

*Volume 873  
April 20, 1999*

**ELECTRICAL BIOIMPEDANCE METHODS:  
APPLICATIONS TO MEDICINE AND  
BIOTECHNOLOGY<sup>a</sup>**

*Editors and Conference Organizers*

PERE J. RIU, JAVIER ROSELL, RAMON BRAGÓS, AND ÓSCAR CASAS

---

**CONTENTS**

---

Preface. By PERE J. RIU .....	xi
The Practical Success of Impedance Techniques from an Historical Perspective. By HERMAN P. SCHWAN .....	1
<b>Part I. Organ State and Tumors</b>	
Monitoring Temperature-Induced Changes in Tissue during Hyperthermia by Impedance Methods. By EBERHARD GERSING .....	13
Application of Linear Circuit Models to Impedance Spectra in Irradiated Muscle. By K. SUNSHINE OSTERMAN, KEITH D. PAULSEN, and P. JACK HOOPES .....	21
A Review of Parameters for the Bioelectrical Characterization of Breast Tissue. By JACQUES JOSSINET and MICHEL SCHMITT .....	30
<i>Ex Vivo</i> Discrimination between Normal and Pathological Tissues in Human Breast Surgical Biopsies Using Bioimpedance Spectroscopy. By N. CHAUVEAU, L. HAMZAOU, P. ROCHAIX, B. RIGAUD, J. J. VOIGT, and J. P. MORUCCI. ....	42
<i>In Vivo</i> and <i>In Situ</i> Ischemic Tissue Characterization Using Electrical Impedance Spectroscopy. By O. CASAS, R. BRAGÓS, P. J. RIU, J. ROSELL, M. TRESÀNCHEZ, M. WARREN, A. RODRIGUEZ-SINOVAS, A. CARREÑO, and J. CINCA .....	51

<sup>a</sup>This volume is the result of the Tenth International Conference on Electrical Bio-Impedance, which was sponsored by the International Committee for Promotion of Research in Bio-Impedance and held on April 5-9, 1998, in Barcelona, Spain.

Dielectric Properties of Skeletal Muscle during Ischemia in the Frequency Range from 50 Hz to 200 MHz. <i>By</i> M. SCHÄFER, H-J. KIRLUM, C. SCHLEGEL, and M. M. GEBHARD . . . . .	59
--	----

Quantitative Analysis of Impedance Spectra of Organs during Ischemia. <i>By</i> MIHAELA GHEORGHIU, EBERHARD GERSING, and EUGEN GHEORGHIU. . . . .	65
---	----

## Part II. Body Composition

Requirements for Clinical Use of Bioelectrical Impedance Analysis (BIA). <i>By</i> HENRY C. LUKASKI . . . . .	72
---	----

Study of the Relation between Fluid Distribution Change in Tissue and Impedance Change during Hemodialysis by Frequency Characteristics of the Flowing Blood. <i>By</i> K. SAKAMOTO, R. SUNAGA, K. NAKAMURA, Y. SATO, M. FUJII, H. KANAI, T. TSUCHIDA, A. UENO, N. KANAI, and K. HASEGAWA . . . . .	77
---	----

Bioimpedance: Is It a Predictor of True Water Volume? <i>By</i> B. J. THOMAS, B. H. CORNISH, L. C. WARD, and A. JACOBS . . . . .	89
--	----

Fat-Free Mass Qualitative Assessment with Bioelectric Impedance Analysis (BIA). <i>By</i> T. TALLURI, R. J. LIETDKE, A. EVANGELISTI, J. TALLURI, and G. MAGGIA . . . . .	94
--	----

Estimation of Extracellular Volume by a Two-Frequency Measurement. <i>By</i> H. G. GOOVAERTS, TH. J. C. FAES, G. W. DE VALK-DE ROO, M. TEN BOLSCHER, J. C. NETELENBOSCH, W. J. F. VAN DER VIJGH, and R. M. HEETHAAR . . . . .	99
---	----

The RXc Graph in Evaluating and Monitoring Fluid Balance in Patients with Liver Cirrhosis. <i>By</i> FRANCESCO WILLIAM GUGLIELMI, TECLA MASTRONUZZI, LORENA PIETRINI, ALBA PANARESE, CARMINE PANELLA, and ANTONIO FRANCAVILLA. . . . .	105
--	-----

## Part III. Cardiovascular System

Measurement of Leg Arterial Compliance of Normal Subjects and Diabetics Using Impedance Plethysmography. <i>By</i> DEOK WON KIM and SOO CHAN KIM . . . . .	112
--	-----

A Meta-analysis of Published Studies Concerning the Validity of Thoracic Impedance Cardiography. <i>By</i> E. RAAJMAKERS, TH. J. C. FAES, R. J. P. M. SCHOLTEN, H. G. GOOVAERTS, and R. M. HEETHAAR . . . . .	121
---	-----

Towards a Theoretical Understanding of Stroke Volume Estimation with Impedance Cardiography. <i>By</i> TH. J. C. FAES, E. RAAJMAKERS, J. H. MEIJER, H. G. GOOVAERTS, and R. M. HEETHAAR . . . . .	128
---	-----

Lead Field Theoretical Approach in Bioimpedance Measurements: Towards More Controlled Measurement Sensitivity. <i>By</i> PASI K. KAUPPINEN, JARI A. HYTTINEN, TIIT KÖÖBI, and JAAKKO MALMIVUO . . . . .	135
---	-----

Impedance Stroke Volume Compared with Dye and Electromagnetic Flowmeter Values during Drug-Induced Inotropic and Vascular Changes in Dogs. By ROBERT P. PATTERSON, DAVID A. WITSOE, and ARTHUR FROM . . . . .	143
A Comparison of Bioimpedance and Echocardiography in Measuring Systolic Heart Function in Cardiac Patients. By H. J. JURN KERKKAMP and ROB M. HEETHAAR. . . . .	149
Thoracic Bioimpedance as a Basis for Pacing Control. By MART MIN, TOOMAS PARVE, and ANDRES KINK . . . . .	155
Evaluation of Systolic Performance by Automated Impedance Cardiography. By ARMIN W. SCHERHAG, JANA STASTNY, STEFAN PFLEGER, WOLFRAM VOELKER, and DIETER L. HEENE. . . . .	167
Impact of Cardiovascular Reactions Using the Impedance Cardiography Method in Borderline Hypertension. By T. NAWARYCZ, L. OSTROWSKA-NAWARYCZ, and J. KACZMAREK . . . . .	174
Stroke Volume Variability—Cardiovascular Response to Orthostatic Maneuver in Patients with Coronary Artery Diseases. By JANUSZ SIEBERT, JERZY WTOREK, and JAN ROGOWSKI. . . . .	182
Assessment of Left Ventricular Systolic Function and Diastolic Time Intervals by the Bioimpedance Polyrheocardiographic System. By MICHAEL ZUBAREV, ANDREY DUMLER, VLADIMIR SHUTOV, and NICOLAY POPOV . . . . .	191
<b>Part IV. Skin Impedance</b>	
<i>In Vivo</i> ac Impedance Spectroscopy of Human Skin: Theory and Problems in Monitoring of Passive Percutaneous Drug Delivery. By A. H. LACKERMEIER, E. T. MCADAMS, G. P. MOSS, and A. D. WOOLFSON . . . . .	197
On Assessment of Skin Reactivity Using Electrical Impedance. By MIRUNA NYRÉN, LENA HAGSTRÖMER, and LENNART EMTESTAM. . . . .	214
Electrical Bioimpedance Related to Structural Differences and Reactions in Skin and Oral Mucosa. By INGRID NICANDER and STIG OLLMAR . . . . .	221
Stress Action on Biological Tissue and Tissue Models Detected by the <i>Py</i> Value. By FRITZ PLIQUETT and UWE PLIQUETT. . . . .	227
<b>Part V. Cells and Cultures</b>	
From Concept to Market in Industrial Impedance Applications. By CHRISTOPHER DAVEY, ROBERT TODD, and JOHN BARRETT . . . . .	239
Orientation and Deformation of Erythrocytes in Flowing Blood. By MAMIKO FUJII, KENGO NAKAJIMA, KATSUYUKI SAKAMOTO, and HIROSHI KANAI . . . . .	245

On the Limits of Ellipsoidal Models when Analyzing Dielectric Behavior of Living Cells: Emphasis on Red Blood Cells. <i>By</i> EUGEN GHEORGHIU . . . . .	262
Electrical Impedance Tomography Study of Biological Processes in a Single Cell. <i>By</i> TERRY C. CHILCOTT and HANS G. L. COSTER . . . . .	269
New Light-Scattering and Field-Trapping Methods Access the Internal Electric Structure of Submicron Particles, like Influenza Viruses. <i>By</i> JAN GIMSA . . . . .	287
Biomass Monitoring Using Impedance Spectroscopy. <i>By</i> R. BRAGÓS, X. GÁMEZ, J. CAIRÓ, P. J. RIU, and F. GÒDIA . . . . .	299

## **Part VI. Instrumentation**

Improvement of a Front End for Bioimpedance Spectroscopy. <i>By</i> DAVID YÉLAMOS, ÓSCAR CASAS, RAMON BRAGÓS, and JAVIER ROSELL. . . . .	306
Virtual Biopsies in Barrett's Esophagus Using an Impedance Probe. <i>By</i> C. A. GONZÁLEZ-CORREA, B. H. BROWN, R. H. SMALLWOOD, N. KALIA, C. J. STODDARD, T. J. STEPHENSON, S. J. HAGGIE, D. N. SLATER, and K. D. BARDHAN . . . . .	313
Inductively Coupled Wideband Transceiver for Bioimpedance Spectroscopy (IBIS). <i>By</i> HERMANN SCHARFETTER, WOLFGANG NINAUS, BERNHARD PUSWALD, GALIDIA I. PETROVA, DIMITER KOVACHEV, and HELMUT HUTTEN . . . . .	322
Magnetic Induction Tomography: A Measurement System for Biological Tissues. <i>By</i> H. GRIFFITHS, W. R. STEWART, and W. GOUGH . . . . .	335
Progress in Realization of Magnetic Induction Tomography. <i>By</i> ALEXANDER V. KORJENEVSKY and VLADIMIR A. CHEREPENIN . . . . .	346
Magnetic Impedance Tomography. <i>By</i> J. C. TOZER, R. H. IRELAND, D. C. BARBER, and A. T. BAKER . . . . .	353

## **Part VII. Electrical Bioimpedance Methods and Applications**

Evaluation of Impedance Technique for Detecting Breast Carcinoma Using a 2-D Numerical Model of the Torso. <i>By</i> MICHAL M. RADAÍ, SHIMON ABBOUD, and MOSHE ROSENFELD . . . . .	360
A Comparison of the Siconolfi and Cole-Cole Procedures for Multifrequency Impedance Data Analysis. <i>By</i> LEIGH WARD, NIGEL FULLER, BRUCE CORNISH, MARINOS ELIA, and BRIAN THOMAS . . . . .	370
Practical Limits of the Kramers-Kronig Relationships Applied to Experimental Bioimpedance Data. <i>By</i> PERE J. RIU and CRISTINA LAPAZ . . . . .	374

Experimental Assessment of Phase Magnitude Imaging in Multifrequency EIT by Simulation and Saline Tank Studies. <i>By</i> ANTHONY FITZGERALD, DAVID HOLDER, and HUW GRIFFITHS. . . . .	381
Some Design Concepts for Electrical Impedance Measurement. <i>By</i> H. G. GOOVAERTS, TH. J. C. FAES, E. RAAIJMAKERS, and R. M. HEETHAAR . . . . .	388
Impedance Modulation by Pulsed Ultrasound. <i>By</i> JACQUES JOSSINET, BERNARD LAVANDIER, and DOMINIQUE CATHIGNOL. . . . .	396
Focused Impedance Measurement (FIM)—A New Technique with Improved Zone Localization. <i>By</i> K. S. RABBANI, M. SARKER, M. H. R. AKOND, and T. AKTER. . . . .	408
Impedance Parameter Characterizing Apple Bruise. <i>By</i> ESZTER VOZÁRY, PÉTER LÁSZLÓ, and GÁBOR ZSIVÁNOVITS . . . . .	421

## Part VIII. EIT Reconstruction

State Estimation in Time-Varying Electrical Impedance Tomography. <i>By</i> JARI P. KAIPIO, PASI A. KARJALAINEN, ERKKI SOMERSALO, and MARKO VAUHKONEN . . . . .	430
A Parametric Method to Resolve the Ill-Posed Nature of the EIT Reconstruction Problem: A Simulation Study. <i>By</i> J. C. DE MUNCK, TH. J. C. FAES, A. J. HERMANS, and R. M. HEETHAAR. . . . .	440
EIT Reconstruction of Static Images by a Genetic Algorithm Approach. <i>By</i> R. OLMÍ, M. BINI, S. MANETTA, and S. PRIORI. . . . .	454
Uniqueness, Shape, and Dimension in EIT. <i>By</i> WILLIAM R. B. LIONHEART . . . . .	466
Static Three-Dimensional Electrical Impedance Tomography. <i>By</i> PÄIVI J. VAUHKONEN, MARKO VAUHKONEN, TUOMO SAVOLAINEN, and JARI P. KAIPIO . . . . .	472
Development of a Reconstruction Algorithm for Imaging Impedance Changes in the Human Head. <i>By</i> A. GIBSON, R. H. BAYFORD, and D. S. HOLDER . . . . .	482

## Part IX. EIT Applications

Monitoring Regional Lung Ventilation by Functional Electrical Impedance Tomography during Assisted Ventilation. <i>By</i> INÉZ FRERICHs, GÜNTER HAHN, HOLGER SCHIFFMANN, CORD BERGER, and GERHARD HELDIGE . . . . .	493
Gastric Emptying in Patients with Type I Diabetes Mellitus. <i>By</i> NACHUM VAISMAN, NOAMI WEINTROB, ALEXANDER BLUMENTAL, ZEEV YOSEFSBERG, and PNINA VARDI. . . . .	506

Assessment and Calibration of a Low-Frequency System for Electrical Impedance Tomography (EIT), Optimized for Use in Imaging Brain Function in Ambulant Human Subjects. <i>By</i> D. S. HOLDER, C. A. GONZÁLEZ-CORREA, T. TIDSWELL, A. GIBSON, G. CUSICK, and R. H. BAYFORD . . . . .	512
Impedance Mammograph 3D Phantom Studies. <i>By</i> JERZY WTOREK, JAROSLAW STELTER, and ANTONI NOWAKOWSKI . . . . .	520
Can We Optimize Electrode Placement for Impedance Pneumography? <i>By</i> N. KHAMBEDE, P. METHERRALL, B. BROWN, R. SMALLWOOD, and R. HOSE . . . . .	534
Index of Contributors . . . . .	543

**Financial assistance was received from:**

- COMISSIONAT PER A UNIVERSITATS I RECERCA—GENERALITAT DE CATALUNYA
- DIRECCIÓN GENERAL DE ENSEÑANZA SUPERIOR—MINISTERIO DE EDUCACIÓN Y CULTURA
- UNIVERSITAT POLITÈCNICA DE CATALUNYA