

Modeling Thermography of the Tumorous Human Breast: From Forward Problem to Inverse Problem Solving

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Background
 • Quantitative modeling aims to discover the causal relationships between the breast surface temperature and the underlying physiological and pathological factors.
 • A combination of physics models, (i) capture the internal factors, (ii) reconstruct the forward modeling, from the known parameters, and (iii) solve the inverse problem.



Figure 1. Diagram of the breast thermography modeling.

Methods
 • **Forward thermal elastic modeling:** study the thermal effects of breast deformations.
 • **Inverse thermal modeling:** study the changes in cold stress and thermal recovery.
 • **Real modeling:** Real breast thermography to estimate the tumor thermal properties.



• **Forward thermal elastic thermography modeling based on thermal and breast methods (FBEM)** to find effect of gravity on the thermogram.



Figure 3. Thermography system modeling. Estimates the tumor properties of the tumor breast tissues for a given thermogram. Tumor-induced thermal contrast was obtained using the nonlinear optimization algorithm.

Results

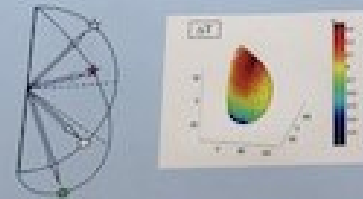


Figure 4. Gravity-induced surface temperature alterations (ST) slightly (-0.3 °C) increased and decreased, respectively, in the upper and lower halves of the breast surface due to changes of the distances from the breast surface to the chest wall.



Figure 5. Tumor-induced temperature alterations at breast upper (left), and the lower (right) halves with tumor size and depth (right). Surface temperature alterations in response to deeper tumor size (2 days) are large.



Figure 6. Dynamic modeling of tumor-induced surface temperature alteration rate (TSTAR) in cold stress and thermal recovery procedures. Tumor-induced contrast larger (top) and reduced (negative) global mean-contrast in TSTAR states.

$$TSTAR = \frac{1}{A} \int_{A} \Delta T_{\text{surface}} \cdot \text{area}(\Delta T_{\text{surface}}) \cdot dA$$

Definition: Tumor-induced surface temperature alteration

References:
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Figure 7. Real breast surface thermogram for tumor-containing extensive vascular blood perfusion and distributed around the tumor (top center). Contrast were the thermogram contrast larger (bottom) than the tumor. Left: Model parameters including heat generation (left) and right: heat perfusion thermal conductivity (right) scale.



Figure 8. Correlation coefficient between estimated and real tumor-induced thermal contrast in breast surface as a function of tumor depth for two sizes, after applying the inverse thermography modeling tool, the estimation of the tumor-induced thermal contrast was improved significantly, especially for deeper and smaller tumors.

Future Work and Conclusion

- Development of inverse modeling by dynamic thermography.
- Validation with in vivo thermogram data.
- Development of patient-recognition-based tumor detection system.
- Conclusion: We expect the proposed new methods to provide a viable foundation for real greater specificity and precision in thermogram diagnosis and treatment of breast cancer.