Thoraco-Abdominal Aorta:
Surgical and Anesthetic Management
To our families
without whose years of selfless sacrifice and loving support
this would not have been possible
The editors, Roberto Chiesa, Germano Melissano, and Alberto Zangrillo, are to be congratulated for the continued success of their educational series, *Aortic Surgery and Anesthesia “How To Do It”*. Also this new volume, entitled *Thoraco-Abdominal Aorta: Surgical and Anesthetic Management*, will undoubtedly be much revered and provide an exceptional educational reference for all aortic surgeons.

I had the good fortune of completing my residency under the late E.S. Crawford, who many of you would agree was the most accomplished aortic surgeon of his era. He taught us that although reparative surgery of the thoraco-abdominal aorta is appropriately complex, it is not impossible to achieve good results in the vast majority of elective cases. Crawford similarly influenced this book’s surgeon editors through personal demonstrations of his techniques. Aortic surgery was, and continues to be, a collaborative effort in which the best approaches are identified and shared. As is evident at the San Raffaele Scientific Institute, the collaborative approach frequently results in outstanding patient care.

As I approach the personal milestone of completing 3,000 thoraco-abdominal aortic repairs, I look back fondly to the surgical mavericks of the past, who helped make my success possible. At the same time, I look forward to ongoing collaboration, such as with the outstanding clinicians at San Raffaele, as I continue to refine my operative approach.

The book before you holds an incredible synthesis of practical knowledge from the world’s foremost experts on thoraco-abdominal aortic repair. Its 62 highly detailed chapters cover the general principles of thoraco-abdominal aortic repair, the variety of imaging techniques available to diagnose aneurysmal and other aortic disease, the spectrum of anesthetic techniques needed to adequately manage patients, comprehensive treatment strategies, and many novel approaches to highly complex, patient-specific aortic conditions. Additionally, several chapters focus on life after surgery, thus reminding us of existing challenges and the need for continued improvement. Toward that goal, the final section of the book details emerging technology, devices, and graft materials.

In closing, this book, to be issued at the surgeon editors’ Fourth International Congress, provides a wonderful synthesis of the past, present, and future of aortic surgery. The academic surgeon has a unique responsibility—to identify and disseminate innovative operative strategies as the relative advantages of various techniques and technology are better understood. Drs. Chiesa, Melissano, and Zangrillo are to be commended for compiling this thought-provoking and comprehensive book on thoraco-abdominal aortic surgery.

*Houston, December 2010*

*Joseph S. Coselli, MD*

*Guest Editor*
Repair of the thoraco-abdominal aorta represents a formidable challenge for surgeons, anesthesiologists and patients alike. As opposed to aortic disease confined to the chest, where the introduction of endografts has radically changed the therapeutical paradigm with much improved results, endovascular options for thoraco-abdominal aortic disease are still burdened by significant mortality and morbidity. In particular the rate of paraplegia, the most devastating complication, has not dropped significantly (as initially hoped) in the endovascular era.

In the near future thoraco-abdominal aortic disease will be diagnosed with increasing frequency due to the aging of the population (with longer exposure to high blood pressure and other risk factors) and the increasing sensitivity of non-invasive imaging modalities; the topic is therefore a very "hot" one. While operative repair is generally carried out in specialized institutions, knowledge of the state-of-the-art diagnostic, anesthesiologic, surgical and endovascular aspects will certainly be of great help to all physicians involved in the care of these patients at any level. Our goal was to bring together in one book information that comes from different specialists and different geographic areas; all the Authors however, share a vast personal experience together with a great dedication and special commitment to these very difficult patients.

While medial degeneration is the most common cause of thoraco-abdominal aortic disease, different conditions (dissection, intramural hematomas, penetrating ulcers, traumatic injury, coarctation, syndromic and non-syndromic inherited forms) represent almost half of the indications for thoraco-abdominal aortic repair. All these will be covered in the book with particular emphasis on preoperative imaging, anesthesiologic management and different therapeutic options. Moreover other less commonly explored aspects such as pharmacological, psychological, ethical and rehabilitation ones have also been covered. Finally, several chapters describe in detail the peculiar features of the devices most commonly used to treat aortic disease.

It has been impossible to avoid a small degree of overlapping among chapters regarding similar or contiguous topics, however we feel that the Authors have made a great job in sticking closely to their subject making each chapter, and the book as a whole, very useful and pleasant to read. The readers will notice that some key topics have been assigned to two different Authors. As a consequence of this decision some degree of overlapping and repetition has been unavoidable, however we believe that this is outweighed by the benefits of sharing the experiences of two different distinguished schools, often from two different continents.

We feel personally in debt and wish to express deep gratitude to all the Authors, both the colleagues from our own Institution and the many other knowledgeable opinion-leaders from different countries who contributed with their outstanding work. Editing this book has been not only a great honor but also an incredibly enriching and enlightening experience. We do hope that you will enjoy reading this book as much as we did editing it.
Don Luigi M. Verzè, founder and president of our Institution, the San Raffaele Hospital and the “Vita-Salute” (“Life-Health”) San Raffaele University, reminds us that the object of medicine is not disease but rather patients. We are treating human subjects with their biological, psychological and spiritual components as well as their social and familiar milieu fused in a very unique personal history. True healing also requires a profound participation of the patient, the human subject, who is the only one to know how much illness he can fight and how much can be accepted. We will always be in debt with Don Luigi for passing on to us not only his teachings but also his never-ending enthusiasm, perseverance and commitment.

*Milan, December 2010*

*Roberto Chiesa*

*Germano Melissano*

*Alberto Zangrillo*

*Editors*
# Contents

## Section I  General Principles

1. **Historical Overview** ................................. 3  
   Angelo Argenteri

2. **Definitions and Classifications** ......................... 17  
   Darrell Wu, Scott A. LeMaire and Joseph S. Coselli

3. **Epidemiology and Natural History of Thoraco-Abdominal Aortic Aneurysms** ............................................ 25  
   Louis H. Stein and John A. Elefteriades

4. **Peculiarities and Natural History of Type B Aortic Dissection** ............................................................. 33  
   Christoph A. Nienaber

5. **Pathology of the Thoraco-Abdominal Aorta** .................. 45  
   Cristina Basso, Stefania Rizzo and Gaetano Thiene

6. **Pathophysiology of Aortic Cross-clamping** ................... 65  
   Leslie M. Cuzick, Alfredo R. Lopez and John R. Cooper Jr

7. **Clinical Presentation and Evidence-based Indications to Treatment** ...................................................... 73  
   Attilio Odero, Vittorio Arici and Antonio Bozzani

## Section II  Imaging

8. **Diagnostic Imaging of the Aortic Arch and Thoraco-Abdominal Aorta** .................................................. 85  
   Giovanni Simonetti, Giovanni Gandini, Gian Paolo Cornalba and Maria Carla Cassinis

9. **Magnetic Resonance Imaging of the Aorta** .................. 103  
   Antonio Esposito, Silvia Ravelli, Maurizio Papa and Alessandro Del Maschio

10. **Transesophageal Echocardiography of the Aorta** ............ 115  
    Michele Oppizzi and Eustachio Agricola
11 **Preoperative Planning and Sizing for Aortic Endovascular Procedures** .................................................. 131
  Germano Melissano, Efrem Civilini and Roberto Chiesa

12 **Assessment of the Spinal Cord Vasculature with Computed Tomography** ......................................................... 147
  Germano Melissano, Luca Bertoglio and Roberto Chiesa

13 **Assessment of the Spinal Cord Vasculature with Magnetic Resonance Angiography** .................................. 161
  Robbert J. Nijenhuis, Michael J. Jacobs and Walter H. Backes

14 **Role of Cardiac CT in Assessment of Patients with Thoraco-Abdominal Aortic Aneurysm** .......................... 173
  Pietro Spagnolo and Manuela Giglio

***Section III Anesthetic Management***

15 **Preoperative Care of Patients with Thoraco-Abdominal Aortic Aneurysms** .................................................. 185
  Fabio Guarracino and Rubia Baldassarri

16 **Cardiovascular Evaluation, Risk Stratification, and Management of Postoperative Myocardial Infarction** .......... 197
  Federico Pappalardo and Giulio Melisurgo

17 **Perioperative Pharmacological Cardiac Protection** .................. 211
  Giovanni Landoni and Elena Bignami

18 **Prevention and Treatment of Renal Insufficiency** ............ 219
  Tiziana Bove and Fabrizio Monaco

19 **Prevention and Treatment of Respiratory Insufficiency** ........ 229
  Roberta Mennella and Alberto Zangrillo

20 **Anesthetic Management of Open Thoraco-Abdominal Aortic Procedures – The Texas Heart Institute Experience** ........ 243
  John R. Cooper Jr

21 **Anesthetic Management of Thoraco-Abdominal Open Procedures – The Mount Sinai Experience** .................... 253
  Javier G. Castillo, George Silvay and Gregory W. Fischer

22 **Perioperative Cardiac Monitoring with Transesophageal Echocardiography** ............................................ 271
  Brian Barrick, Susan M. Martinelli and Madhav Swaminathan

23 **Hemostasis, Bleeding, Blood-sparing Strategies, and Allogeneic Transfusions in Thoraco-Abdominal Aortic Aneurysm Surgery** .......................................................... 287
  Valter Casati and Armando D’Angelo
## Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td><strong>Left Heart Bypass</strong> ....................................................................</td>
<td>Monica De Luca and Francesco De Simone</td>
</tr>
<tr>
<td>25</td>
<td><strong>Management of Postoperative Complications</strong> ...............................</td>
<td>Remo D. Covello and Alberto Zangrillo</td>
</tr>
<tr>
<td></td>
<td><strong>Section IV  Treatment Strategies and Techniques</strong></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Surgical Technique for Extent I, II, and III Thoraco-Abdominal Aortic Aneurysms – The Texas Heart Institute Experience</td>
<td>Joseph S. Coselli and Scott A. LeMaire</td>
</tr>
<tr>
<td>27</td>
<td>Surgical Technique for Extent I, II, and III Thoraco-Abdominal Aortic Aneurysms – The San Raffaele Experience</td>
<td>Roberto Chiesa, Germano Melissano and Efrem Civilini</td>
</tr>
<tr>
<td>28</td>
<td>Surgical Technique for Extent IV Thoraco-Abdominal Aortic Aneurysms</td>
<td>Laurent Chiche, Yannick Le Manach and Edouard Kieffer</td>
</tr>
<tr>
<td>29</td>
<td>Surgical Replacement of the Entire Aorta</td>
<td>LiZhong Sun, JunMing Zhu and RuiDong Qi</td>
</tr>
<tr>
<td>30</td>
<td>The Frozen Elephant Trunk Technique</td>
<td>Roberto Di Bartolomeo, Marco Di Eusanio, Luca Di Marco and Davide Pacini</td>
</tr>
<tr>
<td>31</td>
<td>Deep Hypothermic Circulatory Arrest for Thoracic Aneurysmectomy through the Left Chest</td>
<td>Edouard Kieffer and Laurent Chiche</td>
</tr>
<tr>
<td>32</td>
<td>Neurological Monitoring with Evoked Potentials</td>
<td>Michael J. Jacobs and Werner H. Mess</td>
</tr>
<tr>
<td>33</td>
<td>Spinal Cord Ischemia</td>
<td>Germano Melissano, Luca Bertoglio, Efrem Civilini and Roberto Chiesa</td>
</tr>
<tr>
<td>34</td>
<td>Endovascular Treatment of Thoraco-Abdominal Aortic Aneurysm with Branched Endografts – The Nürnberg-Cleveland Experience</td>
<td>Eric L.G. Verhoeven and Roy K. Greenberg</td>
</tr>
<tr>
<td>35</td>
<td>Endovascular Treatment of Thoraco-Abdominal Aortic Aneurysm with Branched Endografts – The Perugia-Rome Experience</td>
<td>Gianbattista Parlani, Fabio Verzini, Deborah Brambilla and Piergiorgio Cao</td>
</tr>
</tbody>
</table>
Section V Specific Problems

38 **Endovascular Treatment of Type B Dissections** ......................... 471
   Rossella Fattori, Luigi Lovato and Vincenzo Russo

39 **The Sandwich Technique for Type B Dissection** ...................... 483
   Armando C. Lobato

40 **Specific Surgical Problems in Marfan Patients** ...................... 491
   Marc Schepens and Willem Ranschaert

41 **Open Treatment for Aortic Trauma** ...................................... 501
   Kenneth L. Mattox

42 **Endovascular Treatment of Aortic Isthmic Rupture** ................... 511
   Enrico M. Marone, Andrea Kahlberg and Roberto Chiesa

43 **Redo Open and Endovascular Procedures after Open Thoraco-Abdominal Aortic Aneurysm Repair** ......................... 523
   Yamume Tshomba, Germano Melissano and Roberto Chiesa

44 **Endovascular or Open Treatment of Aortic Coarctation (Typical and Atypical)** ........................................... 541
   Edward B. Diethrich

45 **Intramural Hematoma and Penetrating Aortic Ulcers** ............... 555
   Arno von Ristow, Bernardo V. Massière and Felippe Beer

46 **Aortoesophageal and Aortobronchial Fistulas** ......................... 567
   Roberto Chiesa, Andrea Kahlberg, Germano Melissano and Enrico M. Marone

47 **Anomalies and Variant Anatomy of the Aorta and the Supra-aortic Vessels – Additional Challenges Met by Hybrid Procedures** .................................................. 585
   Carlo Setacci, Pasqualino Sirignano, Gianmarco de Donato and Francesco Setacci

48 **Quality of Life after Thoraco-Abdominal Aortic Aneurysm Repair** .......................................................... 595
   Robert S. Crawford and Richard P. Cambria
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td><strong>Relative Risk of Paraplegia between Open, Hybrid, and Endovascular Procedures</strong></td>
<td>Ramin E. Beygui and Ronald L. Dalman</td>
</tr>
<tr>
<td>50</td>
<td><strong>Statistical Analysis of Operative Results</strong></td>
<td>Carlo Setacci, Emiliano Chisci, Pasqualino Sirignano and Francesco Setacci</td>
</tr>
<tr>
<td>51</td>
<td><strong>Communication with the Patient: Ethical Decisions</strong></td>
<td>Gianna Zoppe, Alfredo Anzani and Federica Alemanno</td>
</tr>
<tr>
<td>52</td>
<td><strong>Postoperative Rehabilitation</strong></td>
<td>Guido Felicetti</td>
</tr>
<tr>
<td>53</td>
<td><strong>Psychological Approach to the Aneurysm Patient</strong></td>
<td>Lucio Sarno, Valentina Di Mattei, Chiara Motta and Silvana Villa</td>
</tr>
</tbody>
</table>

**Section VI  Advances in Prosthetic Management**

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td><strong>Advances in Vascular Grafts for Thoraco-Abdominal Aortic Open Surgery</strong></td>
<td>Olivier Goëau-Brissonnière, Isabelle Javerliat and Marc Coggia</td>
</tr>
<tr>
<td>55</td>
<td><strong>Hybrid Procedures with Dedicated Grafts for Extensive Aortic Aneurysms</strong></td>
<td>Giampiero Esposito, Samuele Bichi and Roberto Di Bartolomeo</td>
</tr>
<tr>
<td>56</td>
<td><strong>The Cook Zenith Devices</strong></td>
<td>Stephan Haulon, Jennifer A. McCann-Brown, Blayne A. Roeder and Jarin A. Kratzberg</td>
</tr>
<tr>
<td>57</td>
<td><strong>The Bolton Relay Devices</strong></td>
<td>Jasper W. van Keulen, Anas Zarka, Frans L. Moll and Vincent Riambau</td>
</tr>
<tr>
<td>58</td>
<td><strong>The Jotec Devices</strong></td>
<td>Burkhart Zipfel</td>
</tr>
<tr>
<td>59</td>
<td><strong>The Medtronic Devices – Valiant Stent-graft</strong></td>
<td>Matt Thompson, Ian Loftus and Rob Morgan</td>
</tr>
<tr>
<td>60</td>
<td><strong>The Gore TAG Devices</strong></td>
<td>Dittmar Böckler</td>
</tr>
<tr>
<td>61</td>
<td><strong>Prophylactic Use of Silver-acetate-coated Polyester Dacron Graft in Aortic Disease for Prevention of Graft Infection</strong></td>
<td>Mauro Ferrari, Basilio Crescenzi, Sabrina Ceragioli and Michele Marconi</td>
</tr>
<tr>
<td>62</td>
<td><strong>Hemostatic and Structural Adjuncts</strong></td>
<td>Carlo Setacci, Giancarlo Palasciano, Pasqualino Sirignano and Francesco Setacci</td>
</tr>
</tbody>
</table>
Contributors

Eustachio Agricola  Cardio-Thoraco-Vascular Department, IRCCS H. San Raffaele, Milan, Italy

Federica Alemanno  Experimental Neurophysiology, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Alfredo Anzani  Ethics Committee, IRCCS H. San Raffaele, Milan, Italy

Angelo Argenteri  Chair of Vascular Surgery, University of Pavia, Pavia, and Unit of Vascular Surgery, Provincia di Lodi Hospital, Lodi, Italy

Vittorio Arici  Division of Vascular Surgery, IRCCS Policlinico S. Matteo Foundation, Pavia, Italy

Walter H. Backes  Department of Radiology, Maastricht University Medical Center, Maastricht, The Netherlands

Rubia Baldassarri  Cardiothoracic Department, Pisa University Hospital, Pisa, Italy

Brian Barrick  Department of Anesthesiology, University of North Carolina, Chapel Hill, North Carolina, USA

Cristina Basso  Department of Medical Diagnostic Sciences and Special Therapies, University of Padua Medical School, Padua, Italy

Felippe Beer  Vascular and Endovascular Surgery, Pontificia Universidade Católica do Rio de Janeiro, Rio de Janeiro, Brazil

Luca Bertoglio  Department of Vascular Surgery, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Ramin E. Beygui  Cardiothoracic and Vascular Surgery, Stanford University School of Medicine, Stanford, California, USA

Samuele Bichi  Department of Cardiovascular Surgery, Città di Lecce Hospital, GVM Hospitals of Care and Research, Lecce, Italy

Elena Bignami  Department of Anaesthesia and Intensive Care, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Dittmar Böckler  Department of Vascular and Endovascular Surgery, Ruprecht-Karl University of Heidelberg, Heidelberg, Germany

Tiziana Bove  Department of Anaesthesia and Intensive Care, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Antonio Bozzani  Division of Vascular Surgery, IRCCS Policlinico S. Matteo Foundation, Pavia, Italy
Deborah Brambilla  Division of Vascular and Endovascular Surgery, University of Perugia, S. Maria della Misericordia Hospital, Perugia, Italy

Richard P. Cambria  Division of Vascular and Endovascular Surgery, Massachusetts General Hospital, Boston, Massachusetts, USA

Piergiorgio Cao  Vascular Surgery, S. Camillo-Forlanini Hospital, Rome, and Chair of Vascular Surgery, University of Perugia, Perugia, Italy

Valter Casati  Division of Cardiothoracic and Vascular Anesthesia and Intensive Care, S. Gaudenzio Clinic (Policlinico di Monza Group), Novara, Italy

Maria Carla Cassinis  Department of Medical and Surgical Disciplines, Diagnostic Imaging Division, S. Giovanni Battista (Molinette) Hospital, University of Turin, Turin, Italy

Javier G. Castillo  Department of Cardiothoracic Surgery, The Mount Sinai School of Medicine, New York, USA

Sabrina Ceragioli  Vascular Surgery Residency Program, University of Pisa, Pisa, Italy

Nicholas Cheshire  Regional Vascular Unit, St Mary’s Hospital, Mary Stanford Wing, Imperial College Healthcare, London, United Kingdom

Laurent Chiche  Department of Vascular Surgery, Pitié-Salpêtrière University Hospital, Paris, France

Roberto Chiesa  Department of Vascular Surgery, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Emiliano Chisci  Vascular and Endovascular Surgery Unit, Department of Surgery, University of Siena, Siena, Italy

Efrem Civilini  Department of Vascular Surgery, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Frédéric Cochennec  Regional Vascular Unit, St Mary’s Hospital, Mary Stanford Wing, Imperial College Healthcare, London, United Kingdom

Marc Coggia  Department of Vascular Surgery, Ambroise Paré Hospital, Boulogne-Billancourt, and Paris-Ile-de-France-Ouest Faculty of Medicine, Versailles Saint-Quentin-en-Yvelines University, France

John R. Cooper Jr  Department of Cardiovascular Anesthesiology, Texas Heart Institute at St. Luke’s Episcopal Hospital, and Baylor College of Medicine, Houston, Texas, USA

Gian Paolo Cornalba  Department of Diagnostic Imaging and Interventional Radiology, S. Paolo Hospital, University of Milan, Milan, Italy

Joseph S. Coselli  Texas Heart Institute at St. Luke’s Episcopal Hospital, and Division of Cardiothoracic Surgery, Michael E. DeBakey Department of Surgery, Baylor College of Medicine, Houston, Texas, USA

Remo D. Covello  Department of Anaesthesia and Intensive Care, “Vita-Salute” University, IRCCS H. San Raffaele, Milan, Italy

Robert S. Crawford  Division of Vascular and Endovascular Surgery, Massachusetts General Hospital, Boston, Massachusetts, USA

Basilio Crescenzi  Vascular Surgery Residency Program, University of Pisa, Pisa, Italy