Temperature Effect of HIFU with Thermal Dose Estimation

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OUTLINE

• Introduction
• Materials and Methods
• Results
INTRODUCTION
• Cancer is one of the most important health problems of our era.

• General treatment methods for cancer include:
  – Chemotherapy,
  – Radiation Therapy,
  – Surgical Operation

High Intensity Focused Ultrasound (HIFU)
HIFU=High-Intensity Focused Ultrasound

• In High Intensity Focused Ultrasound (HIFU) application, the target tissue is exposed to burning temperatures.
The acoustic energy density at the focal point is between 1,000 and 10,000 W/cm². The tissue temperature can reach very high temperatures of more than 80 °C in a very short time. While the maximum temperature increase is observed at the focal point, the temperature effect is almost negligible in a few mm distance.
Thermal Dose Calculations

Sapareto and Dewey’s formula for thermal dose

\[ TD = EM_{43} = \sum_{t=0}^{t=\text{final}} R^{(43-T)} \Delta t \]

In this equation, \( T \) represents the mean value of the temperature applied during the time \( \Delta t \), and \( R \) denotes a constant number equal to 0.25 for \( T < 43 \, ^\circ C \) and 0.5 for \( T > 43 \, ^\circ C \).

| Desired TD (min) | Application time (s) | Application Temp. (°C) | Input Voltages (mV) | TD Value |
|------------------|-----------------------|------------------------|---------------------|-----------|
| 60               |                       | 50                     | 76                  | 64 ± 4 (TD 60 min) |
| 120              | 30 s                   | 51                     | 77                  | 128 ± 9 (TD 120 min) |
| 240              |                       | 52                     | 78                  | 253 ± 13 (TD 240 min) |
MATERIALS AND METHODS
Application System

- User Interface
- 3D Motion System
- Water container
- Thermocouples
- HIFU
- Temperature measurement module
- Impedance matching unit
- Signal generator
- Power amplifier
Temperature Characterization System

1) T Type Ultrafine thermocouples (Physitemp),
2) Analog input module (IOTech DBK83),
3) PCI Data Acq card (IOTech Daqboard 2000),
4) PC
Thermocouples

- Physitemp Ultra thin IT Series Flexible Micro prob IT-24P
- Poliester insulated and poliurethan coated
- Maximum outer diameter 0,23 mm and isolated tip 0,13 mm x 0,07 mm
- Fast responding time (4 ms).
Temperature Characretizations & Application System
RESULTS
application time is selected as 30 seconds for thermal dose values of 60, 120 and 240 equivalent minutes (units are indicated as min), the temperature values that should be applied are calculated as in table

| Desired TD (min) | Application Time (s) | Application Temperature (°C) |
|------------------|-----------------------|-----------------------------|
| 60               | 30 s                  | 50                          |
| 120              |                       | 51                          |
| 240              |                       | 52                          |

$$TD = EM_{43} = \sum_{t=0}^{t=final} R^{(43-t)} \Delta t$$
The average of the temperature values obtained at the focal point is 50 °C. An increase of 1-1.5 °C occurred in the neighboring well.
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• Temperature effect of HIFU was determined by the ultrasonic thermal dose approach suggested by Sapareto and Dewey

• For this purpose, for 30 seconds of application times, the temperature values which should be applied to reach the desired thermal doses were calculated

• Input voltage values that should be applied to the HIFU in order to reach the desired temperature values at certain application times were determined by repeated experiments

• Determination of dose has critical importance in high intensity focused ultrasound applications especially since the uncontrolled application of ultrasound may result the cauterization of healthy tissue.

• The dose concept will give a change for quantitative compare of the applications realized by different operators at different times and environments.
ACKNOWLEDGMENT

• This study was supported by Marmara University Scientific Research Projects Commission with project number SAG-C-DRP-081117-0615.

• We wish to thank our trainees, Hakan Gürbüz and Selçuk Altınay for their contributions.
Thank You!

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