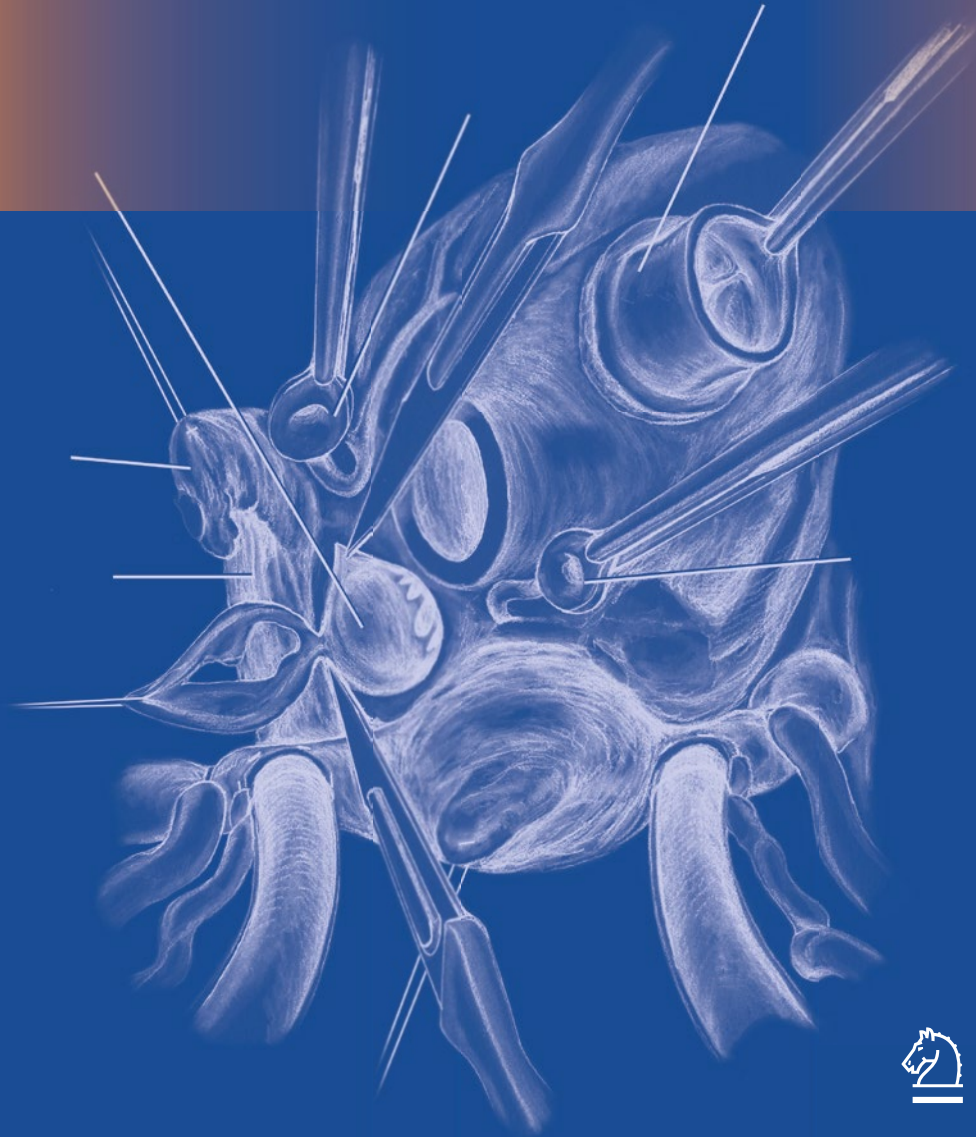


Constantine Mavroudis  
Carl Lewis Backer *Editors*

*Illustrations by*  
Rachid F. Idriss

# Atlas of Pediatric Cardiac Surgery



 Springer

---

# Atlas of Pediatric Cardiac Surgery



---

Constantine Mavroudis



Florida Hospital  
for Children

Carl Lewis Backer



Ann & Robert H. Lurie  
Children's Hospital of Chicago

Editors

# Atlas of Pediatric Cardiac Surgery

Illustrations by Rachid F. Idriss



Springer

*Editors*

Constantine Mavroudis, MD  
Florida Hospital for Children  
Johns Hopkins Children's Heart Surgery  
Orlando, FL  
USA

Carl Lewis Backer, MD  
Ann and Robert H Lurie Children's Hospital  
Chicago, IL  
USA

ISBN 978-1-4471-5318-4      ISBN 978-1-4471-5319-1 (eBook)  
DOI 10.1007/978-1-4471-5319-1

Library of Congress Control Number: 2015949701

Springer London Heidelberg New York Dordrecht  
© Springer-Verlag London 2015

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

Springer-Verlag London Ltd. is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

---

## Preface

The raison d'être for a new atlas of congenital heart surgery is based on the reality that our specialty has undergone numerous changes in the past few years, resulting in improved techniques and new operations. The sheer number of new procedures and the required attendant technical skills to successfully complete an operation have become a challenge to master, especially for residents who are pursuing a career in congenital heart surgery.

After three editions of our textbook, *Pediatric Cardiac Surgery*, and after numerous years of following and contributing to the literature, we concluded that there have been enough changes and enough advances to support an updated atlas of pediatric congenital heart surgery. The techniques espoused are mostly our own, but there is a great deal of similarity amongst international centers, owing to the influence of video presentations, manuscript publications, and chapter reviews. We therefore believe that the techniques illustrated in this atlas are likely to be similar to the techniques that are taught to residents and fellows throughout the world.

The atlas is organized generally by diseases and the procedures pertaining thereto. Many of the illustrations are from our textbook, *Pediatric Cardiac Surgery*, 4th Edition. Others are from our previous manuscripts, and still others have never been published before. Two general sections involve cannulation techniques and palliative procedures. A special section depicts difficult problems in the form of clinical vignettes that may arise during cardiopulmonary bypass, such as decreased venous return, undiagnosed patent ductus arteriosus, and technical errors leading to hemodynamic complications. This section will help the reader to become cognizant of the reparative measures needed to resolve these problems.

We have chosen procedures that cover the breadth of congenital heart surgery. This text perhaps is not totally inclusive, but we believe that the reader will find the greater majority of congenital heart procedures illustrated and explained.

An atlas of surgery is only as good as the medical illustrator. We are indeed privileged to be working with Rachid Idriss, MFA, who has immeasurable talents both in the execution of the detail and in the more difficult task of visualizing the anatomy in his own mind's eye. The details of depth, texture, and light are brilliantly shown to the observer. Except to explain the anatomy and different procedures from time to time, we have had little to offer him regarding how to organize the drawing or create his art. His ability to determine and emphasize the important steps of the operation seemed to be innate, a talent that Plato would find consistent with his theory of anamnesis, the idea that humans possess knowledge in the psyche that is rediscovered. The result is this very fine and well-illustrated atlas of pediatric congenital heart surgery.

Orlando, FL, USA  
Chicago, IL, USA

Constantine Mavroudis, MD  
Carl Lewis Backer, MD



---

## Acknowledgments

The editors would like to acknowledge the stellar editorial and organizational skills of Ms Allison Siegel whose indefatigable and conscientious efforts brought this book to fruition. This book was the culmination of 6 years of on again, off again labors that were interrupted any number of times for other so called more important tasks and responsibilities. Allison had the tenacity and vision to engage and reengage with this project, always keeping clear the eventual outcome that came together in the end as a worthy accomplishment.





---

## Contents

<b>1 Cannulation Techniques</b> .....	1
Constantine Mavroudis	
<b>2 Palliation Techniques</b> .....	19
Constantine Mavroudis	
<b>3 Patent Ductus Arteriosus Ligation</b> .....	35
Constantine Mavroudis	
<b>4 Vascular Rings, Tracheoplasty, and Pulmonary Artery Sling</b> .....	45
Carl Lewis Backer	
<b>5 Coarctation of the Aorta</b> .....	73
Constantine Mavroudis	
<b>6 Interrupted Aortic Arch Repair</b> .....	83
Constantine Mavroudis	
<b>7 Atrial Septal Defect</b> .....	89
Constantine Mavroudis	
<b>8 Ventricular Septal Defect</b> .....	99
Constantine Mavroudis	
<b>9 Atrioventricular Septal Defects (Atrioventricular Canal)</b> .....	117
Constantine Mavroudis	
<b>10 Truncus Arteriosus</b> .....	131
Constantine Mavroudis	
<b>11 Aortopulmonary Window</b> .....	145
Constantine Mavroudis	
<b>12 Tetralogy of Fallot</b> .....	153
Constantine Mavroudis	
<b>13 Transposition of the Great Arteries</b> .....	165
Constantine Mavroudis	
<b>14 Double-Outlet Ventricles (with Two Adequate Ventricles)</b> .....	199
Constantine Mavroudis	
<b>15 Congenitally Corrected Transposition of the Great Arteries</b> .....	211
Constantine Mavroudis	
<b>16 Fontan Operation and 1½ Ventricular Repair</b> .....	225
Constantine Mavroudis	

<b>17</b>	<b>Fontan Conversion and Arrhythmia Surgery</b> .....	235
	Constantine Mavroudis	
<b>18</b>	<b>Arrhythmia Surgery and Pacemaker Placement Not Associated with Fontan Conversion</b> .....	255
	Constantine Mavroudis	
<b>19</b>	<b>Left Ventricular Outflow Tract Obstruction</b> .....	273
	Constantine Mavroudis	
<b>20</b>	<b>Norwood Operation/Damus-Stansel-Kaye</b> .....	297
	Constantine Mavroudis	
<b>21</b>	<b>Aortico–Left Ventricular Tunnel</b> .....	305
	Constantine Mavroudis	
<b>22</b>	<b>Mitral Valve Repairs</b> .....	311
	Constantine Mavroudis	
<b>23</b>	<b>Total Anomalous Pulmonary Venous Return</b> .....	325
	Constantine Mavroudis	
<b>24</b>	<b>Anomalous Systemic Venous Return</b> .....	339
	Constantine Mavroudis	
<b>25</b>	<b>Sinus of Valsalva Aneurysm</b> .....	355
	Constantine Mavroudis	
<b>26</b>	<b>Coronary Artery Anomalies</b> .....	359
	Constantine Mavroudis	
<b>27</b>	<b>Pectus Excavatum Repair</b> .....	387
	Carl Lewis Backer	
<b>28</b>	<b>Cardiac Transplantation</b> .....	393
	Carl Lewis Backer	
<b>29</b>	<b>Complications Associated with the Initiation of Cardiopulmonary Bypass</b> . . . .	401
	Constantine Mavroudis	
	<b>Index</b> .....	407

---

## Abbreviations

Ao	Aorta
AAo or Asc	Ascending aorta
ALCAPA	Anomalous left coronary artery from the pulmonary artery
AP	Aortopulmonary
APL	Transmural atrial pacemaker lead
ART	Atrial reentrant tachycardia
ASD	Atrial septal defect
A-V or AV	Atrioventricular
avn	Atrioventricular node
CA	Coronary artery
CPV	Common pulmonary vein or confluence of pulmonary veins
CS	Coronary sinus
Cx	Chest x-ray
Dao	Descending aorta
DV	Ductus venosus
FO	Foramen ovale
HV	Hepatic vein
INN A	Innominate artery
INN V	Innominate vein
IVC	Inferior vena cava
LA	Left atrium
LAA	Left atrial appendage
LAD	Left anterior descending coronary artery
LC or LCA	Left coronary artery or left carotid artery
LCC	Left coronary cusp
LCCA	Left common carotid artery
LCir	Left circumflex
LIV	Left innominate vein
LLPV	Left lower pulmonary vein
LPA	Left pulmonary artery
LSA	Left subclavian artery
LSVC	Left superior vena cava
LUPV	Left upper pulmonary vein
LV	Left ventricle
LVOT	Left ventricular outflow tract
MPA	Main pulmonary artery
MV	Mitral valve
NCC	Noncoronary cusp
NF	Nonfacing sinus
ORT	Orthodromic reentrant tachycardia
PA	Pulmonary artery
PDA	Patent ductus arteriosus

---

PFO	Patent foramen ovale or portal vein
PV	Pulmonary valve
RA	Right atrium or right arch
RAA	Right atrial appendage
RCC	Right coronary cusp
RC or RCA	Right coronary artery or right carotid artery
RCCA	Right common carotid artery
RLPV	Right lower pulmonary vein
RPA	Right pulmonary artery
RSA	Right subclavian artery
RSVC	Right superior vena cava
RUPV	Right upper pulmonary vein
RV	Right ventricle
RVOT	Right ventricle outflow tract
S-A or SA	Sinoatrial
SVC	Superior vena cava
TAPVR	Total anomalous pulmonary venous return
TV	Tricuspid valve
VSD	Ventricular septal defect
VV	Vertical vein
WPW	Wolff-Parkinson-White

Constantine Mavroudis

## 1.1 Aortic Cannulation

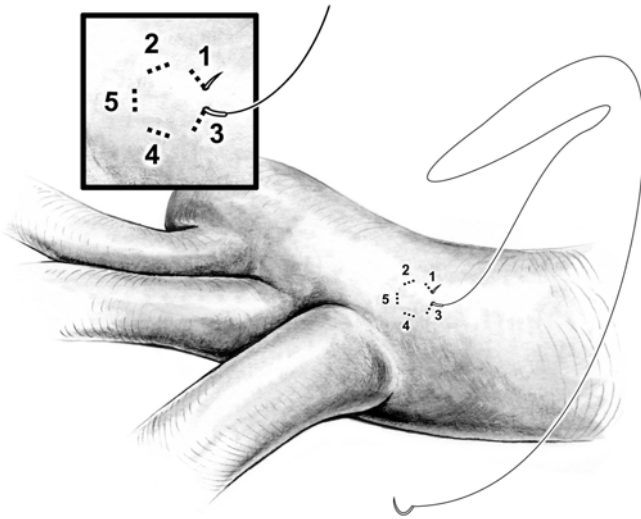
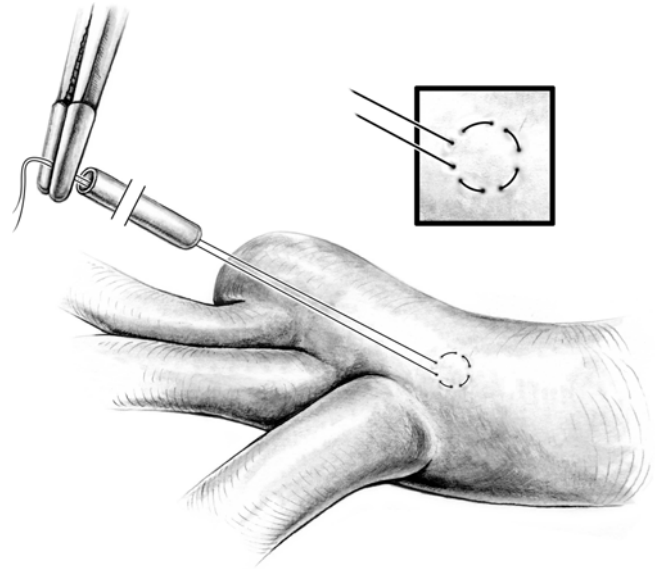
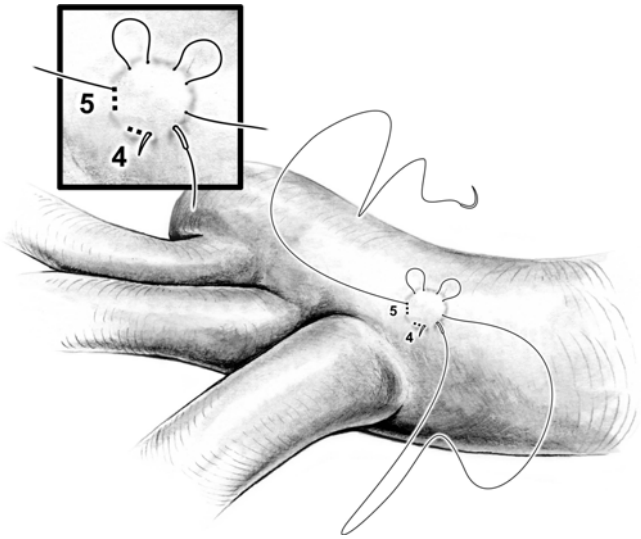
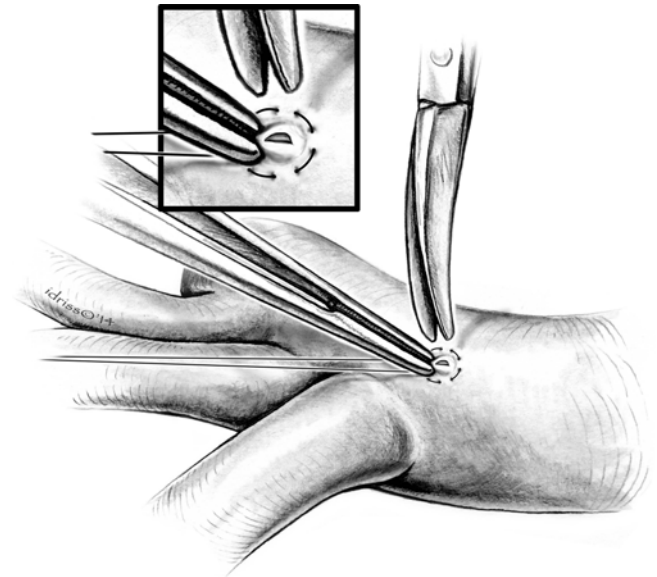
Aortic cannulation requires special care, especially in a neonate. In general, we use only one purse-string suture, employing a one-needle technique (Fig. 1.1) or a two-needle technique (Fig. 1.2). The site is just below the takeoff of the common brachiocephalic artery. The sutures are placed through the adventitia and into—but not through—the media. Transaortic sutures are avoided to prevent bleeding. If unwanted transaortic suture placement results in bleeding, the surgeon must assess its extent and magnitude. A transaortic suture often (but not always) must be removed and replaced to prevent ongoing bleeding during the procedure.

Once the suture is placed, a snugger tourniquet is applied (Fig. 1.3). The adventitia is dissected to the media within the confines of the purse-string suture line (Figs. 1.4 and 1.5) in preparation for aortic cannulation. With the left hand, vascular forceps firmly grip the aortic wall above (upstream to) the

aortic purse-string. The surgeon retracts the forceps superiorly to expose the dissected cannulation site. A #11 blade is used to perform a small horizontal aortotomy within the confines of the dissected aorta inside the suture line (Fig. 1.6). As the blade is removed, downward traction is placed with the forceps to control the bleeding. In a coordinated movement, the forceps loosen the downward traction and expose the aortotomy (Fig. 1.7). Sometimes the aortotomy is too small, and the catheter may need to be manipulated. At other times, a small, curved mosquito clamp can be inserted to dilate the opening with or without opening the clamp. Once the cannula is placed (Fig. 1.8), the snugger is engaged and the cannula is secured with two ties, as shown in Figure 1.9. If bleeding persists from the purse-string suture line, a free silk tie can be placed around the base of the cannula while dragging the adventitia to the base (Fig. 1.10a–c). This maneuver generally controls the bleeding, as this tie can act as a second suture line.

---

C. Mavroudis, MD  
Professor of Surgery, Johns Hopkins University School of Medicine,  
Site Director, Johns Hopkins Children's Heart Surgery,  
Florida Hospital for Children, Orlando, FL, USA  
e-mail: [Constantine.Mavroudis.MD@flhosp.org](mailto:Constantine.Mavroudis.MD@flhosp.org)

**Fig. 1.1****Fig. 1.3****Fig. 1.2****Fig. 1.4**