagation distance divided by a time of flight of ultrasonic propagation.

- A specimen is thin to uniformly raise the temperature in the specimen.
- Since the change in sound velocity during the temperature rise from room temperature to body temperature is small.

The accuracy of measurement of sound velocity is required.





The thickness and the flatness of a specimen are ensured by the depth of depression and the surface of aluminum and acrylic block.

Sound velocity

A planar transducer was driven by one cycle sinusoidal wave of 5 MHz and 10.0 $V_{p\text{-}p}$. The echo signals were received by the transducer.

$$c = \frac{2d}{t_{sd}}$$

d	Thickness of the specimen
t_{sd}	Propagation time inside the specimen

Temperature

Two thermocouples of 0.5 mm in diameter inserted into the specimen was used.

Measurement condition

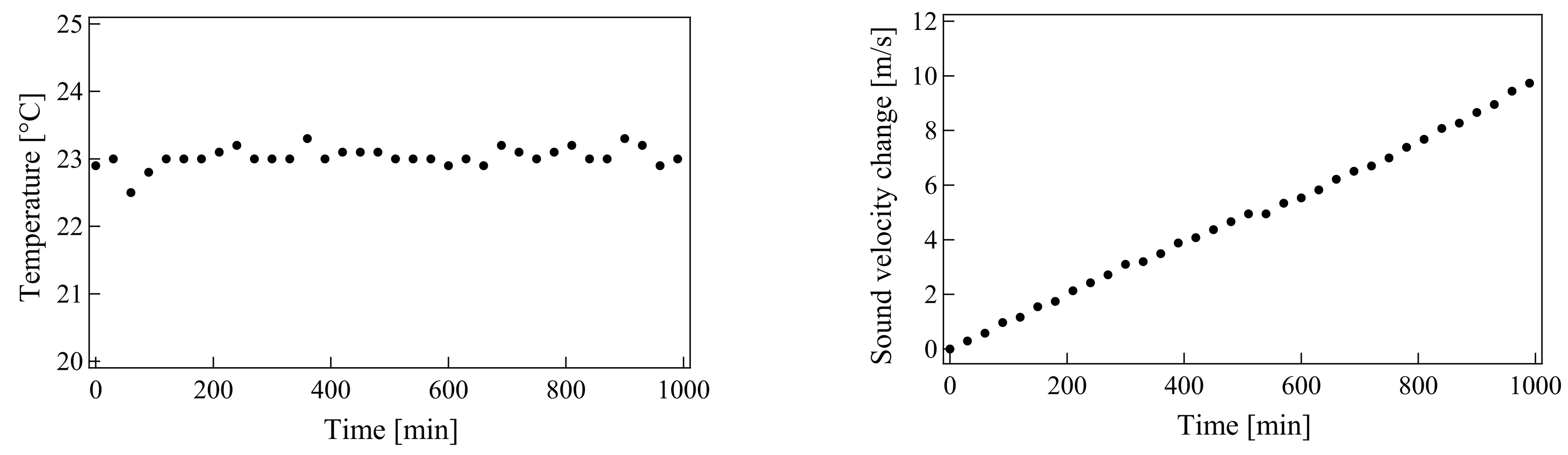
1. Measurement of temporal stability
2. Confirm of the temperature uniformity
3. Calculation of temperature coefficients of sound velocity

Initial temperature	Room temperature
Time interval	10 min
Sampling interval	0.4 ns

Results and Discussion

1. Temporal stability

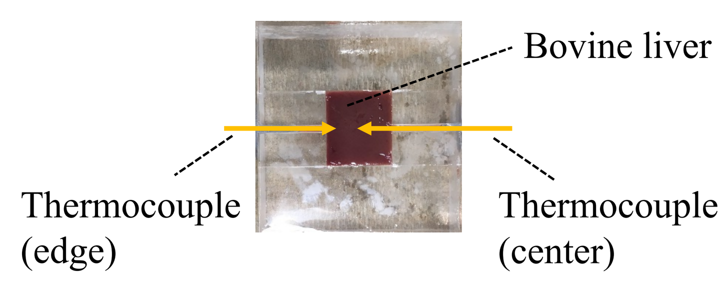
The relation of temperature and sound velocity to elapsed time by neither exposure to ultrasound nor operation of temperature was measured.

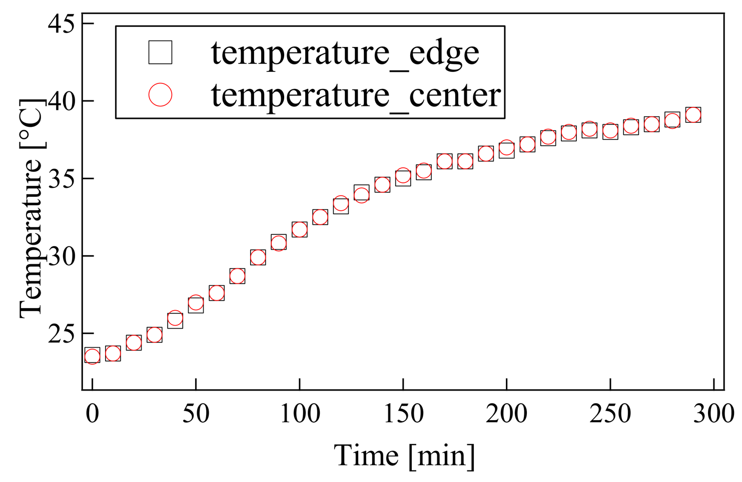


The sound velocity was increased at 1.0 × 10^{-2} m/s a minute. ▶ Measurement time was decided to 180 minutes to preserve the accuracy as less than 1 %.

2. Temperature uniformity

The temperature fluctuation was measured without exposure to ultrasound. Incubator was set at 40 degrees.





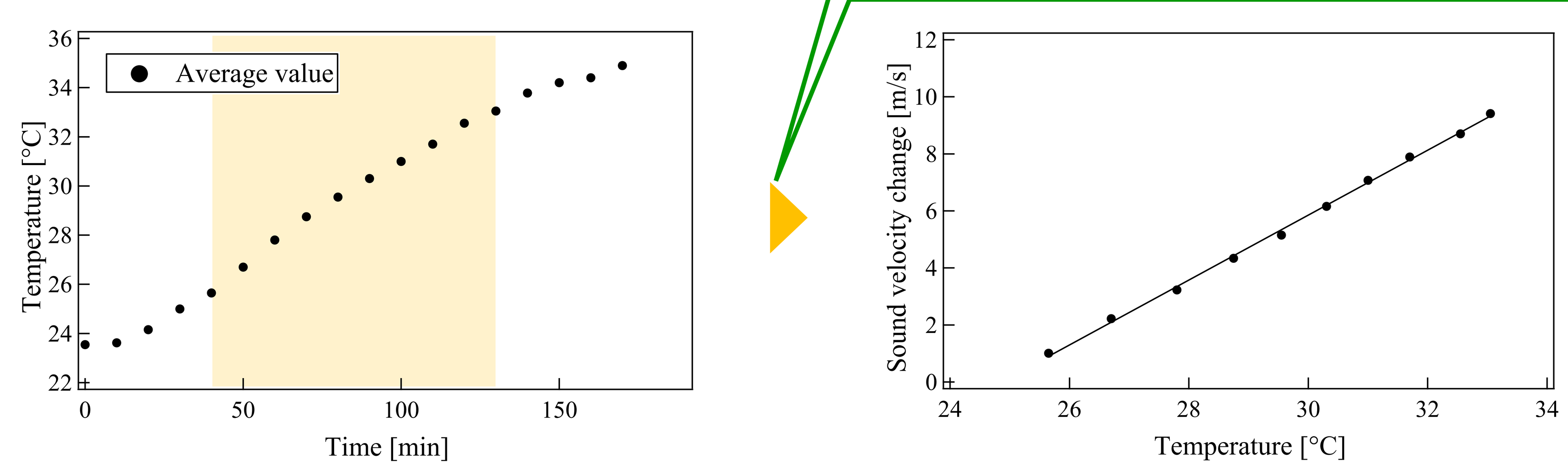
Temperature rise at the edge and the center was agreed within 1 %.

3. Temperature coefficients of sound velocity

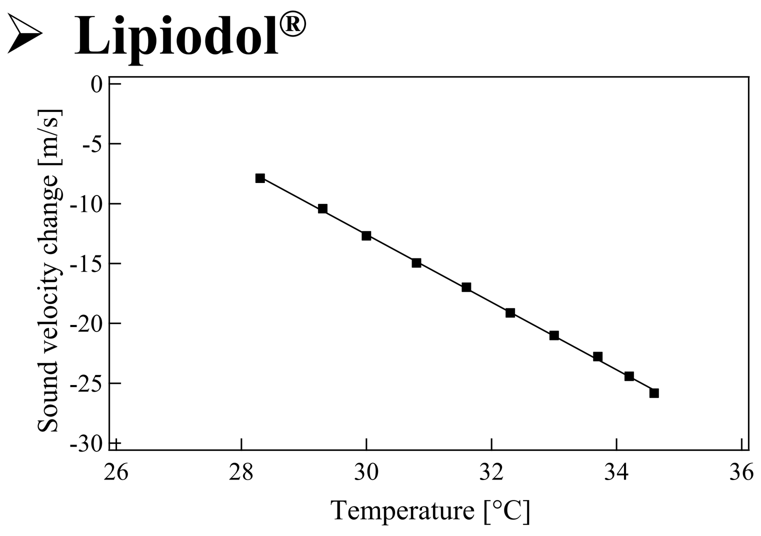
➢ Bovine liver

Incubator temperature	40 °C
Measurement time	180 min

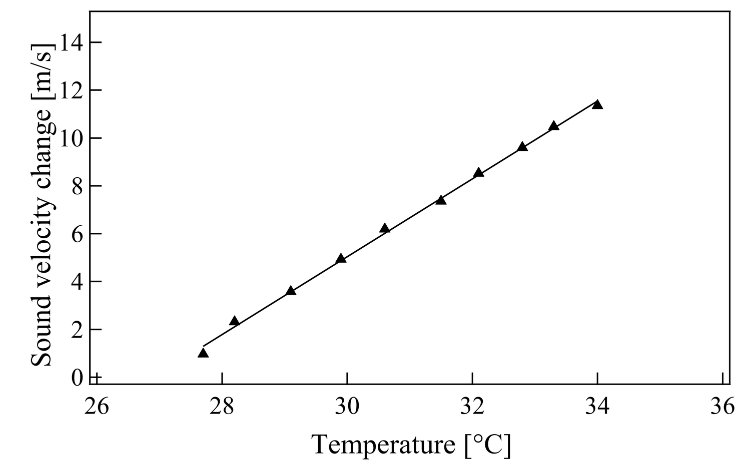
Line fitting in the range where the temperature rise rate was constant



➢ Lipiodol®



➢ Rat liver cancer



Specimen	$\partial c/\partial T$ [m/s/°C]
Bovine liver	1.1
Lipiodol®	-2.8
Rat liver cancer	1.6

Non-fat tissue of bovine liver and rat liver cancer was positive temperature dependence, and Lipiodol® comprising poppy-seed oil was negative temperature dependence.

Conclusion

This study proposed a method to measure the temperature dependence of sound velocity and showed measured values of rat liver cancer and Lipiodol® as 1.6 and -2.8 m/s/°C, respectively. As result, it was suggested to be possible to evaluate the Lipiodol® densely deposition inside tumors.

References

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