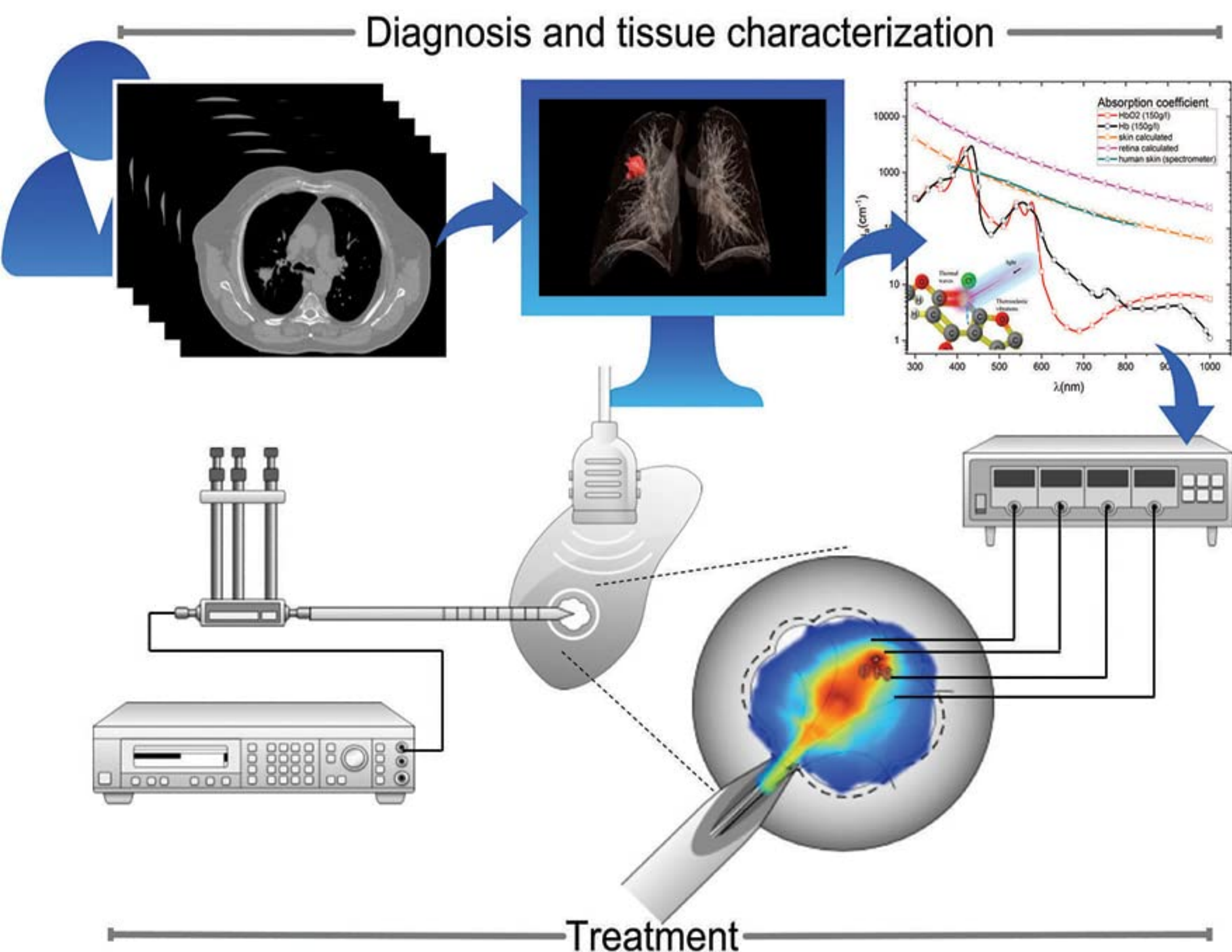


DIAGNOSIS AND TREATMENT OF CANCER USING THERMAL THERAPIES

MINIMAL AND NON-INVASIVE TECHNIQUES

Citlalli J. Trujillo-Romero *and* Dora-Luz Flores (eds.)



First edition published 2024
by CRC Press
2385 NW Executive Center Drive, Suite 320, Boca Raton FL 33431

and by CRC Press
4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

© 2024 Citlalli J. Trujillo-Romero and Dora-Luz Flores

CRC Press is an imprint of Taylor & Francis Group, LLC

Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, access www.copyright.com or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. For works that are not available on CCC please contact mpkbookspermissions@tandf.co.uk

Trademark notice: Product or corporate names may be trademarks or registered trademarks and are used only for identification and explanation without intent to infringe.

Library of Congress Cataloging-in-Publication Data (applied for)

ISBN: 978-1-032-37936-4 (hbk)

ISBN: 978-1-032-37937-1 (pbk)

ISBN: 978-1-003-34266-3 (ebk)

DOI: 10.1201/9781003342663

Typeset in Times New Roman
by Radiant Productions

Contents

<i>Dedication</i>	iii
<i>Preface</i>	iv
1. Main Problems in Cancer Diagnosis and Treatments	1
1.1 Introduction	1
1.2 Main challenges in cancer detection	2
1.2.1 Standard methods for cancer detection	2
1.2.2 Recent methods for cancer detection and diagnosis	3
1.3 Main challenges in cancer treatments	9
1.3.1 Main cancer treatments vs thermotherapies	9
1.4 Main challenges in the clinical application of new treatments	12
Reference list	17
2. Bioimpedance and Cancer Detection	21
2.1 Bioimpedance basics	22
2.1.1 Electrical properties of the cells	22
2.1.2 Electrical properties of malignant tissues	24
2.1.3 Electrodes and probe	26
2.1.4 Instrumentation	28
2.2 Bioimpedance applications	30
2.2.1 Circulating tumoral cells detection (CTC)	30
2.2.2 Breast cancer detection by EIS	32
2.2.3 Breast cancer detection by MIS	33
Reference list	37
3. Thermal Images: Towards Cancer Detection	41
3.1 Introduction	41
3.2 Thermal images principles and applications	42
3.2.1 Infrared sensors, readings, and data arrays	44
3.2.2 Thermal camera characterization	45

3.2.3	Thermal imaging in medicine	48
3.2.4	Correlation between physiology and thermal images	50
3.2.5	Thermal data and image processing	50
3.3	Breast cancer thermal imaging	52
3.3.1	Device criteria	53
3.3.2	Procedures for routine tests and preparing patients	54
3.3.3	Image analysis and interpretation	56
3.3.4	Risk and prognostic diagnosis	57
3.3.5	A comparison of thermography and other medical techniques	58
3.4	Current advances and perspectives	58
3.5	Conclusions	60
	Reference list	61
4.	Artificial Intelligence and Cancer Detection	64
4.1	Introduction: Artificial Intelligence and its clinical relevance	65
4.2	Data acquisition	66
4.2.1	Clinical data	66
4.2.2	Cancer medical imaging	67
4.3	Preprocessing	67
4.4	Processing	70
4.4.1	Feature extraction and selection methods	70
4.4.2	Classification methods	71
4.4.3	Segmentation methods	72
4.5	Visualization and presentation	75
4.6	Validation and assessment of results	75
4.7	Conclusion	76
	Reference list	79
5.	Hyperspectral Imaging for Cancer Applications	81
5.1	Introduction	82
5.2	HSI Instrumentation	84
5.3	HSI analysis algorithms	86
5.4	HSI applications in cancer detection	87
5.4.1	Skin cancer applications	88
5.4.2	Brain cancer applications	90
5.4.3	Gastrointestinal cancer applications	92
5.4.4	Head and neck cancer applications	93
5.4.5	Histological samples in cancer applications	94
5.5	Conclusions	95
	Reference list	96

6. Oral Cancer Detection by Multi-Spectral Fluorescence Lifetime Imaging Microscopy (m-FLIM) and Linear Unmixing	102
6.1 Introduction	103
6.2 Non-invasive mFLIM techniques	104
6.3 m-FLIM optical instrumentation	107
6.4 m-FLIM data processing and fluorescence lifetime estimation	108
6.5 Linear unmixing	110
6.6 EBEAE analysis of m-FLIM datasets for oral cancer detection	111
6.7 Conclusions	113
Reference list	115
7. Thermotherapies based on Microwaves (MW) and Radiofrequencies (RF)	118
7.1 Introduction	119
7.2 Thermotherapies classification	119
7.2.1 Physical principles of Microwaves (MW) and Radiofrequency (RF)	120
7.2.2 RF and MW applicators	122
7.3 Clinical applications	124
7.3.1 Requirements for the clinical application of thermal therapies	124
7.3.2 Main application and features according to the body region	128
7.3.3 Treatment quality and clinical studies	128
7.4 Computational modeling and treatment planning	132
7.4.1 Electromagnetic models (MW and RF)	132
7.3.2 Thermal models	134
7.4.3 Treatment planning	135
7.5 Conclusion	137
Reference list	138
8. Thermotherapies based on Ultrasound	143
8.1 Introduction	144
8.2 Physical principles of ultrasound	144
8.2.1 Ultrasonic sources	144
8.2.2 Acoustic propagation modeling	147
8.2.3 Acoustic field characterization	150
8.2.4 Tissue mimicking-material for ultrasonic source validation	150

8.3	Clinical applications	152
8.3.1	Requirements for the clinical applications	152
8.3.2	Extracorporeal applications	154
8.3.3	Intracavitary and interstitial applications	155
8.3.4	Combining therapies and clinical studies	156
	Reference list	159
9.	Biological Effects of Thermal Therapies (EM Waves and Mechanical Waves)	164
9.1	Introduction	165
9.2	Thermal effects	165
9.2.1	Biological aspects	166
9.2.2	Biological tissues and temperature increase	167
9.2.3	Tissue injury	172
9.3	Non-thermal effects	173
9.4	Exposure guidelines for electromagnetic radiation	176
9.5	Conclusion	178
	Reference list	179
10.	Photothermal Techniques in Cancer Detection-Photoacoustic Imaging	184
10.1	Introduction	184
10.2	The photoacoustic techniques	185
10.3	Ultrasound resolution	188
10.4	Photoacoustic time-resolved sensitivity	190
10.5	Photoacoustic imaging	190
10.6	Photoacoustic in bone analysis	191
10.7	Cancer detection zones	192
10.7.1	Melanoma	192
10.7.2	Breast	193
10.7.3	Ovarian	194
10.7.4	Prostate	195
10.8	Final words	195
	Reference list	196
11.	Tissue Characterization for Microwave and Ultrasonic Applications	200
11.1	Introduction	201
11.2	Tissue characterization by using open-ended coaxial probes	201
11.2.1	Dielectric properties: relative permittivity and electrical conductivity	203

11.3	Temperature dependence of tissue properties	206
11.3.1	Electrical and thermal conductivity	207
11.3.2	Blood perfusion	209
11.3.3	Speed of sound	213
11.4	Tissue characterization by acoustic propagation measurements	214
11.4.1	Speed of sound	214
11.4.2	Attenuation	215
	Reference list	216
12.	Nanotheranostics in Cancer	222
12.1	Introduction	223
12.2	Fundamentals of nanomaterials	223
12.2.1	Nanomaterials classification	223
12.2.2	Nanoparticles in cancer	225
12.2.3	Mechanisms for diagnostics and therapy	227
12.3	Multifunctional nanomaterials	229
12.3.1	Functionalization	229
12.3.2	Characterization of functionalized nanoparticles	232
12.4	Applications	232
	Reference list	241
13.	Magneto Hyperthermia	244
13.1	Introduction	244
13.2	Clinical basis of induced hyperthermia	246
13.3	Mechanisms of magnetic nanomaterials-based hyperthermia	248
13.4	Factors influencing the design of formulations for magneto hyperthermia-based therapy	250
13.4.1	Chemical composition	250
13.4.2	Method of synthesis	252
13.4.3	Surface modification	253
13.5	Performance of nanomedicine systems developed for magnetic hyperthermia therapy, clinical phase studies	256
	Reference list	259
	<i>Index</i>	267

CHAPTER 9

Biological Effects of Thermal Therapies (EM Waves and Mechanical Waves)

Christian Chapa González,^{1,} Citlalli J. Trujillo-Romero² and Raquel Martínez-Valdez³*

¹Autonomous University of Ciudad Juarez. Av. del Charro 450 nte. Ciudad Juárez, Chihuahua, México. C.P. 32310

²Division of Medical Engineering Research, National Institute of Rehabilitation LGII. Calz. Mexico Xochimilco No. 289, Col. Arenal de Guadalupe, Mexico City, 14389, Mexico

³Biomedical Engineering Program, Polytechnic University of Chiapas. Carretera Tuxtla Gutierrez Portillo Zaragoza km 21+500, Col. Las Brisas, Suchiapa, Chiapas, 29150, Mexico

Emails: cjtrujillo@inr.gob.mx; rmartinez@ib.upchiapas.edu.mx

* Corresponding author: christian.chapa@uacj.mx

Thermal therapies based on the exposition of the tumor to electromagnetic (EM) fields or ultrasonic energy produce several thermal and biological effects. Due to thermal therapies are based on the application of non-ionizing radiations, heating tissue is the expected outcome. However, it is required to increase the tumor temperature up to therapeutic levels (hyperthermia or thermal ablation) without affecting the surrounding healthy tissue. Tissue thermal injury will always depend on the energy/powers applied as well as the reached temperature and treatment time. The temperature increase produces several biological effects not only on the healthy tissue but also on the tumor. Physiological changes such as blood perfusion, vascular permeability, and metabolism are modified by the temperature increase. These conditions, together with the rates of cell survival due to heat, tumor conditions, and tissue thermotolerance are the main reasons for thermotherapy success.

9.1