Liver Phantom for Microwave Ablation Device Testing

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Microwave Ablation

- Treatment for many abdominal cancers
- Kills tumor cells by rapidly heating
- Many advantages compared to other medical treatments[1]
- Phantom needed to test

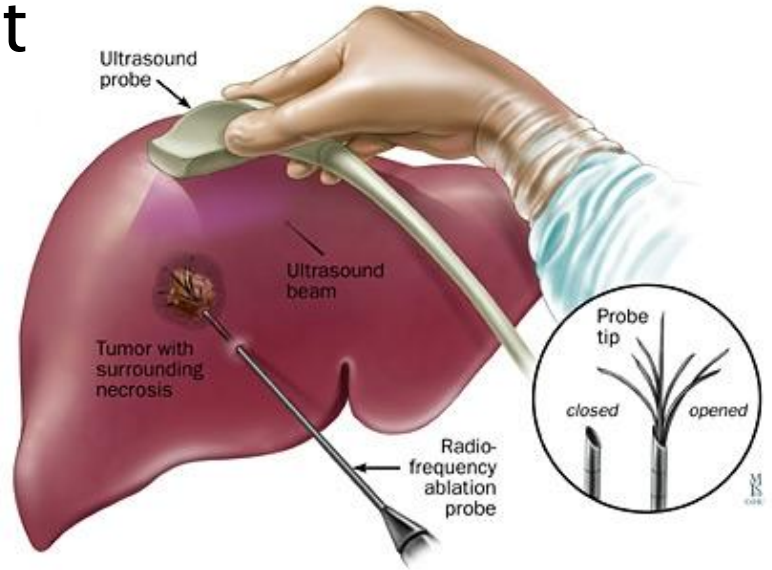

Figure 1: Microwave ablation procedure[2]

Problem Statement

- Design a phantom liver to test microwave ablation devices
- Requirements:
  - Reproducible
  - Homogenous
  - Ideally transparent
  - Indicates Ablation Zone
  - Cost effective
  - Similar to liver

Liver Properties at 2.45 GHz[3]

- Dielectric Constant: 43.3
- Electrical Conductivity: 1.68 S/m
- Wavelength: 1.8 cm
- Thermal Conductivity: 0.564 W/m·K
- Density: 1,050 kg/m^3
- Perfusion Rate: 1,000 mL/min·kg

Current Testing Methods

- Liver tissues[3]

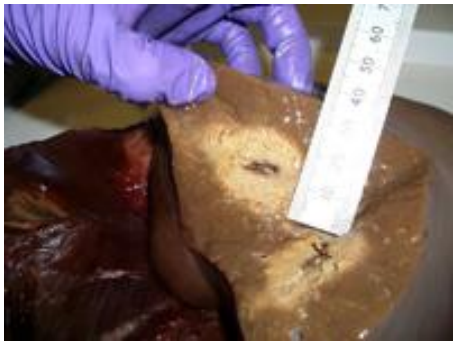

Figure 2: ablation zones in liver tissue[9]

- Polyacrylamide hydrogel with BSA[5,6,7]

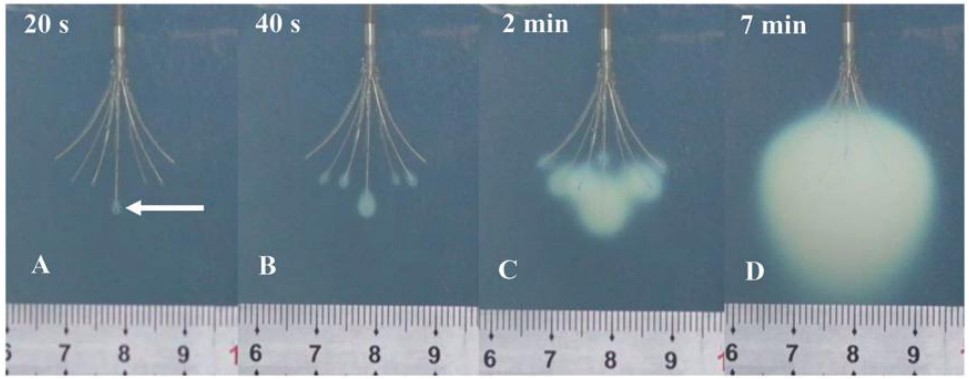

Figure 3: ablation zones in PAG[7]

Base Gel

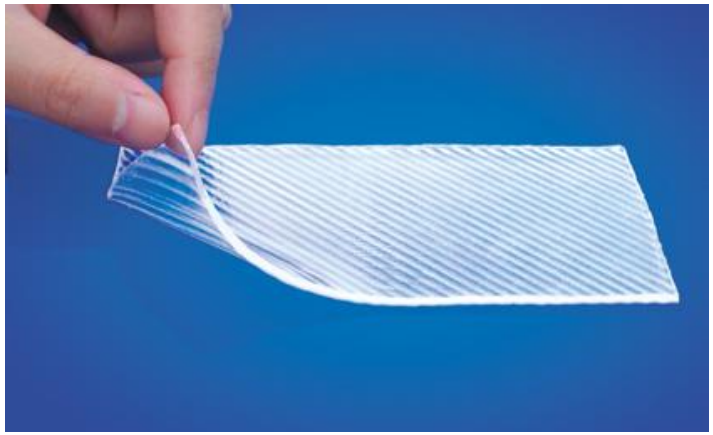

Figure 4: Dielectric Silicone Gel[10]

Figure 5: Sodium Alginate[11]

Figure 6: Polyvinyl Alcohol (PVA)[12]

Figure 7: Polyacrylamide Gel[13]

Weight	Design Aspects	Dielectric Silicon Gel	Polyvinyl Alcohol	Sodium Alginate	Polyacryl-amide Gel
0.2	Melting Point	8	10	9	4
0.2	Transparency	9	8	0	5
0.2	Dielectric Properties	10	6	5	10
0.15	Cost	4	8	8	5
0.05	Safety	9	9	8	3
0.05	Shelf Life	8	4	4	6
0.15	Assembly Simplicity	8	7	7	4
1	-	8.05	7.7	5.65	5.6

Table 1: Base Gel Design Matrix

Thermochromic Dyes
(color change in response to temperature[14])

Permanent		Reversible	
Advantage: Cheaper substitute for albumin protein	**Disadvantage:** Very sensitive to environment	**Advantage:** Reversible color change allows long term use	**Disadvantage:** Extremely expensive ($12,500)

Table 2: Comparison of Thermochromic Dyes

Protein Indicators

Albumin (Bovine Hormone)		Ovalbumin (Egg Whites)	
Advantage: Denatures at 50°C; successfully implemented	**Disadvantage:** Relatively expensive	**Advantage:** Cheap; Easy to test	**Disadvantage:** Denatures around 80°C

Table 3: Comparison of Protein Indicators

Weight	Design Aspects	Albumin (Bovine Protein)	Ovalbumin (Egg White)	One Time Use Dye	Reversible Thermochromic Dye
-	Reversible	No	No	No	Yes
.20	Accuracy	10	6	8	8
.20	Cost	3	9	7	1
.10	Preparation	9	7	9	9
.25	Effectiveness	10	10	7	7
.15	Dielectric Properties	8	8	3	3
.05	Safety	10	10	6	6
.05	Shelf Life	7	7	10	10
1	-	8.05	8.25	6.9	5.3

Table 4: Indicators Design Matrix

Final Design

- Base gel: Dow Corning Dielectric Silicon Gel
- Indicator: Ovalbumin (Egg White)

Figure 8: Silicon Gel Sheet[14]

Figure 9: Eggs (i.e. ovalbumin protein)[15]

Design Alternative

- Thermal Camera
  - Advantages
    - readily available
    - reusable
  - Disadvantages
    - Limited by detection depth
    - Expensive (up to $5000)

Figure 10: Nikon Infrared Thermal Camera[16]

Future Work

- Test current design for:
  - Accuracy and effectiveness
  - Dielectric properties
  - Shelf Life and waste
- Possible alternatives:
  - HallCrest Thermochromic Permanent Dye
  - Whey Protein
  - Polyvinyl Alcohol
- Continue research

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References

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Questions?