Clinical Magnetoencephalography and Magnetic Source Imaging

Andrew C. Papanicolaou
Contents

Contributors v
Preface xi

Section 1 The method
1 Basic concepts 3
2 The nature and origin of magnetic signals 7
3 Recording the magnetic flux 13
4 Overview of MSI using the single equivalent current dipole (ECD) model as an example 23
5 The fundamental problems of MSI 26
6 Head models 29
7 Source models – discrete source models 34
8 Source models – distributed source models 40
9 Source models – beamformers 44
10 Pragmatic features of the clinical use of MEG/MSI 47

References 51

Section 2 Spontaneous brain activity
11 MEG recordings of spontaneous brain activity – general considerations 59
### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Normal spontaneous MEG – frequently encountered artifacts</td>
<td>63</td>
</tr>
<tr>
<td>13</td>
<td>Spontaneous MEG morphology</td>
<td>68</td>
</tr>
<tr>
<td>14</td>
<td>Abnormal spontaneous MEG</td>
<td>75</td>
</tr>
<tr>
<td>15</td>
<td>Contributions of MEG to the surgical management of epilepsy – general considerations</td>
<td>83</td>
</tr>
<tr>
<td>16</td>
<td>MEG investigations in lesional epilepsies</td>
<td>88</td>
</tr>
<tr>
<td>17</td>
<td>MEG investigations in nonlesional epilepsies</td>
<td>90</td>
</tr>
<tr>
<td>18</td>
<td>Pediatric nonlesional epilepsy surgery</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>102</td>
</tr>
</tbody>
</table>

### Section 3 Evoked magnetic fields

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Recording evoked magnetic fields (EMFs)</td>
<td>111</td>
</tr>
<tr>
<td>20</td>
<td>Somatosensory evoked fields (SEFs)</td>
<td>118</td>
</tr>
<tr>
<td>21</td>
<td>Movement-related magnetic fields (MRFs) – motor evoked fields (MEFs)</td>
<td>128</td>
</tr>
<tr>
<td>22</td>
<td>Auditory evoked magnetic fields (AEFs)</td>
<td>134</td>
</tr>
<tr>
<td>23</td>
<td>Visual evoked magnetic fields (VEFs)</td>
<td>138</td>
</tr>
<tr>
<td>24</td>
<td>Language-related brain magnetic fields (LRFs)</td>
<td>144</td>
</tr>
<tr>
<td>25</td>
<td>Alternative techniques for evoked magnetic field data – future directions</td>
<td>157</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>159</td>
</tr>
</tbody>
</table>

### Postscript: Future applications of clinical MEG

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>173</td>
</tr>
<tr>
<td>Normal aging and neurodegenerative disorders</td>
<td>174</td>
</tr>
<tr>
<td>Neurodevelopmental disorders</td>
<td>178</td>
</tr>
</tbody>
</table>
Contents

Psychiatric disorders 183
Neurological disorders 186
Functional reorganization 190

References 192

Index 200
Contributors

Section 1
Andrew C. Papanicolaou, Ph.D.
University of Texas Health Science Center at Houston
Richard E. Greenblatt, Ph.D.
Source Signal Imaging, Inc.
Cheryl J. Aine, Ph.D.
University of New Mexico Health Sciences Center
George Zouridakis, Ph.D.
University of Houston
Eduardo Martinez Castillo, Ph.D.
University of Texas Health Science Center at Houston
D. Scott Buchanan, Ph.D.
4-D Neuroimaging, Inc.
Selma Supek, Ph.D.
University of Zagreb

Section 2
Eduardo Martinez Castillo, Ph.D.
University of Texas Health Science Center at Houston
Andrew C. Papanicolaou, Ph.D.
University of Texas Health Science Center at Houston
Hermann Stefan, M.D.
University of Erlangen-Nuremberg
James W. Wheless, M.D.
The University of Tennessee Health Science Center
Hiroshi Otsubo, M.D.
The Hospital for Sick Children, Toronto
Marta Santiuste, M.D., Ph.D.
Centro Medico Teknon

Stefan Rampp, M.D.
University of Erlangen-Nuremberg

Rafal Nowak, Ph.D.
Centro Medico Teknon

Antonio Russi, M.D.
Centro Medico Teknon

Roozbeh Rezaie, Ph.D.
University of Texas Health Science Center at Houston

Mark H. McMannis, Ph.D.
Le Bonheur Children’s Hospital, Memphis

Rüdiger Hopfengärtner, M.D.
University of Erlangen-Nuremberg

Andrea Paulini-Ruf, M.D.
University of Erlangen-Nuremberg

Tanja Ehrenfried
University of Zurich

Martin Kaltenhäuser, Ph.D.
University of Erlangen-Nuremberg

Section 3
Panagiotis G. Simos, Ph.D.
University of Crete

Andrew C. Papanicolaou, Ph.D.
University of Texas Health Science Center at Houston

Eduardo Martinez Castillo, Ph.D.
University of Texas Health Science Center at Houston

D. Scott Buchanan, Ph.D.
4-D Neuroimaging, Inc.

Postscript
Richard E. Frye, M.D., Ph.D.
University of Texas Health Science Center at Houston
Contributors

Roozbeh Rezaie, Ph.D.
University of Texas Health Science Center at Houston

Andrew C. Papanicolaou, Ph.D.
University of Texas Health Science Center at Houston

Fernando Maestú, Ph.D.
Complutense University of Madrid

Alberto Fernandez, Ph.D.
Complutense University of Madrid

Cheryl J. Aine, Ph.D.
University of New Mexico Health Sciences Center

Susan M. Bowyer, Ph.D.
Oakland University-Henry Ford Hospital

Hari Eswaran, Ph.D.
University of Arkansas For Medical Sciences

Ronald T. Wakai, Ph.D.
University of Wisconsin-Madison
Preface

This handbook is the result of the collective effort by a number of members of the recently formed International Society for the Advancement of Clinical Magnetoencephalography (ISACM). The book has two purposes: to articulate the empirical knowledge gained during the last two decades in the diagnostic use of magnetoencephalography (MEG) and magnetic source imaging (MSI), and to serve in the clinical training of new users.

As the knowledge of the clinical uses of MEG/MSI is at present rather limited and in some aspects uncertain, we hope and expect that this small volume will be augmented and some of its contents will be updated in the future. We therefore offer this handbook not as a definite authoritative reference volume, but as a blueprint of work in progress in an ever-expanding area of clinical sciences.

On behalf of all the co-authors I wish to thank Richard Marley and Katie James of Cambridge University Press for their patience and their support in producing this volume. I also wish to thank Drs. Wenbo Zhang and Stephan Moratti for their comments, and 4-D Neuroimaging for their material support. In particular, I wish to recognize here the following people associated with 4-D Neuroimaging: Dr. Kenneth Squires for his substantive comments, Carol Squires for her careful editing of the entire manuscript, and Jennifer Pecina for her help with the illustrations. Finally, I would like to thank Vanessa Fuller who, once again, lent me her unequalled skills in turning heaps of handwritten material into a cohesive text.

Andrew C. Papanicolaou