

Practical Approach
to
PEDIATRIC INTENSIVE CARE

Jaypee Brothers

Practical Approach to **PEDIATRIC INTENSIVE CARE**

Third Edition

Chief Editor

Praveen Khilnani

MD FICCM FAAP FCCM (USA)

Diplomate American Board of Pediatric Critical Care Medicine

Chair Guidelines Committee 2001 (for IAP and ISCCM)

Senior Consultant and Head

Pediatric Critical Care and Pulmonology

BLK Super Speciality Hospital

New Delhi, India

Associate Editor

Rajiv Uttam MRCP (UK)

Editorial Board

Mritunjay Pao MD

Nitesh Singhal MD

Rachna Sharma MD

Nameet Jerath MD

Vishal K Singh MD

Maninder S Dhaliwal MD

Prabhat Maheshwari MRCP (UK)

Foreword

Janakiraman N



The Health Sciences Publisher

New Delhi | London | Philadelphia | Panama



Jaypee Brothers Medical Publishers (P) Ltd

Headquarters

Jaypee Brothers Medical Publishers (P) Ltd
4838/24, Ansari Road, Daryaganj
New Delhi 110 002, India
Phone: +91-11-43574357
Fax: +91-11-43574314
Email: jaypee@jaypeebrothers.com

Overseas Offices

J.P. Medical Ltd
83 Victoria Street, London
SW1H 0HW (UK)
Phone: + 44 20 3170 8910
Fax: +44(0)20 3008 6180
Email: info@jpmepub.com

Jaypee-Highlights Medical Publishers Inc
City of Knowledge, Bld. 237, Clayton
Panama City, Panama
Phone: +1 507-301-0496
Fax: +1 507-301-0499
Email: cservice@jphmedical.com

Jaypee Medical Inc
The Bourse
111 South Independence Mall East
Suite 835, Philadelphia, PA 19106, USA
Phone: +1 267-519-9789
Email: jpmed.us@gmail.com

Jaypee Brothers Medical Publishers (P) Ltd
17/1-B Babar Road, Block-B, Shaymali
Mohammadpur, Dhaka-1207
Bangladesh
Mobile: +08801912003485
Email: jaypeedhaka@gmail.com

Jaypee Brothers Medical Publishers (P) Ltd
Bhotahity, Kathmandu
Nepal
Phone: +977-9741283608
Email: kathmandu@jaypeebrothers.com

Website: www.jaypeebrothers.com
Website: www.jaypeedigital.com

© 2015, Jaypee Brothers Medical Publishers

The views and opinions expressed in this book are solely those of the original contributor(s)/author(s) and do not necessarily represent those of editor(s) of the book.

All rights reserved. No part of this publication may be reproduced, stored or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission in writing of the publishers.

All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Medical knowledge and practice change constantly. This book is designed to provide accurate, authoritative information about the subject matter in question. However, readers are advised to check the most current information available on procedures included and check information from the manufacturer of each product to be administered, to verify the recommended dose, formula, method and duration of administration, adverse effects and contraindications. It is the responsibility of the practitioner to take all appropriate safety precautions. Neither the publisher nor the author(s)/editor(s) assume any liability for any injury and/or damage to persons or property arising from or related to use of material in this book.

This book is sold on the understanding that the publisher is not engaged in providing professional medical services. If such advice or services are required, the services of a competent medical professional should be sought.

Every effort has been made where necessary to contact holders of copyright to obtain permission to reproduce copyright material. If any have been inadvertently overlooked, the publisher will be pleased to make the necessary arrangements at the first opportunity.

Inquiries for bulk sales may be solicited at: jaypee@jaypeebrothers.com

Practical Approach to Pediatric Intensive Care

First Edition: 2004
Second Edition: 2009
Third Edition: 2015

ISBN 978-93-5152-739-8

Printed at

Dedicated

to

My Mother



Late Smt Laxmi Devi Khilnani

Who left for heavenly abode on May 2001

She always knew I could do it whenever I thought I could not
She was the one who taught me to always be optimistic and hardworking
God will take care of the rest

Contributors

Agnisekhar Saha MD

Consultant Pediatric Intensivist
Fortis Hospital
Kolkata, West Bengal, India
Inotropes and Vasopressors in the Pediatric Intensive Care Unit

Ajay Kumar Gupta MD

Associate Consultant
Fortis Escorts Heart Institute
New Delhi, India
Perioperative Management of Transposition of Great Arteries

Akshay Kapoor MD

Consultant Pediatric Gastroenterologist and Hepatologist
Indraprastha Apollo Hospital and BLK Hospital
New Delhi, India
Liver Transplantation in Children: Indian Scenario

Amit Gupta MD

Neonatologist and Pediatric Intensivist
Max Super Speciality Hospital
Noida, Uttar Pradesh, India
Assessment and Initial Management: A Practical Approach

Amita Mahajan MD

Senior Consultant
Pediatric Hemato-oncologist
Indraprastha Apollo Hospital
New Delhi, India
Immunocompromised Child in the Pediatric Intensive Care Unit

Amit Varma MBBS

American Board Certified in Internal Medicine
(Critical Care Medicine, Perinatal and Neonatal)
Director, Critical Care
Fortis Escorts Heart Institute
New Delhi, India
Hypertension in Children
Perioperative Management of Transposition of Great Arteries
Perioperative Management of Total Anomalous Pulmonary Venous Drainage
Perioperative Management Strategy of Univentricular Heart

Anand Bhutada MD

Consultant Pediatric Intensivist
Child Hospital
Nagpur, Maharashtra, India
Respiratory Monitoring in Pediatric Intensive Care Unit

Anil Sachdev MD

Director, Pediatric Emergency
Critical Care and Pulmonology
Department of Pediatrics
Institute of Child Health—Sir Ganga Ram Hospital
New Delhi, India
Cardiac Pacing in Pediatric Intensive Care Unit

Anita S Bakshi MD

Senior Consultant, Pediatric Intensivist
and Pulmonologist
Indraprastha Apollo Hospital
New Delhi, India
Acute Liver Failure

Anjali A Kulkarni MD

Senior Consultant, Neonatologist and Director
Department of Pediatrics
Sir HN Reliance Foundation Hospital
and Research Centre
Mumbai, Maharashtra, India
Neonatal Ventilation

Anupam Sibal MD

Senior Consultant Pediatric
Gastroenterologist, Hepatologist
Indraprastha Apollo Hospital
New Delhi, India
Liver Transplantation in Children: Indian Scenario

Bala Ramachandran MD

Consultant and Head
Department of Intensive Care and Emergency Medicine
Kanchi Kamakoti Child Trust Hospital
Chennai, Tamil Nadu, India
Pediatric Tracheostomy
Near-drowning
Pediatric Brain Death Guidelines

Bhaskar Saikia MD

Consultant Pediatric Intensivist
Sri Balaji Action Medical Institute
New Delhi, India
Empyema Thoracis in Children
Disease-specific Ventilation
Pediatric Head Injury

Bichitrovanu Sarkar MRCP (UK)

Consultant Pediatric Intensivist
AMRI Group of Hospital
Kolkata, West Bengal, India
Inotropes and Vasopressors in the Pediatric Intensive Care Unit

Chhabi Ranu Gupta MS

Consultant Pediatric Surgery
Holy Family Hospital
New Delhi, India
Multiple Trauma: Stabilization and Management in Pediatric Intensive Care Unit

David Todres I (Late) MD FAAP FCCM

Professor, Pediatrics, Anesthesia and Critical Care
Harvard Medical School—Massachusetts General Hospital
Boston, Massachusetts, USA
Upper Airway Obstruction in Children

Deepika Singhal MD

Consultant Pediatric Intensivist
Pushpanjali Crosslay Hospital
Ghaziabad, Uttar Pradesh, India
*Neonatal Congenital Lung Lesions
Basic Mechanical Ventilation
Pediatric Human Immunodeficiency Viral Infections
Bacterial, Viral and Fungal Meningitis*

Dhiren Gupta MD

Consultant Pediatric Intensive Care
Department of Pediatrics
Sir Gangaram Hospital
New Delhi, India
*Airway Management
Cardiac Pacing in Pediatric Intensive Care Unit
Coma: Encephalitis and Cerebral Malaria*

Dipankar Gupta MD

Fellow Pediatric Cardiology and Critical Care Medicine
Department of Pediatrics
Congenital Heart Center
University of Florida College of Medicine
Gainesville, Florida, USA
*Pediatric Mechanical Circulatory Support
Heart Transplantation in Pediatrics*

Ebor Jacob MD

Consultant Pediatric Intensivist
Christian Medical College (CMC)
Vellore, Tamil Nadu, India
Nosocomial Infections and Management

Farhan Shaikh MD

Consultant Pediatric Intensivist and NABH Consultant
Rainbow Children Hospital
Hyderabad, Andhra Pradesh, India
*Transport of Critically Ill Children
Concept of Quality Improvement in Pediatric Intensive Care Unit*

Frank Zimmerman MD

Assistant Professor
The University of Chicago Medicine
Comer Children's Hospital
Chicago, Illinois, USA
Pediatric Pacemaker and Implantable Cardioverter-defibrillator Therapy

Frederick Jay Fricker MD

Professor and Chief
Division of Pediatric Cardiology, Congenital Heart Center
University of Florida College of Medicine
Gainesville, Florida, USA
Heart Transplantation in Pediatrics

Gaurav Kharya MD

Consultant Pediatric Hemato-oncologist and BMT Specialist
BLK Centre for Bone Marrow Transplant
BLK Super Speciality Hospital
New Delhi, India
Bone Marrow Transplantation in Children

Gnanam R MD IDPCCM

Consultant Pediatric Intensivist and Incharge
Pediatric Intensive Care Unit
Manipal Hospital
Bengaluru, Karnataka, India
Status Epilepticus

Giuseppe Marraro MD

Professor of Pediatrics and Anesthesiology
Ophthalmic Hospital
Milan, Italy
*Airway Management
Upper Airway Obstruction in Children*

Gurinder Pal Singh (Late) IDPCCM

Consultant Pediatric Intensivist
BLK Super Speciality Hospital
New Delhi, India
Blood Transfusion in Neonatal and Pediatric Intensive Care

Harish Vyas MRCP (UK)

Consultant Pediatric Intensive Care Unit
Birmingham, UK
Viral Pneumonias: Common Pneumonias and Recent Advances

Indira Jayakumar MD

Consultant Pediatric Intensivist
Apollo Hospital
Chennai, Tamil Nadu, India
Endocrine Emergencies in Critically Ill Children

Indumathy Santhanam MD

Incharge Pediatric Emergency Care
Institute of Child Health
Chennai, Tamil Nadu, India
Dengue with Shock

Jai P Udassi MD

Assistant Professor
Division of Pediatric Cardiology
Congenital Heart Center
University of Florida College of Medicine
Gainesville, Florida, USA
Heart Transplantation in Pediatrics

Jashua Caresky MD

Consultant Pediatric Surgeon
Chippenham, Johnston-Wills Hospital
Richmond, Virginia, USA
Multiple Trauma: Stabilization and Management in Pediatric Intensive Care Unit

Jeffrey C Benson MD

Pediatric Intensivist
Children's Hospital of Wisconsin
Wisconsin, Michigan, USA
High-frequency Ventilation

Jesal Sheth MD

Consultant Pediatric Intensivist and Neonatologist
Fortis Hospital
Mumbai, Maharashtra, India
Common Congenital Heart Defects and Perioperative Issues

Jhuma Sankar MD

Associate Professor
Department of Pediatrics
All India Institutes of Medical Sciences (AIIMS)
New Delhi, India
Role of Echocardiography in the Pediatric Intensive Care Unit

John M Downey MD

Assistant Professor
The University of Chicago Medicine
Comer Children's Hospital
Chicago, Illinois, USA
Liver Transplantation

Jose Irazzuzta MD

Director Pediatric ICU
Wolfson Children's Hospital
Jacksonville, Florida, USA
Bacterial, Viral and Fungal Meningitis

Jyotinder Kaur MD

Head, Department of Pediatrics
Apollo Hospital
Ahmedabad, Gujarat, India
*Flexible Bronchoscopy in Infants and Children
Sedation, Analgesia and Neuromuscular Blockade*

Kala Ebnezar MD

Consultant Pediatric intensivist
Christian Medical College (CMC)
Vellore, Tamil Nadu, India
Nosocomial Infections and Management

Kanav Anand MBBS MD Pediatrics Fellowship in Pediatric Nephrology

Pediatric Nephrologist
Division of Pediatric Nephrology
Institute of Child Health—Sir Ganga Ram Hospital
New Delhi, India
*Acute Kidney Injury in Children and Renal Replacement Therapy
Pediatric Renal Transplantation*

Krishan Chugh MD

Director Pediatrics
Pediatric Pulmonologist and Intensivist
Fortis Memorial Research Institute
Gurgaon, Haryana, India
Coma: Encephalitis and Cerebral Malaria

Leticia Castillo MD FCCM

Associate Professor
Pediatric Intensive Care Unit
Baylor College of Medicine Houston
Texas, USA
Pediatric Septic Shock

Madelyn Kahana MD

Director, Pediatric Intensive Care Unit
The University of Chicago Medicine
Comer Children's Hospital
Chicago, Illinois, USA
*Pediatric Pacemaker and Implantable Cardioverter-Defibrillator Therapy
Liver Transplantation*

Madhulika Kabra MD

Department of Pediatrics
All India Institutes of Medical Sciences (AIIMS)
New Delhi, India
Cystic Fibrosis: Clinical Manifestations and Treatment

Makroo RN MD

Senior Consultant and Incharge
Department of Transfusion Medicine
Indraprastha Apollo Hospital
New Delhi, India
Blood Transfusion in Neonatal and Pediatric Intensive Care

Mallikarjun RP MD DCH

Assistant Professor Pediatrics
Fellowship in Pediatric Intensive Care
AJ Institute of Medical Sciences
Mangaluru, Karnataka, India
Malaria

Mani RK MD

Senior Consultant
Respiratory and Critical Care Medicine
Saket City Hospital
New Delhi, India
Ethical Issues Related to End-of-life

Maninder S Dhaliwal MD

Consultant Pediatric Intensivist
Medanta—The Medicity Hospital
Gurgaon, Haryana, India
*Hemodynamic Monitoring in Pediatric Intensive Care Unit
Procedures in Pediatric Intensive Care Unit*

Manish Malik MRCP (UK)

Consultant Neonatologist
Max Super Speciality Hospital
New Delhi, India
*Meconium Aspiration Syndrome and Persistent
Pulmonary Hypertension of Newborn*

Manish Vaish MS

Senior Registrar Neurosurgery
Sir Ganga Ram Hospital
New Delhi, India
Hydrocephalus

Mark S Bleiweis MD

Professor and Cardiothoracic Surgeon
Director Congenital Heart Center
University of Florida College of Medicine
Gainesville, Florida, USA
Heart Transplantation in Pediatrics

Meera Luthra MCh (Pediatric Surgery)

Senior Consultant
Pediatric Surgeon
Holy Family Hospital and Medanta—The Medicity Hospital
New Delh, India
*Neonatal Congenital Lung Lesions
Multiple Trauma: Stabilization and Management in
Pediatric Intensive Care Unit
Perioperative Anesthetic and Surgical Issues*

Meera Ramakrishnan MD

Pediatric Intensivist and Emergency Incharge
Manipal Hospital
Bengaluru, Karnataka, India
Care of the Ventilated Patient

Michael A Maymi CPNP-AC

PICU Nurse Practitioner
Department of Pediatrics
University of Florida
Gainesville, Florida, USA
Pediatric Mechanical Circulatory Support

Mosharraf Shamim MD

Consultant Pediatric Intensivist
King Fahd Hospital
Saudi Arabia
*Cardiac Arrhythmias in Pediatric Intensive Care Unit
Intensive Care Unit-acquired Weakness*

Mritunjay Pao MD

Consultant Pediatric Intensivist and Neonatologist
Sanjeevani Hospital
Jorhat, Assam, India
*Flexible Bronchoscopy in Infants and Children
Basic Mechanical Ventilation
Status Epilepticus*

Mukesh Desai MD

Consultant Pediatric Hemato-oncologist
Bai Jerbai Wadia Hospital for Children
Mumbai, Maharashtra, India
*Immunocompromised Child in the Pediatric Intensive
Care Unit*

Nameet Jerath MD

Senior Consultant Pediatric Intensivist
and Pulmonologist
Indraprastha Apollo Hospital
New Delhi, India
*Cardiogenic Shock
Acute Liver Failure*

Neeraj Gupta MD

Consultant Pediatric Critical Care
Department of Pediatrics
Institute of Child Health
Sir Ganga Ram Hospital
Cardiac Pacing in Pediatric Intensive Care Unit

Nitesh Singhal MD

Consultant
Pediatric Intensive Care Unit
The Hospital for Sick Children
Toronto, Canada
Inborn Errors of Metabolism

Pankaj Vohra MD

Pediatric Gastroenterologist

Max Healthcare

New Delhi, India

*Parenteral Nutrition for the Pediatrician***Pooja Verma MS**

Clinical Psychologist

Fellow Social Research Methods

The London School of Economics and Political Science

London, UK

*Psychological Issues in Pediatric Intensive Care Unit***Prabhat Maheshwari MRCP (UK)**

Incharge

Consultant Pediatric Intensivist

Artemis Hospital

Gurgaon, Haryana, India

*Acute Respiratory Distress Syndrome in Children***Pradeep Sharma MD**

Consultant Pediatric Intensivist

Sri Balaji Action Medical Institute

New Delhi, India

*Oxygen Therapy in Pediatrics**Empyema Thoracis in Children**Poisoning and Bites***Pranay Oza MS**

Senior Perfusionist and ECMO Specialist

Incharge Extracorporeal Membrane Oxygenation (ECMO)

Program

Riddhivinayak Cardiac Centre

Mumbai, Maharashtra, India

*Extracorporeal Membrane Oxygenation***Prasanna C Tellis MD**

Consultant Pediatric Cardiology

Narayana Hrudyalaya

Bengaluru, Karnataka, India

*Hypertension in Children***Prashant Jain MCh (Pediatric Surgery)**

Consultant Pediatric Surgery

BLK Super Speciality Hospital

New Delhi, India

*Pediatric Thoracoscopy**Empyema Thoracis in Children***Prashant Pruthi MD**

Consultant Pediatric Intensive Care

Sydney Children's Hospital

NSW, Australia

*Hypertension in Children**Disseminated Intravascular Coagulation***Praveen Khilnani MD FICCM FAAP FCCM (USA)**

Diplomate American Board of Pediatric Critical Care Medicine

Chair Guidelines Committee 2001 (for IAP and ISCCM)

Senior Consultant and Head

Pediatric Critical Care and Pulmonology

BLK Super Speciality Hospital

New Delhi, India

*Assessment and Initial Management: A Practical Approach**Airway Management**Consensus Guidelines for Pediatric Intensive Care Units in**India**Nursing Care in the Pediatric Intensive Care Unit**Procedures in Pediatric Intensive Care Unit**Flexible Bronchoscopy in Infants and Children**Ultrasound in Pediatric Intensive Care Unit**Respiratory Physiology**Oxygen Therapy in Pediatrics**Blood Gas and Acid-base Interpretation**Upper Airway Obstruction in Children**Meconium Aspiration Syndrome and Persistent**Pulmonary Hypertension of Newborn**Acute Respiratory Failure**Acute Severe Asthma Management in Pediatric Intensive**Care Unit**Viral Pneumonias: Common Pneumonias and Recent**Advances**Persistent and Recurrent Pneumonias**Recent Advances in the Rapid Diagnosis of Respiratory**Tract Infection**Human Immunodeficiency Virus Disease and Respiratory**Infection in Children**Acute Respiratory Distress Syndrome in Children**Empyema Thoracis in Children**Neonatal Congenital Lung Lesions**Bronchodilator Therapy in Mechanically Ventilated**Children**Basic Mechanical Ventilation**Commonly Available Ventilators**Disease-specific Ventilation**Advanced Mechanical Ventilation**Ventilator Graphics and Clinical Applications**Weaning from Mechanical Ventilation**Complications of Mechanical Ventilation**High-frequency Ventilation**Inhaled Nitric Oxide**Extracorporeal Membrane Oxygenation**Shock: Management in Pediatric Intensive Care Unit**Pediatric Septic Shock**Multiorgan Failure in Critically Ill Children**Role of Echocardiography in the Pediatric Intensive Care**Unit*

Interventional Pediatric Cardiology: An Overview
Cardiac Arrhythmias in Pediatric Intensive Care Unit
Common Congenital Heart Defects and Perioperative Issues
Pediatric Pacemaker and Implantable Cardioverter-defibrillator Therapy
Diabetic Ketoacidosis
Gastrointestinal Bleeding: Diagnosis and Management
Liver Transplantation
Nutrition in the Pediatric Intensive Care Unit
Blood Transfusion in Neonatal and Pediatric Intensive Care
Pediatric Human Immunodeficiency Virus Infections
Bone Marrow Transplantation in Children
Antibiotic Therapy in the Pediatric Intensive Care Unit
Multiple Trauma: Stabilization and Management in Pediatric Intensive Care Unit
Child Abuse and Shake Injuries
Perioperative Anesthetic and Surgical Issues
Poisoning and Bites
Thermal Burns
Bacterial, Viral and Fungal Meningitis
Hydrocephalus
Status Epilepticus
Pediatric Head Injury
Sedation, Analgesia and Neuromuscular Blockade Intensive Care Unit-acquired Weakness
Care of Terminally Ill Children
Psychosocial Issues in Pediatric Intensive Care Unit
Ethical Issues Related to End-of-life
Training in Pediatric Critical Care Medicine
Simulation-based Training in Pediatric Intensive Care
Research in the Pediatric Intensive Care Unit
Drugs Used in the Pediatric Intensive Care Unit

Preetha Joshi MD

Consultant Pediatric Intensivist and Neonatologist
Kokilaben Dhirubhai Ambani Hospital & Medical Research Institute
Mumbai, Maharashtra, India
Myocarditis in Children
Fluid and Electrolyte Abnormalities in the Critically Ill Children

Priyanka Sharma DNB FNB

Consultant Pediatric Hemato-oncologist
Christian Medical College (CMC)
Ludhiana, Punjab, India
Immunocompromised Child in the Pediatric Intensive Care Unit

Pruthi PK MBBS MD (Pediatrics) MNAMS

Senior Pediatric Nephrologist
Division of Pediatric Nephrology
Institute of Child Health
Sir Ganga Ram Hospital
New Delhi, India
Acute Kidney Injury in Children and Renal Replacement Therapy
Pediatric Renal Transplantation

Purnima Dhar MD

Senior Consultant Anesthesia
Indraprastha Apollo Hospital
New Delhi, India
Heat Disorders

Rachna Sharma MD

Consultant Pediatric Intensivist
BLK Super Speciality Hospital
New Delhi, India
Procedures in Pediatric Intensive Care Unit
Empyema Thoracis in Children
Bone Marrow Transplantation in Children

Rajesh Chawla MD

Senior Consultant
Respiratory and Critical Care Medicine
Indraprastha Apollo Hospital
New Delhi, India
Bronchodilator Therapy in Mechanically Ventilated Children

Rajesh Mehta MD

Professor of Pediatrics and Consultant
World Health Organization, New Delhi, India
Disseminated Intravascular Coagulation

Rajesh Sharma MS MCh (Cardiothoracic Surgery)

Director and Head
Pediatric Cardiac Surgery
Fortis Escorts Heart Institute & Research Centre
New Delhi, India
Perioperative Management of Transposition of Great Arteries
Perioperative Management of Total Anomalous Pulmonary Venous Drainage
Perioperative Management Strategy of Univentricular Heart

Rajiv Uttam MRCP (UK)

Senior Consultant
Pediatric Intensivist and Pulmonologist
Max Super Speciality Hospital
New Delhi, India
Non-invasive Ventilation
Multiorgan Failure in Critically Ill Children

Rakesh Lodha MD
 Additional Professor
 Department of Pediatrics
 All India Institutes of Medical Sciences (AIIMS)
 New Delhi, India
Air Leak Syndromes
Cystic Fibrosis: Clinical Manifestations and Treatment

Rakshay Shetty MD
 Consultant Pediatric Intensivist
 Rainbow Children's Hospital
 Bengaluru, Karnataka, India
Intracranial Pressure Monitoring
Simulation-based Training in Pediatric Intensive Care

Ramesh S MD
 Pediatric Anesthesiologist
 Kanchi Kamakoti Child Trust Hospital
 Chennai, Tamil Nadu, India
Commonly Available Ventilators
Perioperative Anesthetic and Surgical Issues

Ramesh Sachdeva MD MBA
 Pediatric Intensivist and Vice President
 Children's Hospital of Wisconsin
 Wisconsin, Michigan, USA
High-frequency Ventilation

Ravi R Thiagarajan MBBS MPH
 Senior Associate in Cardiology
 Department of Cardiology
 Cardiac Intensive Care Unit
 Boston Children's Hospital
 Associate Professor of Pediatrics
 Harvard Medical School
 Boston, MA, USA
*Postoperative Care of Cardiac Patients After
 Open Heart Surgery*

Reeta Singh MD
 Consultant Pediatrics
 Royal Children's Hospital
 Melbourne, Australia
Inhaled Nitric Oxide
Nutrition in the Pediatric Intensive Care Unit

Ricardo Munoz MD
 Director, Cardiac Intensive Care Unit
 Children's Hospital of Pittsburgh
 Pittsburgh, Pennsylvania, USA
Blood Gas and Acid-base Interpretation

Sagar Lad MD
 Consultant Pediatric Intensivist and Neonatologist
 Jehangir Hospital
 Pune, Maharashtra, India
Drugs Used in the Pediatric Intensive Care Unit

Sandeep Chopra MCh (Neurosurgery)
 Consultant Pediatric Neurosurgery
 Sir Ganga Ram Hospital
 New Delhi, India
Hydrocephalus
Pediatric Head Injury

Sankaran Krishnan MD
 Pediatric Pulmonologist
 Cornell University Medical Center
 New York, USA
Weaning from Mechanical Ventilation

Sanjeev Sharma MD
 Associate Consultant Pediatric Hemato-oncologist
 and BMT Specialist
 BLK Center for Bone Marrow Transplant
 BLK Super Speciality Hospital
 New Delhi, India
Bone Marrow Transplantation in Children

Santosh T Soans MD DCH FIAP
 Professor and Head, Department of Pediatrics
 AJ Institute of Medical Sciences
 Mangaluru, Karnataka, India
Malaria

Satish Deopujari MD
 Consultant Pediatric Intensivist
 Central India's Child Hospital and Research Institute
 Nagpur, Maharashtra, India
Oxygen Therapy in Pediatrics

Seth RK MCh (Plastic Surgery)
 Senior Consultant Plastic Surgery
 Indraprastha Apollo Hospital
 New Delhi, India
Thermal Burns

Shekhar T Venkataraman MD
 Professor, Department of Critical Care Medicine
 and Pediatrics
 University of Pittsburgh School of Medicine
 Medical Director, Respiratory Care Services
 Children's Hospital of Pittsburgh
 Pittsburgh, Pennsylvania, USA
Basic Mechanical Ventilation
Pediatric Heart and Lung Transplantation

Shipra Gulati MD
 Consultant Pediatric Intensivist
 Max Super Speciality Hospital
 Patparganj, New Delhi, India
Non-invasive Ventilation

Shiv Kumar Rajdev MD MRCP (UK)

Senior Consultant Pediatrics
NHS, Birmingham, UK
Pediatric Human Immunodeficiency Virus Infections

Shushil Kabra MD

Professor
Department of Pediatrics
All India Institute of Medical Sciences (AIIMS)
New Delhi, India
Cystic Fibrosis: Clinical Manifestations and Treatment

Sidharth Luthra LLB

Senior Advocate
Supreme Court and Additional Solicitor
General (ASG) of India
New Delhi, India
Medicolegal Issues in Intensive Care

Sister Gracey BSc (Nursing)

Head Nurse PICU
Acting Director, Nursing
Indraprastha Apollo Hospital
New Delhi, India
Nursing Care in the Pediatric Intensive Care Unit

Soonu Udani MD

Head, Department of Pediatrics and Consultant
Pediatric Intensivist
PD Hinduja Hospital
Mumbai, Maharashtra, India
Electrical Shock

Suchita Khadse MD

Consultant Pediatric Intensivist
Central India's Child Hospital and Research Institute
Nagpur, Maharashtra, India
Poisoning and Bites

Suchitra Ranjit MD

Pediatric Intensivist Incharge
Apollo Hospitals
Chennai, Tamil Nadu, India
Oxygen Therapy in Pediatrics

Sujatha Thyagarajan MD

Consultant Pediatric Intensivist
HCG Hospital
Bengaluru, Karnataka, India
Simulation-based Training in Pediatric Intensive Care

Sukhmeet Singh MD

Consultant Pediatrics
Dayananda Medical College & Hospital
Ludhiana, Punjab, India
Diabetic Ketoacidosis

Suneel Pooboni MD MRCP (UK)

Head, Department of Pediatric ICU and ECMO
Program
KIMS Hospital
Hyderabad, Telangana, India
Extracorporeal Membrane Oxygenation

Sunil Gomber MD

Professor and Head
Department of Pediatrics
Guru Teg Bahadur Hospital
New Delhi, India
Methemoglobinemia

Suresh Panda MD

Consultant Pediatric Intensivist
Rainbow Children Hospital
Hyderabad, Andhra Pradesh, India
Intracranial Pressure Monitoring

Taneja LN MD

Consultant
Department of Pediatrics
PAST National Convener
IAP ALS Group
Max Super Speciality Hospital
Patparganj, New Delhi, India
*Cardiopulmonary Resuscitation:
2010 Guidelines Summary*

Ted A Williams MD

Pediatric Gastroenterologist
St Mary's Hospital
Richmond, Virginia, USA
*Gastrointestinal Bleeding: Diagnosis and
Management*

Thangavelu S MD

Consultant Pediatric Intensivist Incharge
Dr Mehta's Children's Hospital
Chennai, Tamil Nadu, India
Dengue with Shock

Thomas Albrecht G MD

Pediatric Cardiologist
Chippenham and Johnston-Willis Hospital
Richmond, Virginia, USA
Interventional Pediatric Cardiology: An Overview

Utkarsh Kohli MD

Consultant Pediatric Intensivist
The University of Chicago Medicine
Comer Children's Hospital
Chicago, Illinois, USA
Air Leak Syndromes

Uttara Babbar LLB

Advocate
Supreme Court of India
New Delhi, India
Medicolegal Issues in Intensive Care

Verma IC MD

Incharge
Department of Genetics and Metabolic Disorders
Sir Ganga Ram Hospital
New Delhi, India
Inborn Errors of Metabolism

Vidya Gupta MRCP (UK)

Senior Consultant Neonatologist
Indraprastha Apollo Hospital
New Delhi, India
Surfactant Therapy in Newborn

Vidyut Bhatia MD

Consultant Pediatric Gastroenterologist
and Hepatologist
Indraprastha Apollo Hospital
New Delhi, India
Liver Transplantation in Children: Indian Scenario

Vikram Gagneja MD

Consultant Pediatric Intensivist
Max Super Speciality Hospital
New Delhi, India
*Ultrasound in Pediatric Intensive Care Unit
Pediatric Septic Shock*

Vinayak K Patki MD

Consultant Pediatric Intensivist
Wanless Hospital
Miraj, Maharashtra, India
Drugs Used in the Pediatric Intensive Care Unit

Vinay Joshi MD

Consultant Pediatric Intensivist and Neonatologist
Kokilaben Dhirubhai Ambani Hospital & Medical
Research Institute
Mumbai, Maharashtra, India
*Myocarditis in Children
Fluid and Electrolyte Abnormalities
in the Critically Ill Children*

Vinay Kukreti MD

Consultant Pediatric Intensivist
The Hospital for Sick Children
Toronto, Canada
*Cardiac Arrhythmias in Pediatric Intensive Care Unit
Intensive Care Unit-acquired Weakness in Children*

Vinay K Aggarwal MRCP (UK)

Senior Consultant, Pediatric Nephrologist
Max and BLK Super Speciality Hospitals
New Delhi, India
Inborn Errors of Metabolism

Vishal K Singh DCH MD DNB (Pediatrics)

Senior Consultant, Pediatric Cardiac Care
Fortis Escorts Heart Institute & Research Centre
New Delhi, India
*Perioperative Management of Transposition of Great
Arteries
Perioperative Management of Total Anomalous
Pulmonary Venous Drainage
Perioperative Management Strategy of Univentricular
Heart*

Vishram B Buche MD

Consultant Pediatric Intensivist
Central India's Child Hospital and Research Institute
Nagpur, Maharashtra, India
Respiratory Monitoring in Pediatric Intensive Care Unit

Wendy E Barnes CPNP-AC

PICU Nurse Practitioner
Department of Pediatrics
University of Florida
Gainesville, Florida, USA
Pediatric Mechanical Circulatory Support

Yogesh Govil (Late) MD

Professor
Department of Pediatrics
King George's Medical University
Lucknow, Uttar Pradesh, India
Acute Respiratory Failure

Zahid Hussain MD

Fellow Pediatric Intensive Care
BLK Super Speciality Hospital
New Delhi, India
Empyema Thoracis in Children

Foreword

Pediatric critical care is a relatively new subspecialty and has developed rapidly in many parts of the world. In India, it is still in infancy, but over the last few years, it has made great strides. The standard of care for the critically ill or injured child is more or less at par with other countries. It is very gratifying to see that many institutions have excellent pediatric intensive care units with current state of the art. The Indian Society of Critical Care Medicine and the Indian Academy of Pediatrics are to be commended for their lead and enormous input to disseminate the knowledge and skills to physicians, nurses and other healthcare personnel. With the explosion in current technology and monitoring techniques, many lives are being saved.

This book entitled *Practical Approach to Pediatric Intensive Care* edited by Dr Praveen Khilnani, Senior Consultant and Head, Pediatric Critical Care and Pulmonology, BLK Super Speciality Hospitals, New Delhi, India, will be a valuable companion to all the medical and nursing personnel. Many areas and topics have been covered well by the author who is well experienced to conditions that prevail the world over.

A book like this cannot be exhaustive and complete. But, it contains practical guidance for the routine daily care of the sick child. I commend the editor for his efforts and venture.

Janakiraman N MD FAAP FCCM (USA)
Professor
Pediatrics and Critical Care
University of Illinois
Cook County Health and Hospitals System
Chicago, Illinois, USA

Jaypee Brothers

Preface to the Third Edition

Since the publication of the first edition in 2004, the field of pediatric critical care has grown by leaps and bounds, newer developments and guidelines have emerged. New resuscitation guidelines (AHA PALS, 2010) as well as International Surviving Sepsis Guidelines (2012) have been included, in addition to overall upgrading of latest information and technology in the field of pediatric critical care. Pediatric intensive care delivery is cost intensive and can be a limiting factor in resource-limited countries, such as India. Resource limitations have been particularly kept in mind, while discussing various treatment and investigative modalities. Practice-oriented flowcharts have been updated in several chapters for giving a quick overview of management of common pediatric intensive care unit problems.

I hope that this book *Practical Approach to Pediatric Intensive Care* will emerge as truly practical companion to doctors and nurses at various levels of training, consultants in teaching programs, and also in corporate practice of pediatric critical care in saving lives of critically ill children.

Praveen Khilnani

Jaypee Brothers

Preface to the First Edition

The field of pediatric critical care (pediatric intensive care) is rapidly advancing, and new innovations and technologies are being frequently incorporated into the delivery of pediatric critical care. The role of the pediatric critical care specialist (pediatric intensivist) has become more defined as pediatrician who specializes in the field of diagnosis of critical pediatric illnesses and prompt management employing all the principles of pediatric pathophysiology, including hemodynamic disturbances, tissue oxygen delivery, septic process, trauma and surgical stress, and systemic inflammatory response syndrome (SIRS). Treatment of critical illness involves a good grasp on ways to improve the oxygen delivery for management of shock, respiratory failure and sepsis. Clinical reserve in a pediatric patient is far less compared to an adult patient; therefore, a timely detection of a clinically deteriorating patient as well as a prompt institution of appropriate resuscitative efforts goes a long way. A pediatric intensivist must be well trained in emergency procedures, such as central line placement, endotracheal intubation, bag-mask ventilation, arterial line placement, sedation, ventilator management, chest tube placement, lumbar puncture, oxygen therapy, cardiopulmonary resuscitation, intraosseous line placement, and above all the application of appropriate clinical judgment to use the above skills effectively and safely to improve patient outcome.

This book has been written and edited to emphasize practical aspects of pediatric intensive care contributed by various national and international authors involved in routine day-to-day management in the multidisciplinary pediatric intensive care unit with collaboration of a team of specialists including medical, surgical, nursing and other important ancillary services. Ethical, legal and nursing issues have also been included. I sincerely hope this book will be a resource to those practicing and training in the field of pediatric critical care medicine.

The effort has been made to present currently accepted consensus on therapy rather than dogmatic opinions. I wish to thank all the contributors and my family members for their unconditional support.

Praveen Khilnani

Contents

Section 1: Basic Practical Issues

1. Assessment and Initial Management: A Practical Approach	3
<i>Praveen Khilnani, Amit Gupta</i>	
Evaluate, Identify and Intervene	3
Initial Impression	3
Primary Assessment	4
Secondary Assessment	6
2. Pediatric Advanced Life Support 2010 Guidelines	11
Pediatric Advanced Life Support	11
Basic Life Support Considerations	
During Pediatric Advanced Life Support	12
Monitoring	17
Emergency Fluids and Medications	18
Medications	18
Pulseless Arrest	20
Defibrillators	22
Automated External Defibrillators	23
Special Resuscitation Situations	27
Children with Special Healthcare Needs	28
Postresuscitation Stabilization (Postcardiac Arrest Care)	30
Interhospital Transport	32
Family Presence During Resuscitation	32
Termination of Resuscitative Efforts	33
Sudden Unexplained Deaths	33
Credit and Acknowledgment	35
3. Cardiopulmonary Resuscitation: 2010 Guidelines Summary	36
<i>Taneja LN</i>	
History of Cardiopulmonary Resuscitation	36
Sequence of CPR	37
Sequence in Pediatric BLS	37
Pulse Check (De-emphasized)	39
Electrical Therapy (Automated External Defibrillator)	39
Postcardiac Arrest Care	39
De-emphasis on Devices and Advanced Cardiovascular Life Support Drugs	
During Cardiac Arrest	40
4. Airway Management	41
<i>Praveen Khilnani, Dhiren Gupta, Giuseppe Marraro</i>	
Anatomical Differences	41
Physiological Differences	41
Airway Management Techniques	42
Difficult Intubation	47

5. Transport of Critically Ill Children	56
<i>Farhan Shaikh</i>	
Transport Team Composition	56
Equipments, Supplies and Medications	57
Mode of Transport	57
Point of Communication	58
Stabilization of the Critically Ill or Injured Child for Transport	58
Respiratory Care and Ventilatory Support	59
Regulatory and Medicolegal Issues	60
Intrahospital Transport	61
6. Consensus Guidelines for Pediatric Intensive Care Units in India	62
<i>Praveen Khilnani, Chair Guidelines Committee (for IAP and ISCCM)</i>	
Unit Design	62
Equipment	64
Organization and Staffing	64
Ancillary Support Staff	65
Levels of PICU Care and Admission and Discharge Criteria	66
Consensus Guidelines	67
Appendix: Drugs Recommended to be Stored in PICU	68
7. Hemodynamic Monitoring in Pediatric Intensive Care Unit	70
<i>Maninder S Dhaliwal</i>	
Hemodynamic Monitoring	70
8. Intracranial Pressure Monitoring	95
<i>Suresh Panda, Rakshay Shetty</i>	
Pathophysiology	95
Interaction with Blood Pressure and Cerebral Blood Flow	96
Normal and Pathologic ICP	96
Causes of Raised Intracranial Pressure	97
Intraventricular Catheters	97
Why Monitor ICP?	100
Opinions Against ICP Monitoring	101
9. Respiratory Monitoring in Pediatric Intensive Care Unit	104
<i>Vishram B Buche, Anand Bhutada</i>	
Physical Examination	104
Non-invasive Respiratory Monitoring	104
Limitations	110
Pulmonary Function Tests	111
Invasive Monitoring	112

10. Nursing Care in the Pediatric Intensive Care Unit	117	Section 2: Respiratory System Issues	
<i>Praveen Khilnani, Sister Gracey</i>			
Basic Life Support Protocol	118	15. Respiratory Physiology	229
Bradycardia Algorithm	118	<i>Praveen Khilnani</i>	
Tachycardia Algorithm	118	Basic Respiratory Physiology	229
Pulseless Arrest	121	Applied Respiratory Physiology for Mechanical Ventilation	233
Care of the Hemodynamically Unstable Ventilated Pediatric Patient	123	16. Oxygen Therapy in Pediatrics	235
Use of DOPE	124	<i>Pradeep Sharma, Satish Deopujari, Suchitra Ranjit, Praveen Khilnani</i>	
Routine Ventilator Management Protocol	124	Oxygen Transport	235
Care of a Patient with Intracranial Pressure Monitoring	129	Oxygen Content and Delivery	235
Legal Considerations in Withdrawing Treatment	130	Indications for Oxygen Therapy	236
Breaking Bad News: The Nurse's Role (for Pediatrics)	131	Oxygen-dissociation Curve	236
Appendix: Commonly Done PICU Nursing Procedures and Policies	133	Administration of Oxygen Therapy	237
11. Procedures in Pediatric Intensive Care Unit	152	Oxygen Hood	238
<i>Rachna Sharma, Maninder S Dhaliwal, Praveen Khilnani</i>		Goals of Oxygen Therapy	238
Intubation	152	Cautions for Oxygen Therapy	238
Laryngoscopy	160	17. Blood Gas and Acid-base Interpretation	240
Central Line Placement	163	<i>Ricardo Munoz, Praveen Khilnani</i>	
Arterial Line Placement	169	Acidosis	240
Intracranial Pressure Monitoring	173	Alkalosis	240
Chest Tube Placement	177	Buffering System	240
Intra-abdominal Pressure Monitoring	184	Homeostasis	240
12. Flexible Bronchoscopy in Infants and Children	189	Pathophysiology	241
<i>Praveen Khilnani, Jyotinder Kaur, Mritunjay Pao</i>		Metabolic Acidosis	241
Indications	190	Metabolic Alkalosis	242
Contraindications	193	Respiratory Acidosis	243
Bronchoscopic Equipments	193	Respiratory Alkalosis	244
Physics of Flexible Fiberoptic Endoscopes	195	Practical Tips to Approach Acid-base Disorders	245
Basic Anatomy of a Bronchofiberscope	196	Mixed Acid-base Disorders	245
Comparison of Available Fiberscopes	198	18. Upper Airway Obstruction in Children	247
Accessory Instruments	199	<i>David Todres I (Late), Giuseppe Marraro, Praveen Khilnani</i>	
Cleaning and Sterilization	199	Pediatric Airway	247
Fiberoptic Cart	200	Specific Diseases	250
Suggestions for Fiberscope Usage	200	Supraglottitis (Epiglottitis)	256
Anatomy for the Bronchoscopist	201	Laryngotracheobronchitis	257
13. Pediatric Thoracoscopy	213	Bacterial Tracheitis	259
<i>Prashant Jain</i>		Foreign Bodies	259
Indications of Thoracoscopy in Children	213	Traumatic Injury	261
Anesthesia and Operative Technique	214	Burn Injury	261
Thoracoscopy in Empyema	214	Angioedema	261
Postoperative Care	216	Tracheal Stenosis	261
14. Ultrasound in Pediatric Intensive Care Unit	218	Tracheomalacia	262
<i>Vikram Gagneja, Praveen Khilnani</i>		Mediastinal Masses	263
Basic Technology	218	19. Meconium Aspiration Syndrome and Persistent Pulmonary Hypertension of Newborn	266
Clinical Application of Ultrasound	218	<i>Manish Malik, Praveen Khilnani</i>	
Fast Examination	224	Pathophysiology of MAS	266
		Clinical Manifestations	267
		Management Strategies	267
		Outcome	269

20. Acute Respiratory Failure	271	Bacteria Identification 324
<i>Yogesh Govil (Late), Praveen Khilnani</i>		Fungi 324
Pathophysiology 272		Other Specific Technologies 324
Clinical Evaluation of a Child with		Non-invasive Markers 325
Impending Respiratory Failure 274		
Specific Disorders Leading to Acute		26. Human Immunodeficiency Virus Disease
Respiratory Failure: Important Issues		and Respiratory Infection in Children
in Diagnosis and Management 281		326
		<i>Praveen Khilnani</i>
21. Pediatric Tracheostomy	287	Incidence of Childhood HIV Infection 326
<i>Bala Ramachandran</i>		Diagnosis of HIV Infection in Infancy 327
History 287		Causes and Management
Indications 287		of Respiratory Infections 327
Types of Tracheostomy Tubes 288		Other Causes of Respiratory Disease 331
Choice of a Tube 289		
Technique 290		27. Acute Respiratory Distress Syndrome
Postoperative Care 291		in Children
Routine Care 291		335
Parent Teaching and Home Care 293		<i>Praveen Khilnani, Prabhat Maheshwari</i>
Decannulation 294		Pathophysiology 335
Complications 294		Physiological Derangements in ARDS 336
		Management of ARDS 337
22. Acute Severe Asthma Management		Other Adjunctive Therapies 341
in Pediatric Intensive Care Unit	296	
<i>Praveen Khilnani</i>		28. Empyema Thoracis in Children
Admission to the Pediatric Intensive		345
Care Unit 296		<i>Pradeep Sharma, Bhaskar Saikia, Rachna Sharma,</i>
Preparation for Intubation 297		<i>Prashant Jain, Zahid Hussain, Praveen Khilnani</i>
Endotracheal Intubation 297		Pathophysiology 345
Mechanical Ventilation 297		Biomarkers and Diagnostic
Non-invasive Ventilation and		Biochemical Tests 346
Status Asthmaticus 300		Imaging of Pleural Infection 346
Summary of Treatment of Acute		Bacterial Tests and Bacteriology
Severe Asthma 301		of Pleural Fluid 347
		Management 347
23. Viral Pneumonias: Common Pneumonias		Indications for Pleural Cavity Drainage 348
and Recent Advances	302	Treatment Failure and Complications 351
<i>Harish Vyas, Praveen Khilnani</i>		Discharge and Follow-up 351
Common Viral Pneumonias 302		
Specific Viral Pathogens and Their Clinical		29. Air Leak Syndromes
Syndromes 302		355
Specific Atypical Pathogens and		<i>Utkarsh Kohli, Rakesh Lodha</i>
Their Clinical Syndromes 306		Pneumothorax 355
Recent Advances 307		Pulmonary Interstitial Emphysema 356
Common Viruses Producing Pneumonia 307		Pneumomediastinum 357
		Pneumopericardium 358
24. Persistent and Recurrent Pneumonias	314	
<i>Praveen Khilnani</i>		30. Cystic Fibrosis: Clinical Manifestations
Differential Diagnosis 315		and Treatment
Investigations 319		360
		<i>Shushil Kabra, Madhulika Kabra, Rakesh Lodha</i>
25. Recent Advances in the Rapid Diagnosis of		Molecular Genetics of Cystic Fibrosis 360
Respiratory Tract Infection	323	Clinical Manifestations 360
<i>Praveen Khilnani</i>		Diagnosis 361
Molecular Probes 323		Supportive Laboratory Tests 361
Detection of Virus 323		Management 361
Detection of Novel Agents of Disease 323		Recombinant Human DNase 362
		Antibiotic Therapy 362
		Management of Other Gastrointestinal Manifestations
		of Cystic Fibrosis 366
		Emerging Therapies 367

31. Neonatal Congenital Lung Lesions	371	38. Care of the Ventilated Patient	443
<i>Deepika Singhal, Meera Luthra, Praveen Khilnani</i>		<i>Meera Ramakrishnan</i>	
Congenital Diaphragmatic Hernia 371		Physiotherapy 443	
Pulmonary Sequestration 373		Humidification 444	
Congenital Lobar Emphysema 375		Suggested Method for Delivery of Drug by Nebulization (Modified from Recommendations by Hess) 445	
Bronchogenic Cysts 377			
Congenital Cystic			
Adenomatoid Malformation 377		39. Weaning from Mechanical Ventilation	449
Esophageal Atresia and		<i>Sankaran Krishnan, Praveen Khilnani</i>	
Tracheoesophageal Fistula 379		Pathophysiology of	
		Ventilator Dependence 449	
32. Bronchodilator Therapy in Mechanically Ventilated Children	385	Recommendation 1 449	
<i>Rajesh Chawla, Praveen Khilnani</i>		Determinants of Weaning Outcome 449	
Principles of Aerosol Therapy 385		Criteria to Assess	
		Ventilator Dependence 451	
33. Basic Mechanical Ventilation	389	Recommendation 2 451	
<i>Praveen Khilnani, Mritunjay Pao, Deepika Singhal, Shekhar T Venkataraman</i>		Recommendation 3 451	
Basic Mechanics of Ventilation 389		Recommendation 4 452	
Indications of Mechanical Ventilation 390		Managing the Patient	
Modes of Ventilation 391		Who has Failed an SBT 452	
Basic Fundamentals of Ventilation 392		Procedure of Weaning from Mechanical Ventilation 453	
Routine Ventilator Management Protocol 395		Weaning Modes 453	
Weaning from Mechanical Ventilation 395		Extubation 456	
Extubation 396		40. Complications of Mechanical Ventilation	459
Appendix: Invasive		<i>Praveen Khilnani</i>	
Mechanical Ventilation 398		Airway Injury from	
		Mechanical Ventilation 459	
34. Commonly Available Ventilators	404	41. Non-invasive Ventilation	462
<i>Praveen Khilnani, Ramesh S</i>		<i>Rajiv Uttam, Shipra Gulati</i>	
Structure and Function		Pathophysiology and	
of a Conventional Ventilator 404		Mechanism of Action 462	
Types of Ventilators 404		Advantages of Non-invasive Ventilation 462	
Specific Ventilators 405		Non-invasive Ventilation	
		Techniques and Equipment 463	
35. Disease-specific Ventilation	414	Applications of Non-invasive Ventilation 463	
<i>Praveen Khilnani, Bhaskar Saikta</i>		Contraindications to	
Disease-specific Mechanical		Non-invasive Ventilation 464	
Ventilation Strategies 414		Signs of Effective Response	
		to Non-invasive Ventilation 464	
36. Advanced Mechanical Ventilation	424	Reasons to Discontinue	
<i>Praveen Khilnani</i>		Non-invasive Ventilation 464	
Advanced Modes and Modalities		Acute Non-invasive	
of Ventilation 424		Ventilation Monitoring 464	
		Author's Experience 464	
37. Ventilator Graphics and Clinical Applications	431	42. High-frequency Ventilation	466
<i>Praveen Khilnani</i>		<i>Jeffrey C Benson, Ramesh Sachdeva, Praveen Khilnani</i>	
Clinical Parameters 431		Concept of Ventilator-induced	
Technique of Respiratory		Lung Injury 466	
Mechanics Monitoring 433		Basic Concepts of	
Ventilator Waveforms 433		High-frequency Ventilation 467	
Abnormal Waveforms		Types of High-frequency Ventilation 467	
Auto-PEEP or Air Trapping 437		Clinical Application 468	

- Settings 468
 Monitoring of Amplitude 470
 Monitoring on HFOV 471
- 43. Inhaled Nitric Oxide 474**
Reeta Singh, Praveen Khilnani
 Endogenous Nitric Oxide 474
 Clinical Pharmacology of Inhaled Nitric Oxide 474
 Persistent Pulmonary Hypertension of Newborns 474
 Doses 475
 Duration of Treatment 475
 Weaning 475
 Unresponsiveness to INO Therapy in PPHN 475
 Monitoring 476
 Transport with INO 476
 Premature Newborns—Uncertainties About Use of INO 476
 Inhaled Nitric Oxide in Chronic Lung Disease 476
 Inhaled Nitric Oxide Therapy in Children with Acute Respiratory Distress Syndrome 476
 Physiological Effects of INO in ARDS 477
 Acute Respiratory Distress Syndrome Controversies with INO Therapy 477
 Adverse Effects of INO 478
- 44. Neonatal Ventilation 480**
Anjali A Kulkarni
 Initiation of Ventilation 480
 Basic Principles of Ventilation 481
 Types of Ventilatory Support 481
 Alternative Modes of Ventilation 482
 Supportive Therapy with Mechanical Ventilation 484
 Complications and Sequelae 485
 Assessing the Outcome 485
- 45. Surfactant Therapy in Newborn 486**
Vidya Gupta
 Surfactant Composition 486
 Surfactant Synthesis and Function 487
 Types of Surfactants 487
 Evidence for Surfactant 488
 Methods of Administration of Surfactant 489
 Surfactant Therapy in MAS 489
- 46. Extracorporeal Membrane Oxygenation 492**
Praveen Khilnani, Pranay Oza, Suneel Pooboni
 Indications of ECMO 492
 Technique of ECMO 494
 Management of ECMO 496
- Complications of ECMO 497
 Setting up an ECMO Program 497
 Indian Scenario and Future of ECMO 498
 Appendix: Murray Score 500
- 47. Pediatric Heart and Lung Transplantation 501**
Shekhar T Venkataraman
 Heart Transplantation 501
 Lung and Heart-lung Transplantation 504
 Physiology of the Transplanted Heart 504
 Physiology of the Transplanted Lung 505
 Chronic Rejection and Problems After Transplantation 511
 Problems Specific to Each Organ Transplant 512
 Psychosocial Issues Before and After Transplantation 514
-
- Section 3: Circulatory System Issues**
-
- 48. Shock: Management in Pediatric Intensive Care Unit 521**
Praveen Khilnani
 Pathophysiology 521
 Phases of Shock 522
 Classification of Shock 522
 Assessment and Recognition of Shock 523
 Laboratory Investigations 524
 Monitoring of Shock 524
 Treatment of Shock 524
 Myocardial Contractility 525
 Supportive Therapy 526
- 49. Inotropes and Vasopressors in the Pediatric Intensive Care Unit 528**
Agnisekhar Saha, Bichitrovanu Sarkar
 Physiological Considerations 528
 Pharmacology of Individual Agents 529
- 50. Cardiogenic Shock 540**
Nameet Jerath
 Pathophysiology 540
 Symptoms 541
 Causes 541
 Investigations 541
 Management 542
 Cardiogenic Shock in a Newborn 542
- 51. Pediatric Septic Shock 546**
Vikram Gagneja, Praveen Khilnani, Leticia Castillo
 Management 546
 Some Newer Concepts and Newer Therapies 551

52. Multiorgan Failure in Critically Ill Children	554	57. Cardiac Arrhythmias in Pediatric Intensive Care Unit	591
<i>Praveen Khilnani, Rajiv Uttam</i>		<i>Vinay Kukreti, Mosharraf Shamim, Praveen Khilnani</i>	
Historical Perspective	554	Approach to Arrhythmia in PICU	591
Clinical Epidemiology	555	Classification of Arrhythmias	592
Pathogenesis	556		
Current Therapy: Multiorgan Support is the Key	558		
53. Dengue with Shock	561	58. Hypertension in Children	599
<i>Indumathy Santhanam, Thangavelu S</i>		<i>Prasanna C Tellis, Amit Varma, Prashant Pruthi</i>	
Pathophysiology	561	BP Measurement	599
Clinical Presentation	561	Etiology	599
Laboratory Diagnosis	562	Investigations	600
Management of Children with Dengue Without Warning Signs	564	Non-pharmacological Management	603
Management of Dengue with Warning Signs Without Shock	564	Pharmacologic Therapy	603
Management of Severe Dengue	565	Hypertensive Emergencies	604
Management of Shock	565		
Management of Bleeding	567	59. Common Congenital Heart Defects and Perioperative Issues	605
Management of Fluid Overload	568	<i>Jesal Sheth, Praveen Khilnani</i>	
		Ventricular Septal Defect	606
		Atrial Septal Defect	606
		Patent Ductus Arteriosus	607
		Aortic Stenosis	607
		Coarctation of Aorta	608
		Some Common Issues in Preoperative Care	609
		60. Postoperative Care of Cardiac Patients After Open Heart Surgery	611
		<i>Ravi R Thiagarajan</i>	
		Postoperative Care of Children Undergoing Congenital Surgery	611
		61. Perioperative Management of Transposition of Great Arteries	616
		<i>Ajay Kumar Gupta, Vishal K Singh, Rajesh Sharma, Amit Varma</i>	
		Incidence and Epidemiology	616
		Definition and Anatomic Features	616
		Pathophysiology	617
		Clinical Manifestations	617
		Diagnosis	617
		Management	618
		Postoperative Critical Care Management	620
		62. Perioperative Management of Total Anomalous Pulmonary Venous Drainage	626
		<i>Vishal K Singh, Rajesh Sharma, Amit Varma</i>	
		Types of Total Anomalous Pulmonary Venous Drainage	626
		Presentation	627
		Treatment	629

Section 4: Pediatric Cardiac Intensive Care Issues

54. Role of Echocardiography in the Pediatric Intensive Care Unit	573		
<i>Jhuma Sankar, Praveen Khilnani</i>			
Echocardiography	573		
55. Interventional Pediatric Cardiology: An Overview	577		
<i>Thomas Albrecht G, Praveen Khilnani</i>			
Vascular Angioplasties	577		
Dilation of Valvular Lesions	579		
Closure of Extracardiac and Intracardiac Communications	580		
Procedures	581		
Complications	582		
56. Myocarditis in Children	584		
<i>Vinay Joshi, Preetha Joshi</i>			
Incidence	584		
Etiology	584		
Pathogenesis	584		
Clinical Presentation	585		
Natural History of Myocarditis	585		
Diagnosis	586		
Management	586		
Prognosis	588		

Guidelines to Postoperative Management	632		
Management of Pulmonary Hypertensive Crisis	634		
63. Perioperative Management Strategy of Univentricular Heart	636		
<i>Vishal K Singh, Amit Varma, Rajesh Sharma</i>			
Obstruction to Systemic Outflow	637		
Obstruction to Pulmonary Outflow	637		
Obstruction to Systemic and Pulmonary Venous Return or Ventricular Inflows	637		
Clinical Features	637		
Diagnostic Evaluation	637		
Management	638		
Preoperative Stabilization and Postoperative Management	640		
Complications and Natural History of Fontan Circulation	644		
64. Cardiac Pacing in Pediatric Intensive Care Unit	648		
<i>Neeraj Gupta, Anil Sachdev, Dhiren Gupta</i>			
Cardiac Pacing	648		
65. Pediatric Mechanical Circulatory Support	656		
<i>Michael A Maymi, Dipankar Gupta, Wendy E Barnes</i>			
Indications	656		
Contraindications	657		
Complications	657		
Short-term Mechanical Circulatory Support	657		
Long-term Mechanical Circulatory Support: Berlin Heart	658		
Syncardia Total Artificial Heart	659		
66. Heart Transplantation in Pediatrics	663		
<i>Dipankar Gupta, Frederick Jay Fricker, Mark S Bleiweis, Jai P Udassi</i>			
Historical Perspective	663		
Indications for Heart Transplantation	663		
Organ Allocation and Matching	665		
Donor Management	666		
Evaluation and Management of the Patient Awaiting Heart Transplantation	666		
Postoperative Management	667		
Follow-up	670		
Survival	670		
Long-term Complications	670		
Neurodevelopmental Outcomes and Functional Status	673		
67. Pediatric Pacemaker and Implantable Cardioverter-defibrillator Therapy	677		
<i>Frank Zimmerman, Madelyn Kahana, Praveen Khilnani</i>			
Indications	677		
Pacemaker Basics	678		
Implantable Cardioverter-defibrillator	683		
Section 5: Metabolic and Endocrine Issues			
68. Inborn Errors of Metabolism	689		
<i>Vinay K Aggarwal, Verma IC, Nitesh Singhal</i>			
Pathophysiology	689		
Laboratory Investigations	691		
Treatment	692		
69. Diabetic Ketoacidosis	694		
<i>Sukhmeet Singh, Praveen Khilnani</i>			
Diabetes Mellitus	694		
Diabetic Ketoacidosis	695		
70. Endocrine Emergencies in Critically Ill Children	700		
<i>Indira Jayakumar</i>			
Hyperglycemia	700		
Hypoglycemia	700		
Adrenal Insufficiency	701		
Non-thyroidal Illness Syndrome (Sick Euthyroid Syndrome)	703		
Thyrotoxic Crisis	704		
Pheochromocytoma (Hypercatecholamine Crisis)	705		
Hypocalcemia	705		
Hypercalcemia	707		
Salt/Water Syndromes	707		
Section 6: Fluids, Electrolytes and Renal Issues			
71. Fluid and Electrolyte Abnormalities in the Critically Ill Children	713		
<i>Preetha Joshi, Vinay Joshi</i>			
Body Water Distribution in Children	713		
Understanding 'Fluid' Concepts	715		
Crystalloids vs Colloids in Critically Ill Children	716		
Electrolyte Disorders	717		
72. Acute Kidney Injury in Children and Renal Replacement Therapy	724		
<i>Kanav Anand, Pruthi PK</i>			
Incidence	724		
Criteria for Defining AKI	724		

Etiology 725
Assessment and Investigations 725
Management 728
Treatment of the Underlying Disease 729
Peritoneal Dialysis 730
Intermittent Hemodialysis 733
Outcome 734
Follow-up of Acute Kidney Injury 735
Prevention 735

73. Pediatric Renal Transplantation 737

Kanav Anand, Pruthi PK
Immediate Preoperative Period 737
Surgery 738
Immunosuppression 741
Monitoring 741
Other Medications 741
Survival 742

Section 7: Gastrointestinal, Hepatic and Nutritional Issues

74. Gastrointestinal Bleeding: Diagnosis and Management 745

Ted A Williams, Praveen Khilnani
Assessment of the Severity of Bleeding 745
Lower GI Bleeding 747

75. Acute Liver Failure 753

Nameet Jerath, Anita S Bakshi
Etiology 753
Metabolic Diseases 753
Toxins/Drugs 754
Autoimmune 754
Vascular 754
Pathogenesis 754
Management 755
Investigations and Monitoring 755
Supportive Therapy 756
Management of Hepatic Encephalopathy 757

76. Liver Transplantation 759

John M Downey, Madelyn Kahana, Praveen Khilnani
Indications 759
Extrahepatic Complications 765

77. Liver Transplantation in Children: Indian Scenario 768

Anupam Sibal, Vidyut Bhatia, Akshay Kapoor
Need 768
Indications 768
Assessment 769

Preparation for Liver Transplantation 769
Critical Care Issues in Management 770
Indian Scenario 770

78. Nutrition in the Pediatric Intensive Care Unit 773

Reeta Singh, Praveen Khilnani
Modes of Nutritional Repletion 774
Nutritional Assessment 774
Nutritional Support 775
Nutrition in Special Circumstances 776

79. Parenteral Nutrition for Critically Ill Child 781

Pankaj Vohra
Contents of Parenteral Nutrition 781
What to do Before Starting Parenteral Nutrition? 782
Contraindications to Parenteral Nutrition 782
Caloric Needs of a Child 782
How to Get Started? 782
How to Administer the Parenteral Nutrition? 783
What to Monitor When a Child is on Parenteral Nutrition? 783
How to Increase Parenteral Nutrition? 783
When to Consider Decreasing Parenteral Nutrition? 784
Complications of Parenteral Nutrition 784
Products Available 784

Section 8: Hematology, Immunology and Oncology Issues

80. Blood Transfusion in Neonatal and Pediatric Intensive Care 787

Gurinder Pal Singh (Late), Makroo RN, Praveen Khilnani
Physiological Principles 787
Anemia in the Intensive Care Unit 788
Appendix: Leukocyte Reduction of Blood Components 799

81. Disseminated Intravascular Coagulation 801

Rajesh Mehta, Prashant Pruthi
Associated Clinical Conditions 801
Miscellaneous Activating Stimuli 802
Pathophysiology of DIC 802
Clinical Features 803
Diagnosis 803
Treatment 803
Prognosis 805

82. Methemoglobinemia	807	Section 9: Infection Management Issues
<i>Sunil Gomber</i>		
Clinical Pharmacology and Toxicology	807	
Hereditary Methemoglobinemia	807	
Acquired Methemoglobinemia	808	
Clinical Features	808	
Diagnosis	808	
Management	809	
83. Malaria	811	87. Antibiotic Therapy in the Pediatric Intensive Care Unit
<i>Santosh T Soans, Mallikarjun RP</i>		869
Life Cycle	811	<i>Praveen Khilnani</i>
Clinical Disease and Epidemiology	811	Infections and Empirical Therapy
Diagnosis	812	Criteria for Selection of Antibiotics
Definition of Uncomplicated Malaria	813	Carbapenem
Severe <i>Plasmodium falciparum</i> Malaria	814	Linezolid
Severe Malarial Anemia	817	Teicoplanin
Cerebral Malaria	817	Tigecycline
		Colistin
		Summary Recommendations
84. Immunocompromised Child in the Pediatric Intensive Care Unit	819	88. Nosocomial Infections and Management
<i>Priyanka Sharma, Mukesh Desai, Amita Mahajan</i>		883
Three Levels of Defense	819	<i>Ebor Jacob, Kala Ebnezar</i>
Balance of Inflammation and Anti-inflammation	819	Nosocomial Infection
Immunodeficiency	820	Infection Control
Immunology in Sepsis	820	
Major Categories of Primary Immunodeficiency and Their Incidence	821	
When to Suspect Immunodeficiency in Critical Care Setting?	822	
How Many Infections are Too Many?	823	
Infectious Complications in the Immunocompromised Child	825	
85. Pediatric Human Immunodeficiency Virus Infections	829	Section 10: Trauma and Pediatric Surgical Issues
<i>Deepika Singhal, Shiv Kumar Rajdev, Praveen Khilnani</i>		
Acquired Immunodeficiency Syndrome	829	89. Multiple Trauma: Stabilization and Management in Pediatric Intensive Care Unit
Identification of Perinatal HIV Exposure	829	897
Monitoring Pediatric HIV Infection	831	<i>Jashua Caresky, Meera Luthra, Chhabi Ranu Gupta, Praveen Khilnani</i>
Prognosis	836	Prehospital Care of an Injured Child
Appendix: Characteristics of Available Antiretroviral Drugs	838	Management at the Accident Site
		Intracranial Hematoma
		Pediatric Intensive Care Unit Management Protocol
86. Bone Marrow Transplantation in Children	854	90. Child Abuse and Shake Injuries
<i>Gaurav Kharya, Sanjeev Sharma, Rachna Sharma, Praveen Khilnani</i>		907
Autologous HSCT	854	<i>Praveen Khilnani</i>
Allogeneic HSCT	854	Diagnosis
Histocompatibility	855	Examination
Indications of HSCT	856	Treatment
Prognosis and Outcomes	860	Laboratory and Diagnostic Imaging Studies
Complications in HSCT	861	Management
Indian Scenario	863	Legal Implications
		91. Perioperative Anesthetic and Surgical Issues
		913
		<i>Ramesh S, Meera Luthra, Praveen Khilnani</i>
		Anesthesia
		Pediatric Anesthesiologist
		Anesthetic Triad
		Is there a Term Fitness for Anesthesia?
		Triad of Anesthetic Risk
		Common Pediatric Problems Faced by the Pediatric Anesthesiologist
		What are the Special Methods Administering Narcotics?

What are the Common Regional Analgesic Techniques Employed in Children? 917

Ten Commandments of Pediatric Anesthesia 917
Postoperative Care After Pediatric Surgery 917
Elective Day Care Surgery 917
Postoperative Care for a Child with Thoracic Surgery 917
Abdominal Surgery 918
Surgery for Trauma 918

Section 11: Environmental and Toxicology Issues

92. Poisoning and Bites 923

Pradeep Sharma, Praveen Khilnani, Suchita Khadse
Evaluation of Children with Suspected Toxin Ingestion 923
Envenomation 929
Snakebite 929
Scorpion Sting 936

93. Thermal Burns 944

Seth RK, Praveen Khilnani
Etiology 944
Classification and Diagnosis 944
Pathophysiology 946
Management 946
Morbidity 949
Rehabilitation of Burn Patients 950

94. Heat Disorders 951

Purnima Dhar
Thermoregulation 951
Environmental Hyperthermia 952
Minor Heat Illnesses 952
Heatstroke 953
Malignant Hyperthermia 954
Sudden Unexpected Cardiac Arrest in Children 955

95. Electrical Shock 957

Soonu Udani
Mechanism of Electrical Injury 957

96. Near-drowning 960

Bala Ramachandran
Epidemiology 960
Pathophysiology 960
Hypothermia and the Diving Reflex 962
Assessment and Management 962
Hypothermia 964
Outcome 965
Prognosis 966

Section 12: Neurological Issues

97. Coma: Encephalitis and Cerebral Malaria 971

Krishan Chugh, Dhiren Gupta
Pathophysiology 971
Etiology 971
Evaluation of a Child in Coma 971
Management 976
Prognosis 977
Management of Some Common Specific Causes 977

98. Bacterial, Viral and Fungal Meningitis 982

Jose Irazzuzta, Praveen Khilnani, Deepika Singhal
Bacterial Meningitis 982
Fungal Meningitis 988
Herpes Simplex Encephalitis 990
Tubercular Meningitis 991

99. Hydrocephalus 994

Praveen Khilnani, Sandeep Chopra, Manish Vaish
Cerebrospinal Fluid Production and Physiology 994
Cerebrospinal Fluid Hydrodynamics 994
Cerebrospinal Fluid Functions 994
Hydrocephalus 995
Options for CSF Drainage Procedure 997

100. Status Epilepticus 1000

Gnanam R, Mritunjay Pao, Praveen Khilnani
Newer Definition of SE 1000
Subtypes 1000
Etiological Classification 1000
Mechanism of SE 1001
Systemic Manifestations Associated with SE 1001
Status Epilepticus Management 1001
Non-convulsive Status Epilepticus 1004
Diagnostic Testing 1005
Algorithm for Management of Status Epilepticus 1005
Risk of Epilepsy 1005
Functional Disabilities 1005

101. Pediatric Head Injury 1006

Bhaskar Saikia, Sandeep Chopra, Praveen Khilnani
Monro-Kellie Doctrine 1006
Pathogenesis of Brain Injury 1006
Clinical Evaluation and Management in Emergency 1007
Intracranial Hematoma 1008
Diffuse Brain Injury 1009
Neurosurgical Management 1010
Non-surgical Management 1010
Complications and Sequelae of Head Injury 1013

Appendix: Guidelines for Acute Medical Management of Severe Traumatic Brain Injury in Infants and Children	1016		
102. Pediatric Brain Death Guidelines	1018		
<i>Bala Ramachandran</i>			
Clinical Examination	1018		
Demonstration of Apnea	1019		
Ancillary Tests	1020		
Tests to Assess Intracranial Blood Flow	1020		
Time Course of Tests for Brain Death	1021		
Pediatric Brain Death Guidelines Group 2011	1021		
103. Sedation, Analgesia and Neuromuscular Blockade	1022		
<i>Jyotinder Kaur, Praveen Khilnani</i>			
Main Goals of Sedation	1022		
Indications of Sedation	1023		
Procedures Requiring Sedation	1023		
Clinical Pharmacology of Commonly Used Sedatives and Analgesics	1024		
Practical Approach to Sedation in the PICU	1027		
Neuromuscular Blockade	1028		
Non-depolarizing Agents	1030		
Appendix: Dexmedetomidine	1033		
104. Intensive Care Unit-acquired Weakness	1036		
<i>Vinay Kukreti, Mosharraf Shamim, Praveen Khilnani</i>			
Incidence	1036		
Risk Factors	1036		
Clinical Features	1037		
Pathogenesis	1037		
Diagnosis	1038		
Electrophysiological and Histological Features	1038		
Differential Diagnosis	1039		
Management	1039		
Prognosis	1041		
Section 13: End-of-life, Ethical and Medicolegal Issues			
105. Care of Terminally Ill Children	1047		
<i>Praveen Khilnani</i>			
Common Sources of Stress for Parents of a Hospitalized Child	1047		
Factors Relating to a Sick Child Admitted to the PICU	1047		
A Child's Reaction to Illness and Hospitalization	1048		
Stress in PICU Team Members	1049		
Issues Related to a Critically Ill Child Dying (or Likely to Die) in PICU and End-of-life Care	1049		
End Stage Palliative Care	1051		
Interventions	1053		
106. Psychosocial Issues in Pediatric Intensive Care Unit	1057		
<i>Pooja Verma, Praveen Khilnani</i>			
Child's Reaction to Hospitalization	1057		
Effects of Hospitalization on the Family of the Child	1058		
Sources of Stress in a Hospital Setting	1059		
Role of Nurse in Helping Child and Family in Coping with Stress of Hospitalization and Illness	1060		
107. Ethical Issues Related to End-of-life	1062		
<i>Mani RK, Praveen Khilnani</i>			
Standards of Practice	1063		
Quality of Care	1063		
Cost Reduction	1064		
Ethical and Legal Issues Related to Life Support Limitation	1064		
Autonomy	1064		
Concept of Futility	1065		
Legal Aspects of Palliative Care	1065		
Physician-assisted Suicide and Euthanasia	1066		
Drawbacks in the Current Strategies	1066		
Indian Scenario	1066		
Appendix: Guidelines for Limiting Life-prolonging Interventions and Providing Palliative Care Towards the End-of-life in Indian Intensive Care Unit	1069		
108. Medicolegal Issues in Intensive Care	1079		
<i>Uttara Babbar, Sidharth Luthra</i>			
Medical Negligence	1079		
Balancing of Risks	1079		
Criminal Negligence	1080		
Consumer Protection Act and the Medical Profession	1081		
Section 14: Pediatric Intensive Care Unit Training, Research and Quality Issues			
109. Training in Pediatric Critical Care Medicine	1085		
<i>Praveen Khilnani</i>			
Components of Training	1085		
Clinical Skills Acquired in the PICU	1085		
Legal Aspects of Pediatric Critical Care	1086		
Death Certification	1086		
Planning Clinical Research	1086		

Leadership 1086
Develop Treatment Protocols 1086
Appendix: Skills and Syllabus 1087

110. Simulation-based Training in Pediatric Intensive Care 1089

Rakshay Shetty, Sujatha Thyagarajan, Praveen Khilnani
Simulation-based Training or Learning 1089

111. Research in the Pediatric Intensive Care Unit 1095

Praveen Khilnani
Evidence-based Medicine 1095
Statistics 1095
Summarizing Data 1097
Publishing in Critical Care Literature 1100

112. Concept of Quality Improvement in Pediatric Intensive Care Unit 1103

Farhan Shaikh
How Does Quality Matter? 1103
How Do I Start Toward Quality Improvement in My PICU? 1105
Concept of Outcome Measurement 1105

Section 15: Drug Index, Useful Equations and Formulae for Pediatric Intensive Care Unit

113. Drugs Used in the Pediatric Intensive Care Unit 1111

Sagar Lad, Vinayak K Patki, Praveen Khilnani
Commonly Used Drugs 1111
Antibiotics 1111
Antimalarial 1114
Antiviral and Antifungal 1114
Cardiovascular 1115
Central Nervous System 1118
Intubation 1121
Gastrointestinal 1122
Respiratory 1122
Miscellaneous 1123
Appendix: Useful Information and Equations in the Pediatric Intensive Care Unit 1129

Index 1133

Development of Pediatric Critical Care

- 1889 : First infant respirator, Egon Braun, Vienna
- 1910 : First positive pressure ventilator
- 1954 : Extracorporeal circulation described
- 1954 : First PICU, Gothenburg, Sweden
Closed chest defibrillation described
ECMO described
- 1957 : Severinghaus electrode: led to blood gas analysis
- 1958 : First physician-directed multidisciplinary adult ICU, Baltimore City Hospital
- 1963 : First liver transplant
- 1964 : Theodore Striker becomes first pediatric critical care fellow, Philadelphia
- 1967 : First US physician-directed PICU, Philadelphia
Society of Critical Care Medicine (SCCM) established
- 1972 : First US Textbook of Pediatric Critical Care, Clement Smith (Editor)
- 1973 : First edition, Critical Care Medicine (CCM), William Shoemaker
- 1974 : Pulse oximetry developed
- 1982 : Pediatric Section of Society of Critical Care Medicine established
- 1983 : First pediatric advanced life support (PALS) copy written
Formation of Section on Critical Care of AAP
- 1986 : US Guidelines published for pediatric air and ground transport
- 1987 : First comprehensive Textbook of Pediatric Critical Care, MC Rogers
First Pediatric Critical Care Board examinations
- 1988 : American College of Critical Care Medicine (ACCM) established
Prism score described by Murray Pollack
- 1989 : First Pediatric Critical Care Fellowship certified by American College of Graduate Medical Education (ACGME)
- 1993 : US Guidelines and Levels of Care for PICUs published
- 1993 : Indian Society of Critical Care Medicine (ISCCM) established, Mumbai
- 1993 : First Indian Academy of Pediatrics (IAP) Intensive Care Conference, New Delhi
Manual of Pediatric Intensive Care published, K Chugh and Praveen Khilnani
- 1997 : World Congress and establishment of World Federation of Pediatric Intensive Care (WFPICC), Baltimore
- 1998 : IAP Intensive Care Chapter established by Krishan Chugh
- 1998 : First National Congress on Pediatric Intensive Care, Nagpur
- 2000 : ISCCM Pediatric Section formed, Founder Chair Praveen Khilnani
- 2001 : IAP and ISCCM PICU Guidelines and Levels of Care published
- 2002 : First Pediatric Critical Care Fellowship started
- 2003 : First Pediatric Critical Care Fellowship examination, Surat, Gujarat
- 2004 : First comprehensive Indian textbook on Pediatric Intensive Care, Praveen Khilnani
- 2007 : DNB Training In Pediatric Critical Care started in India
- 2009 : Basic Pediatric Intensive Care Course (BPICC) developed by IAP (Intensive Care Chapter) and ISCCM Pediatric Section
- 2010 : DM training in Pediatric Critical Care Medicine started at PGIMER, Sunit Singhi, Chandigarh
- 2014 : IAP Intensive Care Journal started, Journal of Pediatric Critical Care (JPCC), Editor-in-Chief Praveen Khilnani
- 2014 : Formation of College of Pediatric Critical Care, India
- 2015 : Advanced Pediatric Intensive Care Course (APICC) by College of Pediatric critical care, India

The diagnosis of brain death in children is generally regarded as being more difficult than in adults and there is considerable variation in the exact protocol followed in different countries, and even between different states in the same country. Nevertheless, the diagnostic procedure is essentially by clinical examination.

The following guidelines are based on multiple sources, including the American Academy of Pediatrics Guidelines for the determination of brain death in children^{1,4} the American Academy of Neurology evidence-based guideline update 2010,² the Australian and New Zealand Intensive Care Society statement on death and organ donation, 2008³ and the general consensus of the Guidelines Committee of Experts from India listed at the end of this article (Guidelines group was chaired and coordinated by Dr Bala Ramachandran in year 2011 and this consensus was compiled by him on behalf of the Guidelines group).

DEFINITION

Brain death is defined as irreversible cessation of all functions of the entire brain, including the brainstem.

Prerequisites

The following conditions must be met before brain death can be determined:

1. There must be a recognized cause of coma sufficient to explain the irreversible cessation of all brain function. Both coma and apnea must coexist to declare brain death.
2. Potentially reversible causes of coma must be excluded:

- a. Hypothermia: Core body temperature must be $> 35^{\circ}\text{C}$, since severely hypothermic patients may appear brain dead.
 - b. Uncontrolled hypotension: The blood pressure must be normal for age (systolic BP not < 2 SD below norm for age).
 - c. Sedatives and other CNS depressant drugs/toxins: Sufficient time must be allowed for any CNS depressant agents to be metabolized. If this cannot be assured, a drug level may be obtained, if possible, to show that the drug in question does not exceed the normal therapeutic levels.
 - d. If neuromuscular blocking agents have been administered, a peripheral nerve stimulator should be used to show that there is no residual neuromuscular blockade.
 - e. Severe metabolic derangements must be excluded, including markedly abnormal plasma concentrations of glucose, sodium, potassium, phosphate, magnesium, calcium.
 - f. Any other sign that suggests a potentially reversible cause of coma.
3. Neurological assessment may be unreliable immediately following cardiopulmonary resuscitation or acute brain injury—brain death evaluation should be deferred by 24 hours in these circumstances.

CLINICAL EXAMINATION

The diagnosis of brain death is essentially clinical. There must be absence of higher brain function—lack of consciousness. There must be absence of brainstem functions. The observations are:

- 1. Observations that are compatible with brain death:**
The following observations can be present in brain death:
 - Spinal reflexes in response to stimulation
 - These may include movements of the upper limbs, deep tendon reflexes, plantar reflexes, respiratory like movements and head turning
 - Sweating, blushing or tachycardia
 - Normal blood pressure without pharmacological support
 - Absence of diabetes insipidus.
- 2. Observations that are incompatible with brain death:** The following observations are incompatible with brain death:
 - Decerebrate or decorticate posturing
 - True extensor or flexor responses to painful stimuli
 - Seizures.
- 3. Number of tests and who should perform them:**
Two examinations (including two apnea tests)

should be performed, separated by an interval. A different Consultant Physician who is taking care of the child should perform each clinical examination. These physicians should have specific expertise and experience in performing such assessment and can include Pediatric Intensivists, Neurologists, Anesthetists, Neurosurgeons or Pediatricians. The same individual may perform the apnea tests. In case the testing is being performed for the purposes of organ harvesting, additional requirements from the individual State Governments may apply (such as preregistration and authorization of the physician performing the tests) (Table 102.1).

DEMONSTRATION OF APNEA

The role of the apnea test has been questioned recently.⁵ Nevertheless, it continues to be a part of the brain death testing protocol in most countries at this time. The apnea test must be performed twice (as part of each clinical

TABLE 102.1: Tests of brain death

Clinical testing	Test procedure and response	Comments
Coma	Apply noxious stimuli in the cranial nerve distribution and all four limbs and trunk. There should be no motor response.	Refer 'Note' below the table.
Pupillary light reflex—cranial nerves II and III	Shine a bright light into each eye and look for pupillary constriction. There should be no pupillary constriction.	Pupils must be ≥ 4 mm in diameter. A magnifying glass may be used, if required. Use of anticholinergic drugs, such as Atropine, can cause pupillary dilatation.
Corneal reflex—cranial nerves V and VII	Touch the corneas with soft cotton wool. There should be no blinking or withdrawal reflex.	Touch only the lateral aspect of the cornea to avoid damage.
Absence of movement of the bulbar musculature—cranial nerves V and VII	Apply deep pressure over the condyles at the temporomandibular joints and over the supraorbital ridges. There should be no grimacing or facial muscle movement.	
Oculovestibular reflex—cranial nerves III, IV, VI and VIII	Inspect the external auditory meatus with an otoscope to make sure that the ear drum is visible and intact—if required, clean any cerumen before proceeding. Elevate head to 30° and place in the neutral position. Instill 20–50 mL of ice water into the ear canal with a syringe. Hold both eyes open and observe for at least 1 minute. There should be no response—both eyes should remain in the midposition. Wait for 5 minutes and repeat test in the other ear.	Fracture of the skull base or petrous temporal may obliterate the response on the side of the fracture.
Gag reflex—cranial nerves IX and X	Stimulate the posterior pharyngeal wall on both sides with a tongue depressor. There should be no gag response.	May be difficult to examine in orally intubated patients.
Cough reflex—cranial nerve X	Stimulate the trachea with a suction catheter. There should be no cough.	
Flaccidity	Evaluate all extremities by passive range of motion (unless contraindicated). There should be flaccid tone and no spontaneous or induced movements.	Refer 'Note' below the table.

Note: Refer point 1–3 given under the Clinical Examination.

examination), but may be performed by the same individual—preferably the physician who is managing the patient's ventilator. The following section describes how to perform the apnea test.

The same prerequisites apply as for performing the clinical tests, i.e. the patient should not be hypothermic, hypotensive or have a serious metabolic or endocrine disturbance. Additional contraindications include a high cervical spinal cord injury or very high oxygen/ventilatory requirements that will result in the inability to disconnect safely from the ventilator. If the apnea tests cannot be performed safely, then an ancillary test must be performed to determine brain death:

1. Preoxygenate the patient for 5 minutes with 100% oxygen.
2. The physician involved in certifying brain death should be physically present at the bedside during the test to attest to the presence of apnea.
3. Manipulate the ventilator to allow the PaCO₂ to rise to > 40 mm Hg—this baseline arterial CO₂ should be confirmed by blood gas analysis or end tidal CO₂.
4. Monitor the patient during the test (ECG, blood pressure and SpO₂) and stop the test if there is significant hypotension, desaturation or cardiac arrhythmia.
5. Disconnect the patient from the mechanical ventilator and insert an appropriately sized oxygen catheter into the endotracheal tube. Adjust the oxygen flow to deliver 100% oxygen at a flow rate between 2 and 6 L/min. Use only the minimum flow required to maintain adequate oxygen saturation. A T-piece or CPAP circuit can also be used to supply oxygen to the patient when disconnected from the ventilator.
6. After a period of apnea between 5 and 10 minutes (depending on the PaCO₂ at the beginning of the test), perform an arterial blood gas (ABG). The PaCO₂ on the ABG should be ≥ 60 mm Hg and ≥ 20 mm Hg more than the baseline level. If the PaCO₂ does not meet these parameters, the test may be continued and the ABG repeated after 5 minutes, provided the patient continues to be stable.
7. Observe the patient continuously for the presence of any respiratory efforts. If any respiratory efforts are noted, abandon the test immediately. If there is complete apnea, note the duration of apnea and the PaCO₂ at the end of the test.
8. Reconnect the patient to the mechanical ventilator.

Response

In a brain dead patient, no respiratory efforts should be seen during the period of apnea.

ANCILLARY TESTS

Ancillary tests are not routinely required to determine brain death and are not a substitute for the clinical examination. A number of ancillary tests are available. However, they may be used in specific situations:

1. When the apnea test cannot be performed safely.
2. If there is uncertainty regarding the results of the neurological examination.
3. If a medication may be present that would preclude declaration of brain death.
4. In order to reduce the waiting period between the two sets of tests.

Electroencephalography

A digital electroencephalography (EEG) should be performed by a technician who has experience in performing EEG's for the purposes of determining brain death. In general, the sensitivity should be increased to 2 μV, the high-frequency filter should be set above 30 Hz and the low-frequency filter set not above 1 Hz. A minimum of eight scalp electrodes should be used. The EEG should demonstrate a lack of reactivity to intense somatosensory and audiovisual stimulation.

TESTS TO ASSESS INTRACRANIAL BLOOD FLOW

The purpose of these tests is to show that there is no flow in the intracerebral vessels, due to occlusion of the vasculature by cerebral edema. The various techniques by which intracranial blood flow can be assessed include four-vessel cerebral angiography, radionuclide imaging, CT angiography, magnetic resonance angiography and transcranial Doppler ultrasonography. Of these techniques, four-vessel cerebral angiography is regarded as the gold standard and involves direct injection of contrast medium into both carotid arteries and both vertebral arteries.

Of all the confirmatory tests mentioned above, EEG is the most easily available test. Radionuclide cerebral blood flow assessment is also acceptable—the remainder are time consuming, not easily available, not always standardized, may require shifting an unstable patient, and in some cases, expensive.

Any one of the following tests may be used (depending on availability) when an ancillary test is required:

- EEG
- Radionuclide cerebral blood flow assessment
- Four-vessel cerebral angiography.

TIME COURSE OF TESTS FOR BRAIN DEATH

- The clinical tests are performed twice, each time by a different physician
- The apnea test is performed twice—may be performed by the same physician
- Death is declared when the second neurological examination and apnea test confirm that the results of the first tests are unchanged and the changes are irreversible
- If an ancillary test performed after the first clinical examination/apnea test is consistent with brain death, then the second clinical examination/apnea test can be performed at any time. The time gap between the clinical tests is detailed in Table 102.2.

Age	Clinical tests	Interval between tests	Ancillary tests
Term newborn (> 37 weeks gestational age to 30 days)	As in adult	24 hour	If required
31 day to 18 year	As in adult	12 hour	If required

PEDIATRIC BRAIN DEATH GUIDELINES GROUP 2011

- Bala Ramachandran, Consultant and Head of the Department of Intensive Care & Emergency Medicine. Kanchi Kamakoti Childs Trust Hospital, Chennai. md-picu@hotmail.com

- Dr Krishan Chugh, Head of the Department of Pediatrics, Fortis Hospital, Gurgaon. chugh.krishan@gmail.com
- Dr Sunit Singhi, Head of the Department of Pediatrics, Post Graduate Institute for Medical Education and Research, Chandigarh. sunit.singhi@gmail.com
- Dr Praveen Khilnani, Consultant Pediatric Intensivist, BLK Super Speciality Hospital, New Delhi. khilnanip@hotmail.com
- Dr Viswanathan V, Consultant Pediatric Neurologist, Kanchi Kamakoti CHILDS Trust Hospital, Chennai. vishneuro@gmail.com
- Dr Joseph Mathew, Consultant Neurosurgeon, Christian Medical College, Vellore, Tamil Nadu. mathewcmc@gmail.com
- Dr Soonu Udani, Consultant Pediatric Intensivist, Hinduja Hospital, Mumbai. drsudani@gmail.com

BIBLIOGRAPHY

1. American Academy of Pediatrics, Task Force on Brain Death in Children. Report of Special Task Force: Guidelines for determination of brain death in children. Pediatrics. 1987;80(2):298-300.
2. Australian and New Zealand Intensive Care Society. The ANZICS Statement on Death and Organ Donation, 3rd edition. Melbourne: ANZICS; 2008.
3. Nakagawa TA, Ashwal S, Mathur M, et al. Guidelines for the determination of brain death in infants and children: An update of the 1987 Task Force recommendations. Crit Care Med. 2011;39:2139-55.
4. Tibballs J. A critique of the apneic oxygenation test for the diagnosis of 'brain death'. Pediatr Crit Care Med. 2010;11(4):475-8.
5. Wijdicks EF, Varelas PN, Gronseth GS, et al. Evidence-based guideline update: determining brain death in adults: Report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology. 2010;74:1911-8.