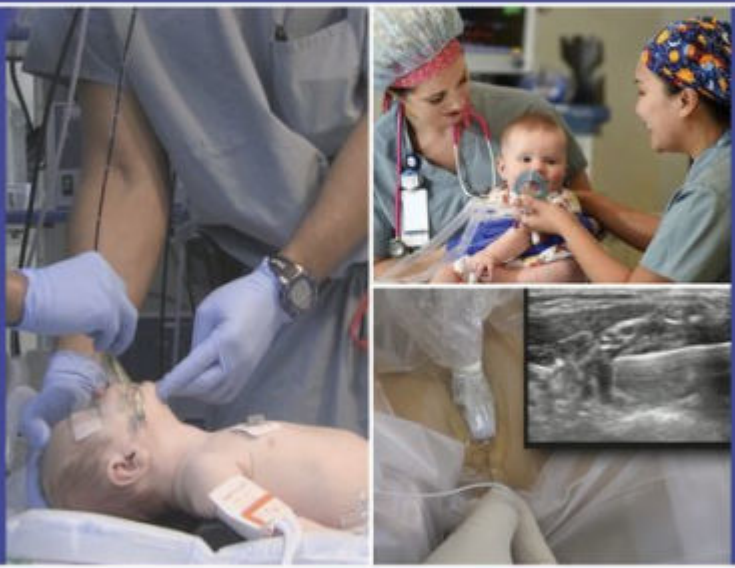
# GREGORY'S PEDIATRIC ANESTHESIA

SIXTH EDITION



EDITED BY
Dean B. Andropoulos and George A. Gregory

WILEY Blackwell

# Gregory's Pediatric Anesthesia

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# Preface

Since the publication of the fifth edition of *Gregory's Pediatric Anesthesia*, both knowledge and practice have advanced in myriad ways. This sixth edition addresses these changes with significant updates and additions to all chapters, reflecting the most recent important literature in pediatric anesthesia. Significantly more figures and tables in nearly all chapters allow us to better illustrate the important principles in each area. Key points boxes have also been added after major sections in each chapter to enhance learning. New chapters have been added addressing the pediatric perioperative surgical home and anesthesia for non-cardiac surgery in congenital heart disease. Several extensive chapters from the fifth edition have been divided into two chapters to allow more space and detail: these cover development of the cardiovascular system and physiology of the cardiovascular system, anesthesia for trauma and anesthesia for burns, and anesthesia for otolaryngologic surgery and anesthesia for ophthalmologic surgery. The very popular case studies have been updated in all the clinical chapters.

The use of ultrasound for anesthesia procedures has increased exponentially in recent years, and this sixth edition has major extensive updates in ultrasound-guided regional anesthesia, with detailed descriptions and ultrasound images of the sonoanatomy for all the major blocks of the upper and lower extremities and trunk. Expanded use of point-of-care ultrasound for vascular access, including peripheral venous cannulation, for assessment of the heart and lungs, and for the airway and gastric contents are exciting new uses of this modality and are presented in detail.

Pediatric anesthesia is truly an international field and this edition's authors include those from the USA, UK, Canada, France, Germany, and Australia, giving a global perspective on practice in our ever-changing discipline. The History of Pediatric Anesthesia chapter was authored by Professor Kester Brown, who was the Director of Anaesthesia at the Royal Children's Hospital in Melbourne, Australia from 1974 to 2000. Professor Brown also traveled extensively around the world to teach and train anesthetists in many countries; the chapter reflects his extensive personal knowledge of the history of our field and its international roots. Sadly, Professor Brown passed away in November 2018; he will be remembered as one of the pioneers of pediatric anesthesia who trained hundreds of clinicians all over the world and who was a role model of professionalism, compassion, scientific curiosity, and outstanding clinical skill. He is missed by all in the community of pediatric anesthesiologists.

We would like to thank the editorial team at Wiley, including Publisher Claire Bonnett, Senior Project Editor Jennifer Seward, Senior Production Editor Nick Morgan, freelance project manager Nik Prowse, freelance copy-editors Ruth Hamilton Swan and Jane Andrew, and Editorial Assistant Bobby Kilshaw. This team of experts has been an absolute pleasure to work with and made many suggestions to improve the content and presentation of the enormous amount of material in this textbook.

Finally, as we acknowledged in the preface to the fifth edition, we thank our students, residents, and fellows for teaching us as much, or more, than we taught them. Their insightful questions, thoughts, and prodding is what academic medicine is about. This probing forces us all to get out of our comfort zone and think differently. We also thank the surgeons and nurses for their support. Most of all, we thank the patients and their parents for giving us the privilege of caring for them and for their continuing to teach us every single day. They are the best teachers!

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George A. Gregory

# List of Abbreviations

| | |
|---|---|
| α1-ATD | α1-antitrypsin deficiency |
| AA | artery-to-artery |
| AAA | asleep/awake/asleep |
| AAG | α1-acid glycoprotein |
| AAGA | accidental awareness under general anesthesia |
| AAP | American Academy of Pediatrics |
| ABA | American Board of Anesthesiology |
| ABC | ATP-binding cassette |
| ABP | arterial blood pressure |
| ACA | anterior cerebral artery |
| ACD | active compression-decompression device |
| ACE | angiotensin-converting enzyme |
| ACEi | angiotensin-converting enzyme inhibitor |
| ACGME | Accreditation Council for Graduate Medical Education |
| ACh | acetylcholine |
| AChR | acetylcholine receptor |
| ACL | anterior cruciate ligament |
| ACLS | advanced cardiac life support |
| ACO | accountable care organization |
| ACP | antegrade cerebral perfusion |
| ACRM | anesthesia crisis resource management |
| ACS | acute chest syndrome/abdominal compartment syndrome/ American College of Surgeons |
| ACTH | adrenocorticotropic hormone |
| ADAPT | Approaches and Decisions in Acute Pediatric TBI (trial) |
| ADH | antidiuretic hormone |
| ADHD | attention deficit hyperactivity disorder |
| ADP | adenosine diphosphate |
| ADPKD | autosomal dominant polycystic kidney disease |
| AED | automated external defibrillator |
| aEEG | amplitude-integrated EEG |
| AFP | α-fetoprotein |
| AGB | adjustable gastric band |
| AGP | α1-acid glycoprotein |
| AHA | American Heart Association |
| AHG | antihuman globulin |
| AHI | apnea-hypopnea index |
| AHT | abusive head trauma |
| AI | artificial intelligence |
| AICD | automatic implantable cardiac defibrillator |
| AIMS | anesthesia information management system/s |
| AIRS | Anesthesia Incident Reporting System |
| AKI | acute kidney injury |
| ALARA | as low as reasonably possible |
| ALCAPA | anomalous origin of the left coronary artery from the pulmonary artery |
| ALI | acute lung injury |
| ALL | acute lymphocytic leukemia |
| ALS | Advanced Life Support |
| ALT | alanine aminotransferase |
| AMC | arthrogryposis multiplex congenital |
| AML | acute myeloid leukemia |
| AMM | anterior mediastinal mass |
| AMPA | α-amino-3-hydroxy-5-methyl-4-isoxazole-propionic acid |
| AN! | Anesthesia Now! |
| ANH | acute normovolemic hemodilution |
| ANP | atrial natriuretic peptide |
| AoDP | aortic diastolic blood pressure |
| AoV | aortic valve |
| AP | anterior–posterior |
| APCC | activated prothrombin complex concentrate |
| APL | adjustable pressure limiting |
| APM | alternative payment model |
| APRICOT | Anaesthesia PRactice In Children Observational Trial |
| APSF | Anesthesia Patient Safety Foundation |
| aPTT | activated partial thromboplastin time |
| AQI | Anesthesia Quality Institute |
| AR | adrenergic receptor/anesthetic room |
| ARB | angiotensin receptor blocker |
| ARDS | acute/adult respiratory distress syndrome |
| ARF | acute renal failure |
| ARPKD | autosomal recessive polycystic kidney disease |
| ARR | absolute risk reduction |
| ARVD | arrhythmogenic right ventricular dysplasia |
| ARVD/C | arrhythmogenic right ventricular dysplasia/cardiomyopathy |
| ASA | American Society of Anesthesiologists |
| ASC | ambulatory surgery center |
| ASCA | anti-*Saccharomyces cerevisiae* |
| ASD | atrial septal defect/autism spectrum disorder |
| ASIS | anterior superior iliac spine |
| ASO | arterial switch operation |
| AST | aspartate aminotransferase |
| AT | antithrombin |
| ATLS | Advanced Trauma Life Support |
| ATP | adenosine triphosphate |
| AUC | area under the curve |
| AV | arterial-venous/atrioventricular |
| AVC | atrioventricular canal |
| AVM | arteriovenous malformation |
| BBB | blood–brain barrier |
| BC | bronchogenic cyst |
| BDG | bidirectional Glenn |
| BDL | balloon dilation laryngoplasty |
| BiPAP | bi-level positive airway pressure |
| BIS | Bispectral Index |
| BMD | Becker muscular dystrophy |
| BMI | body mass index |
| BP | blood pressure |
| BPCA | Best Pharmaceuticals for Children Act |
| BPD | bronchopulmonary dysplasia |
| bpm | beats/min |
| BPS | bronchopulmonary sequestration |
| BSA | body surface area |
| BSEP | bile salt export pump |

| | |
|---|---|
| BT | bleeding time |
| B-T | Blalock–Taussig (shunt) |
| BUN | blood urea nitrogen |
| CA | cardiac arrest |
| cAMP | cyclic adenosine monophosphate |
| CAS | central anticholinergic syndrome |
| CAV | coronary artery vasculopathy |
| CBC | complete blood count |
| CBF | cerebral blood flow |
| CBFV | cerebral blood flow velocity |
| CBV | cerebral blood volume |
| CCAM | congenital cystic adenomatoid malformation |
| CCAS | Congenital Cardiac Anesthesia Society |
| CCL | cardiac cycle length |
| CCLS | Certified Child Life Specialist |
| CCTGA | congenitally corrected transposition of the great arteries |
| CDC | Centers for Disease Control and Prevention |
| CDH | congenital diaphragmatic hernia |
| CDS | clinical decision support |
| cEEG | continuous EEG |
| CF | cystic fibrosis |
| CFTR | cystic fibrosis transmembrane conductance regulator |
| cGMP | cyclic guanosine monophosphate |
| CGRP | calcitonin gene-related peptide |
| CHCT | caffeine–halothane contracture test |
| CHD | congenital heart disease |
| CHEOPS | Children's Hospital of Eastern Ontario Pain Scale |
| CHF | congestive heart failure |
| CIOMS | Council of International Organization and Medical Sciences |
| CIRCI | critical illness-related corticosteroid insufficiency |
| CK | creatine kinase |
| CKD | chronic kidney disease |
| CLABSI | central line-associated bloodstream infection |
| CLD | chronic lung disease |
| CLE | congenital lobar emphysema |
| cLMA | classic laryngeal mask airway |
| CM | cardiomyopathy |
| $C_{max}$ | maximum plasma concentration |
| CME | continuing medical education |
| cMEP | cortical motor evoked potential |
| $CMRO_2$ | cerebral metabolic rate of $O_2$ |
| CMS | Centers for Medicare and Medicaid Services |
| CMV | cytomegalovirus |
| CN | cranial nerve |
| CNI | calcineurin inhibitor |
| CNS | central nervous system |
| CO | cardiac output/carbon monoxide |
| COG | Children's Oncology Group |
| COX | cyclo-oxygenase |
| CP | cerebral palsy |
| CPAM | congenital pulmonary airway malformation |
| CPAP | continuous positive airway pressure |
| CPB | cardiopulmonary bypass |
| CPD | citrate, phosphate, dextrose |
| CPOE | computerized physician order entry |
| CPP | coronary/cerebral perfusion pressure |
| CPR | cardiopulmonary resuscitation |
| CrCL | creatinine clearance |
| CrCP | critical closing pressure |
| CRF | case report form/chronic renal failure |
| CRP | C-reactive protein |
| CRPS | complex regional pain syndrome |
| CRRT | continuous renal replacement therapy |
| CSF | cerebrospinal fluid |
| CSI | Cerebral State Index |
| CSV | Children's Surgery Verification |
| CT | closure time/computed tomography |
| CTFR | cystic fibrosis transmembrane conductance regulator |
| CUF | conventional ultrafiltration |
| CVA | cerebrovascular accident |
| CVC | central venous catheter |
| CVP | central venous pressure |
| CVR | CPAM volume ratio |
| CXR | chest x-ray |
| CYP | cytochrome P450 |
| DA | dopaminergic |
| DAS | distal arthrogryposis syndrome |
| dB | decibel |
| DBS | double-burst stimulation |
| DC | direct current |
| DCD | cardiac (or circulatory) death/donation after cardiac death |
| DCM | dilated cardiomyopathy |
| DDAVP | 1-deamino-8-D-arginine vasopressin |
| DEX | dexmedetomidine |
| DHCA | deep hypothermic circulatory arrest |
| DHPR | dihydropyridine receptor |
| DI | diabetes insipidus |
| DIC | disseminated intravascular coagulation |
| DILV | double-inlet left ventricle |
| DKA | diabetic ketoacidosis |
| DLCO | diffusing capacity for carbon monoxide |
| DLT | double-lumen tube |
| DMD | Duchenne muscular dystrophy |
| DNA | deoxyribonucleic acid |
| DORV | double-outlet right ventricle |
| DPPC | dipalmitoyl phosphatidylcholine |
| DS | Down syndrome |
| DSMC | data safety monitoring committee |
| d-TGA | dextro-transposition of the great arteries |
| DUF | dilutional ultrafiltration |
| EA | emergence agitation/esophageal atresia |
| EACA | ε-aminocaproic acid |
| EAT | ectopic atrial tachycardia |
| EB | epidermolysis bullosa |
| EBV | estimated blood volume/Epstein–Barr virus |
| ECC | emergency cardiovascular care |
| ECF | extracellular fluid |
| ECG | electrocardiogram |
| ECLS | extracorporeal life support |
| ECMO | extracorporeal membrane oxygenation |
| ECoG | electrocorticography |
| ECPR | extracorporeal cardiopulmonary resuscitation |
| ECW | extracellular water |
| ED | emergence delirium/emergency department |
| EDMD | Emery–Dreifuss muscular dystrophy |
| EDV | end-diastolic volume |
| EEG | electroencephalography |
| EF | ejection fraction |
| EGD | esophagogastroduodenoscopy |
| EGDT | early goal-directed therapy |
| eGFR | estimated glomerular filtration rate |
| EHR | electronic health record |
| EMA | European Medicines Agency |
| EMG | electromyography |
| EMLA | eutectic mixture of local anesthetics |
| EMO | Epstein Macintosh Oxford |
| EMR | electronic medical record |
| EMS | emergency medical services |
| ENaC | epithelial sodium channel |
| ENS | enteric nervous system |
| ENT | ear, nose, and throat |
| EP | evoked potential |
| EPA | Entrustable Professional Activity |
| EPO | erythropoietin |
| ERAS | enhanced recovery after surgery |
| ERCP | endoscopic retrograde cholangiopancreatography |
| ERF | established renal failure |
| ESR | erythrocyte sedimentation rate |

| | |
|---|---|
| ESRD | end-stage renal disease |
| ESRT | evoked stapedius reflex threshold |
| ERT | enzyme replacement therapy |
| ET | endothelin/end-tidal |
| $ETCO_2$ | end-tidal carbon dioxide |
| ETT | endotracheal tube |
| ETV | endoscopic third ventriculostomy |
| EVD | external ventriculostomy drain |
| EXIT | *ex utero* intrapartum treatment |
| $F_A$ | alveolar fraction |
| FAST | focused assessment with sonography for trauma |
| FC | fibrinogen concentrate |
| FCC | fetoscopic cord coagulation |
| FDA | Food and Drug Administration |
| FDAMA | FDA Modernization and Accountability Act |
| FET | end tidal fraction |
| FETO | fetal endoscopic tracheal occlusion |
| $FEV_1$ | forced expiratory volume in 1 second |
| FFP | fresh frozen plasma |
| FGFR | fibrous growth factor receptor |
| FHF | first heart field |
| FHR | fetal heart rate |
| $FiO_2$ | fraction of inspired oxygen |
| FISH | fluorescence *in situ* hybridization |
| FLACC | face, leg, activity, cry, and consolability (scale) |
| fMRI | functional MRI |
| FNHTR | febrile non-hemolytic transfusion reaction |
| FOB | fiberoptic bronchoscope |
| FRC | functional residual capacity |
| FS | fractional shortening |
| FVC | forced vital capacity |
| FVL | factor V Leiden |
| FWA | Federal Wide Assurance |
| G | Gauss |
| GA | gestational age/general anesthesia |
| GABA | γ-aminobutyric acid |
| GABAA | γ-aminobutyric acid receptor, A subunit |
| GAS | General Anesthesia compared to Spinal Anesthesia (Study) |
| GCP | Good Clinical Practice |
| GCS | Glasgow coma scale |
| GER | gastroesophageal reflux |
| GERD | gastroesophageal reflux disease |
| GFR | glomerular filtration rate |
| GH | growth hormone |
| GI | gastrointestinal |
| $GP_i$ | globus pallidus internus |
| HAV | hepatitis A virus |
| Hb | hemoglobin |
| HbF | fetal hemoglobin |
| HBV | hepatitis B virus |
| HCG | human chorionic gonadotropin |
| HCM | hypertrophic cardiomyopathy |
| Hct | hematocrit |
| HCV | hepatitis C virus |
| HES | hydroxyethyl starch |
| HFOV | high-frequency oscillatory ventilation |
| HFPV | high-frequency percussive ventilation |
| HHS | US Department of Health and Human Services |
| Hib | *Haemophilus influenzae* type b |
| HIPAA | Health Insurance Portability and Accountability Act |
| HIV | human immunodeficiency virus |
| HLA | human leukocyte antigen |
| HLHS | hypoplastic left heart syndrome |
| HME | heat and moisture exchanger |
| HMWK | high-molecular-weight kininogen |
| HOCM | hypertrophic obstructive cardiomyopathy |
| HPV | hypoxic pulmonary vasoconstriction/human papillomavirus |
| HR | heart rate |
| HSA | human serum albumin |
| HSCT | hematopoietic stem cell transplantation |
| 5-HT3 | 5-hydroxytryptamine-3 |
| HTLV | human T-lymphotrophic virus |
| HTR | hemolytic transfusion reaction |
| HUS | hemolytic uremic syndrome |
| IAP | intra-abdominal pressure |
| IBD | inflammatory bowel disease |
| IBW | ideal bodyweight |
| IC | *in vitro* contracture (test) |
| ICD | implantable cardioverter-defibrillator |
| ICD-9 | *International Classification of Diseases*, 9th edition |
| ICF | intracellular fluid |
| ICN | intensive care nursery |
| ICP | intracranial pressure |
| ICU | intensive care unit |
| ICW | intracellular water |
| ID | internal diameter |
| IDMs | infants of diabetic mothers |
| I:E | inspiratory:expiratory |
| IE | infective endocarditis |
| Ig | immunoglobulin |
| IHCA | in-hospital cardiac arrest |
| IHPS | idiopathic hypertrophic pyloric stenosis |
| IIS | interictal spikes |
| IJ | internal jugular |
| IJV | internal jugular vein |
| IL | interleukin |
| IM | intramuscular |
| IN | intranasal |
| IND | Investigational New Drug |
| iNO | inhaled nitric oxide |
| INR | international normalized ratio/interventional neuroradiology |
| INSS | International Neuroblastoma Staging System |
| IO | intraosseous |
| IOP | intraocular pressure |
| IPPV | intermittent positive pressure ventilation |
| IRB | institutional/investigational review board |
| ISHLT | International Society for Heart and Lung Transplantation |
| ITD | impedence threshold device |
| IU | international unit |
| IV | intravenous |
| IVC | inferior vena cava |
| IVH | intraventricular hemorrhage |
| JRA | juvenile rheumatoid arthritis |
| JVP | jugular venous pressure |
| LA | local anesthetic/left atrium |
| LBW | lean bodyweight |
| LC | locus coeruleus |
| LCR | laryngeal chemoreflex |
| LD50 | median lethal dose |
| LDH | lactate dehydrogenase |
| LDLT | living donor lobar transplant |
| LED | light-emitting diode |
| LES | lower esophageal sphincter |
| LFCN | lateral femoral cutaneous nerve |
| LHR | lung to head ratio |
| LIC | low income countries |
| LiDCO | lithium dilution cardiac output |
| LITT | laser interstitial thermal therapy |
| LMA | laryngeal mask airway |
| LMIC | low middle income countries |
| LMWH | low molecular weight heparin |
| LOH | loss of heterozygosity |
| LOR | loss of resistance |
| LPS | lipopolysaccharide |
| LR | lactated Ringer's (solution) |
| L-R | left-to-right |
| LSMT | life-sustaining medical treatment |
| LV | left ventricle |

| | |
|---|---|
| LVAD | left ventricular assist device |
| LVEDP | left ventricular end-diastolic pressure |
| LVMI | left ventricular mass index |
| LVNC | left ventricular non-compaction |
| LVOT | left ventricular outflow tract |
| LVOTO | left ventricular outflow tract obstruction |
| MABL | maximum allowable blood loss |
| MAC | minimum alveolar concentration |
| MAP | mean arterial pressure |
| MAT | multifocal atrial tachycardia |
| MATE | multidrug and toxin extrusion transporter |
| MCA | middle cerebral artery |
| MCS | mechanical circulatory support |
| MDI | metered dose inhaler |
| MDR | multidrug-resistant |
| MEG | magnetoencephalography |
| MELD | model for end-stage liver disease |
| MEN2 | multiple endocrine neoplasia type 2 |
| MEP | motor-evoked potential |
| MER | microelectrode recording |
| MET | Medical Emergency Teams |
| MH | malignant hyperthermia |
| MIBG | metaiodobenzyl guanidine |
| MIPS | Merit-based Incentive Payment System |
| MIS | minimally invasive surgery |
| MMC | migrating motor complex/myelomeningocele |
| MMF | mycophenolate mofetil |
| MODS | multiple organ dysfunction syndrome |
| 6-MP | 6-mercaptopurine |
| MPAP | mean pulmonary artery pressure |
| MPD | maximum permissible dose |
| MPOG | Multicenter Perioperative Outcomes Group |
| MPP | myocardial perfusion pressure |
| MR | magnetic resonance |
| MRI | magnetic resonance imaging |
| MRI/A | magnetic resonance imaging and angiography |
| MRP | multiple drug resistance-associated protein |
| MRSA | methicillin-resistant *Staphylococcus aureus* |
| MS | molar substitution |
| MTD | maximal tolerated dose |
| MTHFR | methylenetetrahydrofolate reductase |
| mTOR | mammalian target of rapamycin |
| MTP | massive transfusion protocol |
| MUF | modified ultrafiltration |
| $MVO_2$ | mixed venous oxygen saturation |
| MW | molecular weight |
| NAC | N-acetylcysteine |
| NACOR | National Anesthesia Clinical Outcomes Registry |
| NAD | nicotinamide adenine dinucleotide |
| NADPH | nicotinamide adenine dinucleotide phosphate |
| NAT | nucleic acid testing |
| NCA | nurse-controlled analgesia |
| nCPAP | nasal continuous positive airway pressure |
| NCS | non-convulsive seizures |
| Nd:YAG | neodymium:yttrium-aluminum garnet |
| NDA | New Drug Application |
| NE | norepinephrine |
| NEB | neuroendocrine bodies |
| NEC | necrotizing enterocolitis |
| NEHI | neuroendocrine hyperplasia of infancy |
| NF | neurofibromatosis |
| NFκB | nuclear factor κB |
| NGT | nasogastric tube |
| NICU | neonatal intensive care unit |
| NIPPV | nasal intermittent positive pressure ventilation |
| NIRS | near-infrared spectroscopy |
| NMB | neuromuscular blocking drug |
| NMBA | neuromuscular blocking agent |
| NMDA | N-methyl-D-aspartate |
| NNT | number needed to treat |
| NO | nitric oxide |
| NORA | non-operating room anesthesia |
| NPH | nephronophthisis/neutral protamine Hagedorn (insulin) |
| NPMODS | new and progressive multiple organ dysfunction syndrome |
| NPO | nil per os |
| NPPE | negative pressure pulmonary edema |
| NRL | natural rubber latex |
| NRP | Neonatal Resuscitation Program |
| NS | normal saline |
| NSAID | non-steroidal anti-inflammatory drug |
| NSQIP | National Surgical Quality Improvement Program |
| NTCP | $Na^+$/taurocholate co-transporting polypeptide |
| OAT | organic anion transporter |
| OATP | organic anion transporting polypeptide |
| OAVS | oculo-auriculovertebral spectrum |
| OCT | organic cation transporter |
| OELM | optimal external laryngeal manipulation |
| OHCA | out-of-hospital cardiac arrest |
| OHRP | Office for Human Research Protections |
| OI | osteogenesis imperfecta |
| OIB | Oxford inflating bellows |
| OLV | one-lung ventilation |
| OMV | Oxford miniature vaporizer |
| OPTN | Organ Procurement and Transplant Network |
| OR | odds ratio/operating room |
| OSA | obstructive sleep apnea |
| OSAS | obstructive sleep apnea syndrome |
| OSCE | Objective Structured Clinical Examination |
| PA | pulmonary artery/pulmonary atresia |
| PABD | preoperative autologous blood donation |
| PAC | premature atrial contractions |
| $PaCO_2$ | partial pressure of $CO_2$ in arterial blood |
| PACU | postanesthesia care unit |
| PAED | Pediatric Anesthesia Emergence Delirium (scale) |
| PALICC | Pediatric Acute Lung Injury Consensus Conference |
| PALS | pediatric advanced life support |
| $PaO_2$ | partial pressure of oxygen in arterial blood |
| PAS | periodic acid–Schiff |
| PBS | prune belly syndrome |
| PC | protein C |
| PCA | patient-controlled anesthesia/postconceptual age |
| PCC | prothrombin complex concentrate |
| PCRA | patient-controlled regional anesthesia |
| PCWP | pulmonary capillary wedge pressure |
| PD | pharmacodynamic/peritoneal dialysis |
| PDA | patent ductus arteriosus |
| PDE | phosphodiesterase |
| PEA | pulseless electrical activity |
| PEC | Program Evaluation Committee |
| PEEP | positive end-expiratory pressure |
| PEFR | peak expiratory flow rate |
| PEG | percutaneous endoscopic gastrostomy |
| PELD | pediatric end-stage liver disease |
| PELOD | PEdiatric Logistic Organ Dysfunction (score) |
| PET | positron emission tomography |
| PEVPPS | Preverbal, Early Verbal Pediatric Pain Scale |
| PFC | persistent fetal circulation |
| PFIC | progressive familial intrahepatic cholestasis |
| PFO | patent foramen ovale |
| PFT | pulmonary function test |
| PG | prostaglandin |
| PGD | primary graft dysfunction |
| PGE1 | prostaglandin E1 |
| P-gp | P-glycoprotein |
| PH | pulmonary hypertension |
| PHBQ | Post Hospitalization Behavior Questionnaire |
| PICC | percutaneously/peripherally inserted central catheter |
| PiCCO | pulse-contour analysis of the arterial waveform |

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|---|---|
| PICOT | Population, Intervention, Comparison, Outcome, Timeline |
| PICU | pediatric intensive care unit |
| PIPP | premature infant pain profile |
| PIV | peripheral intravenous catheter |
| PK | pharmacokinetic/prekallikrein |
| PKA | protein kinase A |
| PKC | protein kinase C |
| PLV | protective lung ventilation |
| P-MODS | Pediatric-Multiple Organ Dysfunction Score |
| PN | parenteral nutrition |
| PNAM | presurgical nasal alveolar molding |
| PNB | peripheral nerve block |
| PNEC | pulmonary neuroendocrine cells |
| PO | per os |
| POAH | preoptic anterior thalamus |
| POCA | Pediatric Perioperative Cardiac Arrest (registry) |
| POCUS | point-of-care ultrasound |
| POLST | physician order for life-sustaining treatment |
| PONV | postoperative nausea and vomiting |
| POV | postoperative vomiting |
| POVL | postoperative visual loss |
| PPH | portopulmonary hypertension |
| PPHN | persistent/primary pulmonary hypertension of the newborn |
| PPIA | parental presence at induction of anesthesia |
| ppm | parts per million |
| PPROM | preterm premature rupture of membranes |
| PPV | positive pressure ventilation |
| PQRS | Physician Quality Reporting System |
| PRA | panel reactive antibody |
| PRAE | perioperative respiratory adverse event |
| PRAN | Pediatric Regional Anesthesia Network |
| PRBC | packed red blood cells |
| PREA | Pediatric Research Equity Act |
| PRIS | propofol infusion syndrome |
| PRS | Pierre Robin sequence |
| PS | protein S |
| PSH | perioperative surgical home |
| PSRC | Pediatric Sedation Research Consortium |
| PT | prothrombin time |
| PTLD | post-transplant lymphoproliferative disorder |
| PTP | post-transfusion purpura |
| PTSD | post-traumatic stress disorder |
| PTT | partial thromboplastin time |
| PUBS | percutaneous umbilical blood sampling |
| PUV | posterior urethral valves |
| PV | postoperative vomiting/pulmonary valve |
| PVB | paravertebral block |
| PVC | premature ventricular contractions/polyvinyl chloride |
| $PVO_2$ | pulmonary venous $O_2$ content |
| PVR | pulmonary vascular resistance |
| pVT | pulseless ventricular tachycardia |
| QL | quadratus lumborum |
| Qp:Qs | ratio of pulmonary to systemic blood flow |
| RA | right atrium |
| RAE | Ring–Adair–Elwyn |
| RAP | right atrial pressure |
| RBBB | right bundle branch block |
| RBC | red blood cell |
| RCM | radiocontrast media/restrictive cardiomyopathy |
| RCP | regional cerebral perfusion |
| RCT | randomized controlled trial |
| RDS | respiratory distress syndrome |
| REC | research ethics committee |
| REM | rapid eye movement |
| RF | radiofrequency/rheumatoid factor |
| RFA | radiofrequency ablation |
| RFID | radiofrequency identification |
| rFVIIa | recombinant activated factor VII |
| R-L | right-to-left |
| RLFP | regional low-flow perfusion |
| ROP | retinopathy of prematurity |
| ROSC | return of spontaneous circulation |
| RPGN | rapidly progressive glomerulonephritis |
| RR | relative risk |
| RRT | renal replacement therapy |
| RSI | rapid-sequence induction |
| RSII | rapid-sequence induction and intubation |
| $rSO_2$ | regional oxygen saturation |
| RSV | respiratory syncytial virus |
| RV | right ventricle/residual volume |
| RVOT | right ventricular outflow tract |
| RYGB | Roux-en-Y gastric bypass |
| SAE | serious adverse event |
| SAFEKIDS | Safety of Key Inhaled Anesthetics in Children (study) |
| SAH | subarachnoid hemorrhage |
| $SaO_2$ | percent arterial oxyhemoglobin saturation |
| SAR | specific absorption rate |
| SCD | sickle cell disease |
| SCFE | slipped capital femoral epiphysis |
| SCh | succinylcholine |
| SCIWORA | spinal cord injury without radiological abnormalities |
| SCPA | superior cavopulmonary anastomosis |
| SCT | sickle cell trait/sacrococcygeal teratoma |
| $S_{CV}O_2$ | central venous oxygen saturation |
| SD | standard deviation |
| SFLP | selective fetoscopic laser photocoagulation |
| SGA | small for gestational age/supraglottic airway |
| SGS | subglottic stenosis |
| SHF | second heart field |
| SIADH | syndrome of inappropriate secretion of antidiuretic hormone |
| SIDS | sudden infant death syndrome |
| SIOP | International Society of Pediatric Oncology |
| SIRS | systemic inflammatory response syndrome |
| $SjvO_2$ | oxygen saturation in jugular venous bulb |
| SLC | solute carrier |
| SNP | sodium nitroprusside |
| SOFA | Sequential Organ Failure Assessment |
| SOS | Shikani optical stylet |
| SPA | Society for Pediatric Anesthesia |
| SPECT | single photon emission computed tomography |
| SPLIT | Studies in Pediatric Liver Transplantation |
| SR | sarcoplasmic reticulum |
| SSCG | Surviving Sepsis Campaign Guidelines |
| SSEP | somatosensory-evoked potential |
| SSRI | selective serotonin reuptake inhibitor |
| STN | subthalamic nuclei |
| STS | Society of Thoracic Surgeons |
| SV | single ventricle |
| SVAS | supravalvar aortic stenosis |
| SVC | superior vena cava |
| SVL | Storz video laryngoscope |
| SVR | systemic vascular resistance |
| SVT | supraventricular tachycardia |
| T | Tesla |
| TA | tranexamic acid/tricuspid atresia |
| T&A | tonsillectomy and adenoidectomy |
| TACO | transfusion-associated circulatory overload |
| TA-GVHD | transfusion-associated graft versus host disease |
| TAH | total artificial heart |
| TAP | transversus abdominis plane |
| TB | tuberculosis |
| TBI | traumatic brain injury/total body irradiation |
| TBSA | total body surface area |
| TBV | total blood volume |
| TBW | total body water/total bodyweight |
| TCD | transcranial Doppler ultrasound |
| TCI | target-controlled infusion |
| TCPC | total cavopulmonary connection |

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|---|---|
| TEE | transesophageal echocardiogram |
| TEF | tracheoesophageal fistula |
| TEG | thromboelastography |
| TF | tissue factor |
| TFPI | tissue factor pathway inhibitor |
| TGA | transposition of the great arteries |
| TGF | transforming growth factor |
| THAM | tris(hydroxymethyl)aminomethane |
| THRIVE | transnasal humidified rapid insufflation exchange |
| TIVA | total intravenous anesthesia |
| TLR | Toll-like receptor |
| TLV | total lung volume |
| $T_{max}$ | time to maximum concentration |
| TMJ | temporomandibular joint |
| TNF | tumor necrosis factor |
| TOF | tetralogy of Fallot/train-of-four |
| TOI | tissue oxygenation index |
| tPA | tissue plasminogen activator |
| TPN | total parenteral nutrition |
| TPTN | transpulmonary thermodilution |
| TRALI | transfusion-related acute lung injury |
| TRAP | twin reversed arterial perfusion (sequence) |
| TRICC | Transfusion Requirements in Critical Care (trial) |
| TRIM | transfusion-related immunomodulation |
| TSC | tuberous sclerosis complex |
| TSH | thyroid stimulating hormone |
| TT | thrombin time |
| TTN | transient tachypnea of the newborn |
| TTP | thrombotic thrombocytopenic purpura |
| TTTS | twin–twin transfusion syndrome |
| TV | tricuspid valve |
| TXA | tranexamic acid |
| UBF | uterine blood flow |
| UDP | uridine diphosphate |
| UDPGA | uridine diphosphate glucuronic acid |
| UDPGT | uridine diphosphate glucuronyltransferase |
| UDT | undescended testes |
| UGT | UDP-glucuronosyltransferase |
| UNOS | United Network for Organ Sharing |
| UPJ | ureteropelvic junction |
| URI/URTI | upper respiratory tract infection |
| US | ultrasound |
| UTI | urinary tract infection |
| UVJ | ureterovesical junction |
| VA | veno-arterial/ventriculo-arterial/Veterans Administration |
| VACTERL | vertebral, anal, cardiac, tracheoesophageal, renal and limb anomalies |
| VAD | ventricular assist device |
| VAE | venous air embolism |
| VAS | vesicoamniotic shunt/visual analog scale |
| VATS | video-assisted thoracoscopic surgery |
| VCFS | velocardiofacial syndrome |
| VEGF | vascular endothelial growth factor |
| VEPTR | vertical expandable prosthetic titanium rib |
| VF | ventricular fibrillation |
| VGAM | vein of Galen aneurysmal malformation |
| VHL | von Hippel–Lindau |
| VIP | vasoactive intestinal polypeptide |
| VMI | visual motor integration |
| $VO_2$ | maximum oxygen uptake |
| VSD | ventricular septal defect |
| VT | ventricular tachycardia |
| VTi | velocity time integral |
| VUR | vesicoureteric reflux |
| VV | veno-venous |
| vWD | von Willebrand disease |
| vWF | von Willebrand factor |
| vWF:RCo | ristocetin co-factor assay |
| WB | whole blood |
| WBC | white blood cell |
| WEB | wire-guided endobronchial blocker |
| WFSA | World Federation of Societies of Anaesthesiologists |
| WHO | World Health Organization |
| Wu | Woods unit |
| WUS | Wake Up Safe |
| ZBUF | zero-balance ultrafiltration |

CHAPTER 1

# Ethics and Professionalism in Pediatric Anesthesia

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## Introduction

The key to the ethical practice of pediatric anesthesia is: *Treat every child and family with the grace and consideration with which you would want your child and family treated*. Here are seven maxims:

1. *Remember that surgery is a big deal*. Reminding yourself that this banal case is a lifetime event for the child and family helps you be kind and respectful to the child and family. It boosts your ability to mitigate the production pressure that hurries you to induce anesthesia before the premedication has taken effect, inadequately prepare a nervous adolescent for insertion of an intravenous catheter, or skirt safety guidelines.
2. *Meet the needs of the child and family*. Focus on process by being patient, calm, flexible, and nonjudgmental. Anxious, sleep-deprived parents receiving complicated information may need to hear it several times to understand it or may react strongly to the seemingly unremarkable. Interact with the intent of determining their needs, whether it be the extent of information, the preferences for decision making, or the need for reassurance. Respond directly to questions.
3. *Be humble*. As a professional, it is tempting to believe you know what is best. But many of the choices families make reflect values, anxieties, and personal, family, and community experiences that are difficult for you to know, much less appreciate. Denigrating families for choosing what you believe to be a less optimal albeit acceptable choice ravages professionalism and mars interactions with all patients. If you think a decision is unacceptable, consult with respected colleagues before pursuing administrative or legal interventions.
4. *Assume responsibility for the children and their families*. "Own" care for the child and family to ensure that every little thing goes as well as possible. This includes: bringing a chair for the third adult; finding someone to answer questions unrelated to perioperative clinical care; doing a thorough preoperative evaluation; making the extra effort to insert the IV in a way that does not impede the dominant hand; always using the optimal anesthetic technique; being alert for errors in the operating room unrelated to you; and ensuring children and families are physically and emotionally well postoperatively. If you would do it for your child, you should do it for every child.
5. *Serve patients*. Medicine is a noble service profession. For the most part, patients' preferences, values, and needs supersede ours. Our values become relevant only after thorough, thoughtful, and careful consideration and consultation.
6. *Hone your mastery*. Strive to provide first-rate care, critically consider what you know and how you know it, and seek help freely [1].
7. *Use empathic behavior*. Clinicians need to overtly communicate that they understand and appreciate the perspective and experience of the child and family [2]. An effective way to communicate empathy is a heartfelt "I wish things were different" [3].

*Gregory's Pediatric Anesthesia*, Sixth Edition. Edited by Dean B. Andropoulos and George A. Gregory.

Although clinicians may think of medical ethics in dramatic terms – withdrawing life-sustaining therapy, allocating organs for transplant – medical ethics floods our daily practice. Consider the clinician who recommends postponing surgery in an infant because of a borderline upper respiratory infection. Should they be flexible if the infant has missed three surgical dates for non-medical reasons? How should they respond to a parental request to proceed? Within these seemingly medical decisions lie the ethical components of informed consent and obligations to the child and family. How do we decide how much weight to give the parents' strong desire to proceed? Does it matter why they want to proceed (guilt over missing the previous appointments? Concern about their child's health? Convenience because grandma is in town to care for siblings? Concern about being able to get time off from work again? Scheduling because the child will spend the summer with an out-of-town parent, effectively delaying the operation until fall? etc.). Should we even consider the effects on the family? What if there is concern that the parents will not reschedule surgery?

Ethical dilemmas occur when clinicians are faced with "oughts" – that which a physician is bound by duty to do – that conflict. In the above example, clinicians ought to base proceeding with surgery solely on the child's best interest, which may include the effects of the upper respiratory infection and the likelihood that the child will get a timely operation. Medical ethics provides the process by which to resolve these apparently conflicting "oughts."

Resolving ethical dilemmas is not a matter of being a moral person. Identifying, diagnosing and managing ethical conflicts requires the same extent of expertise that is required to identify, diagnose, and manage myocardial ischemia. Training and experience in resolving ethical dilemmas enables ethics consultants to identify the dilemma and critical facts, apply ethical principles and case-based analysis, articulate precise questions, and have the moral imagination to create more palatable solutions.

Despite erstwhile efforts, fewer than 51% of pediatric residents correctly answered questions about some aspects of patient confidentiality, genetic testing, pediatric assent and the ethical similarity of withholding and withdrawing potentially life-sustaining medical treatments (LSMT) [4].

Deficits like these highlight the importance of ethics committees and their consultation services. Clinicians may find consultation services particularly helpful with concerns about disagreements among families and clinicians, appropriate decision-making roles for adolescents, decisions about end-of-life care, and professional obligations [5,6].

Members of ethics committees include representatives from throughout the hospital such as chaplains, administrators, social workers, nurses, and physicians. Many committees also include local community representatives. Depending on local practice, consultations may be performed by an individual, a small group, or the entire ethics committee. Most ethics consultation services permit anyone with standing to request a consultation, which fundamentally includes all clinicians who participate in the care of the patient [5]. Most services enter a written report into the clinical record. The standard of care is that ethics consultation services advise only and have no formal authority. A committee with a strong record, however, has substantial informal authority. The case study provides an example of an ethics consultation.

The law is not a desirable substitute for resolving ethical dilemmas. The law represents a lower bound for acceptable behavior, whereas ethics articulates a standard to which we should aspire. Pragmatically, the law does not provide clear guidance because most law surrounding ethical dilemmas is case law. In addition, the frequently adversarial legal process may pollute future family–clinician–hospital relations. Crude statutes and regulations are unable to govern complex medical care.

### KEY POINTS: THE ETHICAL PRACTICE OF PEDIATRIC ANESTHESIA

- Pediatric medical ethics is a broad and changing field
- Identification, diagnosis, and management of ethical issues requires expert knowledge, experience, and skill
- Anyone involved in a patient's care can request an ethics consultation

## The informed consent process for children

The doctrine of informed consent centers on the belief that patients have a right to self-determination. The right to self-determination is actualized through the legal concept of competency. Except in specific situations, minors are not legally competent to consent for healthcare. But minors do have varying degrees of decision-making capacity, and minors should be included in medical decision making to the extent permitted by the child and situation (Box 1.1) [7].

The process of pediatric informed consent depends on the age and development of the child (Table 1.1). The concepts

**Box 1.1:** Elements of consent and assent as defined by the American Academy of Pediatrics [7]

**Elements of informed consent for medical decision making**

- Provision of information about the following:
  - Nature of the illness or condition
  - Proposed diagnostic steps and/or treatments and the probability of their success
  - The potential risks, benefits, and uncertainties of the proposed treatment and alternative
  - Treatments, including the option of no treatment other than comfort measures
- Assessment of patient and surrogate understanding and medical decision-making capacity, including assurance of time for questions by patient and surrogate
- Ensure that there is voluntary agreement with the plan

**Practical aspects of assent by pediatric patients for medical decision making**

- Help the patient achieve a developmentally appropriate awareness of the nature of the condition
- Tell the patient what to expect with tests and treatments
- Make a clinical assessment of the patient's understanding of the situation and the factors influencing how they respond (including whether there is inappropriate pressure to accept testing or therapy)
- Solicit an expression of the patient's willingness to accept the proposed care

**Table 1.1** Graduated involvement of minors in medical decision making

| Age | Decision-making capacity | Techniques |
|---|---|---|
| Under 6 years | None | Best interest standard<br>Harm threshold standard |
| Ages 7–11 years | Developing | Informed permission<br>Informed assent |
| Ages 12–18 years | Cognitive skills developed<br>Maturity developing | Informed assent<br>(approaching informed consent as developmentally appropriate)<br>Informed permission |
| Mature minor | Developed, as legally determined by a judge, for a specific decision | Informed consent |
| Emancipated minor | Developed, as determined by a situation (e.g. being married, in the military, economically independent) | Informed consent |

This broad outline should be viewed as a guide. Specific circumstances always must be taken into consideration. When children are in the upper range of an age bracket, limited or full inclusion of a more developmentally advanced technique, such as the use of assent for a 6-year-old, may be appropriate.

of best interest, informed permission, and assent are used when considering pediatric informed consent. For convenience, the term "parent" will be used to describe the child's surrogate decision maker. Parents are not always the legal surrogate decision maker and parental authority may be limited in adolescents. The term "decision makers" will refer to those involved in the specific decision and may include parents, children, and their advisors.

The primary lesson of this chapter should be to respect the experiences and opinions of children. The American Academy of Pediatrics emphasizes that "no one should solicit a patient's views without intending to weigh them seriously. In situations in which patients will have to receive medical care despite their objections, the patient should be told that fact and should not be deceived." [8].

## The best interest standard and informed permission

Informed consent can be given only by the patient. Some advocate for the term "informed permission" for when the parent provides legal consent and ethical decision making for the child, to emphasize that the consent is not by the patient [8]. This conceptual framework highlights the ethical limits of parental decision making. It does not affect the legal obligation to obtain informed consent from the parents as defined by local statutes.

Children younger than the age of 7 typically have insufficient decision-making capacities to participate effectively in the informed consent process. When children cannot effectively participate, or when parents are unable to base a decision on previous interactions with the child, the best interest standard traditionally guides decision making. This standard requires determining who will make the decision and what is in the child's best interest. Best interest does not mean the best care as defined by the clinicians. There are often several acceptable options, and clinicians rely on parents to determine which one is in the child's best interest. Parents are given considerable latitude in decision making because society values the role of family, parents want the best for their children, and families often have to live with the result of the choices. Although parents may be wrong in determining the preferences of their child's future self, many accept that parental values serve as a reasonable approximation of those future values [9].

Parental decisions should be scrutinized if they appear to fall outside of the boundaries of acceptable care. Boundaries are determined by the extent and likelihood of potential harms by the intervention or its absence, the likelihood of success, and the overall risk-to-benefit ratio.

The harm threshold standard may be more accurately named and conceptually useful than the best interest standard for determining whether to limit parental decision making. The harm threshold standard bases decisions on whether a parental choice threatens the health and safety of the child [10–12]. Many clinicians probably use a form of this standard to identify the borders of unacceptable decision making.

When parents appear to choose unacceptable treatments, clinicians should consult with colleagues to assess the acceptability of the decision and, if necessary and appropriate, to participate in the discussion. Seek to resolve disagreements without resorting to legal intervention. But the state has an interest in protecting those who cannot protect themselves. If other options have failed, clinicians should initiate an evaluation if they believe parents to be choosing unacceptable treatments.

## Informed assent: the role of the child

Children should participate in decision making to the extent their development permits [7]. Decision-making capacity for children is based on the ability to understand and recall the information, to reason, which includes evaluating the risks and benefits of the options presented, to appreciate the effect of the decision on themselves, which requires advance abstract thinking, and to make a choice. Neurobiological evidence suggests that these abilities change with age and experience and are frequently present by the age of 12 [13].

For children between the ages of 7 and 11, clinicians should seek both informed permission from the parent and assent and participatory decision making from the child. Common decisions in which children participate include whether a 6-year-old wants sedation prior to an inhalation induction, whether a 10-year-old wants inhalation or intravenous induction of anesthesia, and whether an 11-year-old wants a peripheral nerve catheter for postoperative analgesia.

Clinicians should assume that adolescents 12 years and older have sufficient decision-making capacity to fulfill the ethical obligations of informed consent. Their decision-making capacities are affected, however, by their personality,

the situation, emotional impulsiveness, and a tendency to undervalue long-term consequences. The tendency to take risks increases in emotional situations. For these reasons, the influence an adolescent has on decision making is tempered by the adolescent's maturity and the risks of the decision. Decisions are considered higher risk when they include an increased likelihood of permanently lost opportunities that have noteworthy consequences. For example, delayed scoliosis surgery may increase the extent of the curve, subsequently impairing cardiopulmonary function. These impairments can affect the quality of life, future morbidity, and lifespan. In determining the extent of risk in a decision, the quality and relevance of the data must be rigorously considered.

## Emancipated minors and the mature minor doctrine

Emancipated minors are minors who have a statutory right to legally consent for their own healthcare decisions. States often award this status to patients who are in the military, who are married, who have children, and who are economically independent. To be declared a mature minor, the patient must be determined by a judge to be legally and ethically capable of giving legal consent in a specific situation. Judges consider mature minor status based on the extent of the risk in the decision and the developmental maturity and age of the child.

## Disclosure

The legal standard for most of the United States is the reasonable person standard, which declares that the information disclosed should satisfy the hypothetical reasonable person.

It is ethically, morally, and legally unclear as to what satisfies the reasonable person standard for informed consent for pediatric anesthesia. Children and families differ about the type and depth of information they want to receive, their desire to participate in making decisions, and their goals of the informed consent discussion [14]. For example, some want information to make decisions, some want information because they feel obligated to be informed, or some want reassurances that everything will go well, which often results in wanting less information. Sociodemographic characteristics do not reliably predict preferences for disclosure and decision making. These preferences may change given the surgery, stress, and other factors present that day.

A better approach is for the clinician to communicate only the necessary information based on the child's medical status, the risks of the procedure, and the availability of acceptable clinical options, and then seek to meet the informational and decision-making needs of the child and family by asking if they want to know more [15]. This does not burden those tepid about further information while meeting the needs of those who seek a more complete discussion. Patient-driven interactions likely reduce malpractice lawsuits. The likelihood of being sued based on informed consent malpractice issues is very rare. But the improved satisfaction that comes from patient-driven interactions (or, more simply, from listening to and responding to the decision makers' needs and requests) leads to decreased complaints and lawsuits in general [16].

Postoperative nausea and vomiting (PONV) is an archetype of the issues clinicians may want to routinely communicate unless explicitly deferred. PONV is: (1) of great concern to parents; (2) addressable by early use of medications; (3) modifiable by behavioral and eating strategies; and (4) relevant to seeking postoperative medical interventions. Yet, in one study, PONV was discussed in only 36% of preoperative discussions [17].

The literature varies in what must be told to patients and is rarely prescriptive [18]. Practices vary, even within the same institution. For example, in a 2012 observational study of consent for pediatric anesthesia, the five most commonly discussed risks per conversation were nausea and vomiting (36%), sore throat (35%), allergy (29%), hypoxia (25%), and emergence delirium (19%) [17]. Trainees discussed about three risks in each conversation as compared to attendings who discussed only one. Nearly a third of interactions used only general statements about anesthesia risk without further information about their nature, ramifications, or incidence. It is unclear whether these variations are appropriate responses to decision makers' needs or baseline variations in standards.

Adjunct techniques, like regional analgesia, require a modification of the "meet the decision makers' needs" approach. Consider extensive knee surgery in an otherwise healthy young adolescent. Because decision makers understand that general anesthesia is essential for the surgery to proceed, they may defer more thorough risk information because it will not sway their decision. But in this child, regional analgesia is an option but not a necessity. Decision makers should be aware that regional analgesia is not essential to the surgery, and, because there is a greater role for choice, decision makers should be more extensively informed about the risks and benefits.

Patients have difficulty understanding quantitative risks. Table 1.2 describes strategies for communication [19–21].

## Informed refusal

Refusal of a significant recommendation requires clinicians to more fully inform decision makers about the risks, benefits, and alternatives than if the decision makers were following the recommendation. This helps ensure that decision makers are as knowledgeable as possible about the risks of selecting a less desirable path.

Children with significant decision-making capacity (perhaps around the age of 10 years but certainly by the age of 12 years) might refuse non-emergent procedures. Clinicians should respect this refusal of assent and conscientiously avoid pressuring the child. Coercing or manipulating a child into having a procedure damages the child's trust of the medical profession and impairs future cooperation with their care. Maintenance of trust is particularly important in children with chronic medical conditions.

Strategies for resolving conflicts center on maintaining communication, clarifying misunderstandings about the anesthetic and surgical experience, and decreasing the anxiety of both the child and parents. The goal is to resolve the problem without impairing the relationships among the child, parents, and clinicians. Clinicians may want to emphasize that nothing will happen without the child's approval, *but only if that is true*. Moving the discussion away from the preoperative area or letting the child dress in street clothes will often reduce stress and improve communication.

Clinicians should recognize the distinction between using pharmacologic agents to calm an anxious adolescent to enable

**Table 1.2** Communicating quantitative risk to patients [19–21]

Understanding quantitative risks may help patients make decisions. Presentation is key to understanding. Consider a patient who is concerned about PONV. They want to know the relative risks of PONV in regional anesthesia (30%) versus general anesthesia (50%).

**Approach**

1. Use language at the 8th grade level.
2. Use absolute risks and frequencies.
3. Avoid relative descriptions like "regional anesthesia decreases the rate of PONV by 50% compared to general anesthesia."
4. Because patients have different abilities, data should be presented in a variety of ways cautiously. Too much information too quickly is confusing.

| Verbal presentations | Analysis |
|---|---|
| "With regional anesthesia, there is a 30% chance of PONV. With general anesthesia, there is a 50% change of PONV" | • Relies on an understanding of percentages that is not universally present |
| "With regional anesthesia, there is a 30% chance of PONV, which is *3 out of 10 patients*. With general anesthesia, there is a 50% change of PONV, which is *5 out of 10 patients*" | • Adds a frequency (*3 out of 10 patients; 5 out of 10 patients)*<br>◦ Presents a second avenue to understanding<br>◦ Is often easier to understand |
| "With regional anesthesia, there is a 30% chance of PONV, which is 3 out of 10 patients. With general anesthesia, there is a 50% chance of PONV, which is 5 out of 10 patients. That means that *2 more patients out of 10* will have postoperative vomiting if we use general anesthesia | • Adds a direct comparison using an absolute number (*2 more patients out of 10*), which is often helpful<br>• Increases the language complexity<br>• Possible solutions<br>◦ Present information in smaller chunks, which makes it easier to understand<br>◦ Use pictorial representation |

| Pictorial presentations | Analysis |
|---|---|
| **Pictorial representation #1** | • Clinician can draw ten dots and fill in the appropriate number<br>• Described as the number of patients out of 10 who will have PONV with that type of anesthesia |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Regional anesthesia | ■ | ■ | ■ | □ | □ | □ | □ | □ | □ | □ |
| General anesthesia | ☒ | ☒ | ☒ | ☒ | ☒ | □ | □ | □ | □ | □ |

**Pictorial representation #2**

- One line can be used to compare two treatments
- The additional patients who will have PONV can be circled or highlighted

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Regional anesthesia<br>General anesthesia | ■ | ■ | ■ | ☒ | ☒ | □ | □ | □ | □ | □ |

proceeding and using pharmacologic agents to manipulate the adolescent into proceeding. Consider the 15-year-old who becomes overwhelmingly anxious and refuses surgery. It would be inappropriate to unilaterally administer midazolam to gain cooperation. On the other hand, it is wholly appropriate to seek the adolescent's assent to receive sufficient anxiolysis so they may undergo the procedure. Time, respect, and simple strategies often resolve issues satisfactorily and efficiently.

## Children of Jehovah's Witnesses

Jehovah's Witnesses interpret biblical scripture to mean that anyone who accepts blood will be "cut off from his people" and not receive eternal salvation [22]. Adults may refuse potentially life-sustaining transfusion therapy. The presumption is that they are making an informed and voluntary decision. Courts commonly authorize necessary perioperative transfusions for children of Jehovah's Witnesses. The courts base these decisions on the doctrine of *parens patriae,* the obligation of the state to protect the interests of incompetent patients.

Clinicians should directly address perioperative transfusion therapy when caring for a child of Jehovah's Witnesses. The child and family should be informed that, as with all patients, attempts will be made to follow the family's wishes within the standard of care. Because refusal of transfusion therapy is deemed a "matter of conscience," the clinicians should clarify acceptable interventions. Deliberate hypotension, deliberate hypothermia, and hemodilution are often acceptable techniques. Synthetic colloid solutions, dextran, erythropoietin, desmopressin, and preoperative iron are usually acceptable. Some Jehovah's Witnesses will accept blood removed and returned in a continuous loop, such as cell saver blood. The family should be informed that in unexpected critical situations requiring transfusion, the clinician will transfuse while concomitantly or later seeking legal authorization. Clinicians should be familiar with the hospital's preferred mechanism for obtaining legal authorizing. In instances where the likelihood of requiring blood is high, or the local judiciary is not that familiar with case law for Jehovah's Witnesses, clinicians may choose to obtain the court order preoperatively if there is a palpable likelihood of transfusion.

Elective procedures may be postponed until the child is of sufficient age and maturity to decide about transfusion therapy. But delays may increase the risk of morbidity or the quality of outcome. Factors affecting whether to proceed

include the quantitative and qualitative changes in risks and benefits.

Reasonable people disagree as to whether clinicians should change their transfusion triggers for a child of a Jehovah's Witness. On one hand, when to transfuse is often a judgment call, affected by the child's baseline health, clinical findings, lab values, expectation of future blood loss, knowledge of surgeon and procedure, risk tolerance, and gestalt. Given that, it may be reasonable to transfuse later than normal. On the other hand, although clinicians acknowledge transfusion triggers vary, they presumably transfuse only when necessary. In this analysis, changing transfusion triggers provides less optimal care, which is inconsistent with the obligation to treat the child of a Jehovah's Witness like any other child.

When an adolescent wishes to refuse perioperative transfusion, the minor needs to articulate sufficiently mature reasons, be properly engaged with the religion, and understand ramifications to self and family about possible outcomes. A private conversation is necessary to assess for coercion or manipulation. Ethics consultations are particularly useful in making these determinations. When brought to court, judges often determine whether adolescents may refuse transfusion by the likelihood of significant benefits like 5-year survival and the practicality of initiating and maintaining transfusion therapy. Children as young as 14 have been given the right to decline transfusion therapy, even when they had a high probability of 5-year survival.

When arrangements are made to honor an adolescent's preferences to refuse transfusion, plans must be made to ensure other perioperative and postoperative clinicians are willing to honor the agreements, as well as to ensure a plan is in place to honor the agreement in case the child needs to return to the operating room urgently.

## Emergency care

Emergency therapy is considered desirable and should be given to the minor who does not have a parent available to give legal consent or informed permission [23]. Clinicians should err on the side of treating if they are unsure whether to wait for parental consent.

Emergency therapy becomes more complex when adolescents nearing the age of majority refuse to assent to care. Urgency may not permit the extended evaluation necessary to determine whether the minor has sufficient decision-making capacity. Clinicians should use the best interest standard to guide therapy acutely. Consider a 15-year-old with an acute cervical fracture who refuses emergency stabilization. Forgoing cervical stabilization may cause irrevocable harm. The typical adolescent's decidedly short-term outlook and overvaluation of physical abilities make it unlikely that the adolescent possesses sufficient decision-making capacity in the acute situation. It is hard to imagine honoring an adolescent's refusal of emergent therapy in this case.

## The temporarily impaired parent

Chemically intoxicated parents may be disruptive, dangerous, and incapable of fulfilling surrogate responsibilities. Clinicians should use the least restrictive means to protect patient and parent confidentiality while ensuring the safety of the child, the impaired parent, and others present.

Although it seems ethically and legally prudent to postpone routine treatment until informed permission and legal consent can be obtained from an unimpaired parent, clinicians should weigh the benefits of postponement with the risk that impaired parents may not reliably return. It may be in the child's best interests to proceed with a routine procedure even though the impaired parent is unable to give informed permission and legal consent. Consultation with legal, risk management, and ethics colleagues may help.

## Consent for pediatric procedures without direct benefits

Pediatric clinicians may encounter children undergoing bone marrow donation for siblings who would benefit from hematopoietic stem cell transplantation [24]. The stem cell donor receives no direct medical benefit from the donation. The major risks of donation are the anesthetic and the potential need for transfusion.

The benefit of donation is commonly considered to be the psychosocial benefit of helping a family member. Pediatric donors report that the benefits of donations outweigh the physical harm [25]. As can be expected in such a complex dynamic, however, donation can result in moderate post-traumatic stress. Some donors felt they did not have a choice about being a donor and that they may be responsible for unsuccessful transplants.

Given the risks and benefits and the unique position of families in society, the American Academy of Pediatrics believes it is ethically permissible for minors to donate bone marrow when certain requirements are met, including a close relationship between donor and recipient, considerations of the risks of bone marrow donation, a likelihood of benefit to the recipient, and an absence of a suitable medically equivalent adult relative. Parental consent and patient assent is needed. Independent advocates for potential donors have been used to minimize the potential for inappropriate parental influence [26].

## Genetic testing and biobanking

While genetic testing can provide the substantial benefits of confirming a diagnosis, determining carrier status, or testing for disorders of late onset, it can also harm by informing people about their genetic lineage without their consent or adequate preparation.

Whether to test is particularly hazardous with children. Genetic testing may affect personal psychosocial development and business and insurance opportunities and removes the opportunity to choose whether to obtain that genetic information. Testing should be performed only when there are immediate medical benefits to the child or when there are medical benefits to a family member and no expected harm to the child. Otherwise, testing should be deferred until the child can display an understanding of the consequences of genetic testing.

Consent for biobanking, the keeping of tissues for genetic research, is problematic, assuming that the revisions to the more than 25-year-old Common Rule begin as expected in 2018. The Common Rule is the core ethics regulations governing human research in the United States. The revision permits

using broad consent for biobanking [27,28]. Within some limitations, broad consent permits the use of tissues without additional permission from the donor [29]. One of the problems with broad consent is that donors or their surrogates may be consenting to unknown unimaginable risks [29]. No matter the protections, privacy is always at risk [30]. Consequences can include denial of life insurance, and, potentially in the future as health insurance laws change, denial or exorbitant premiums for health insurance.

Children should be involved in the consent process for biobanking to the developmentally appropriate extent [31]. The issues of consent change when the child reaches adulthood. One potential solution is to require biobanks to contact donors when they reach adulthood to either require the now adult to opt in for biobanking or provide the opportunity to opt out. This is not being done routinely [32].

### KEY POINTS: THE INFORMED CONSENT PROCESS FOR CHILDREN

- Respect the "experience, perspective, and power of children" [8]. Legitimately involve children to the developmentally appropriate extent. Avoid pro forma solicitations
- Prioritize meeting the child and family's informational, decision-making, and emotional needs during the informed consent process
- Use verbal and pictorial strategies to quantify risks
- Under certain circumstances, adolescents may refuse potentially life-sustaining transfusion therapy for religious reasons
- Genetic testing and biobanking can lead to unforeseen consequences for the donor and their relatives

## Forgoing potentially life-sustaining treatment

Children, like adults, have the right to limit LSMT when the likelihood and quality of potential burdens outweigh the likelihood and quality of potential benefits, as defined by the child and family [33]. Benefits include a prolonged acceptable quality of life. Burdens include intractable pain, disability, emotional suffering, or effects that diminish the child's quality of life.

The term "life-sustaining medical treatment" is preferred to the older term "do not resuscitate" to emphasize that treatment preferences range along a continuum instead of being binary. "Potentially" acknowledges the uncertain effectiveness of the treatments.

## Perioperative limitations on potentially life-sustaining treatment

Limiting perioperative potentially LSMT allows children to have an opportunity to receive beneficial therapy without being forced to accept unwanted burdens [33,34]. Treatments may include procedures that increase quality of life, enable living at home, improve ability to interact, improve pain management, decrease pain, and treat non-terminal problems or urgent problems unrelated to the primary problem. Potential burdens from procedures may arise from resuscitation attempts, post-resuscitation medical care, or resultant functional or cognitive decrements. These burdens may make further resuscitation or intensive care therapy not "worth it." Considering both short- and long-term potential benefits and burdens helps clinicians understand the child's perspective, which improves honoring preferences.

The American Society of Anesthesiologists, the American Academy of Pediatrics, and the American College of Surgeons mandate reconsideration of existing limitations on LSMT before going to the operating room or procedure area.

Reconsidering the order prior to surgery requires clarifying the goals for the procedure and end-of-life care through discussions with the child, parents, and relevant clinicians such as surgeons and primary care physicians. Children should be involved in a developmentally appropriate manner. In practice, the reconsideration of LSMT for the perioperative period should result in either full resuscitation or a goal-directed approach toward perioperative resuscitation.

Goal-directed approaches permit decision makers to guide therapy by prioritizing outcomes (e.g. "I don't want to suffer in the ICU for two weeks before I die.") rather than specific therapies (e.g. cardiopulmonary resuscitation) [35]. Clinicians can guide the discussion by exploring acceptable burdens, desirable benefits, and the likelihood of the ranges of outcomes. Clinicians should explain the differences between ward and operating room resuscitation, emphasizing the idea that a dedicated clinician with understanding of the end-of-life goals and the ability to make a real-time assessment of the clinical problem as well as the ability to institute treatment immediately will be present throughout. Box 1.2 lists additional information to include in the discussion.

Operating room clinicians use their clinical judgment to determine whether and to what extent resuscitation will help achieve these goals. The decision about whether to use a certain intervention, such as chest compressions, will likely be more consistent with the end-of-life goals if the decision to

**Box 1.2:** Components of the discussion for perioperative limitations on potentially life-sustaining medical treatment (LSMT) [33–35]

- Planned procedure and anticipated benefit to child
- Description of advantages of perioperative LSMT as compared to ward LSMT
- Likelihood of requiring resuscitation
- Reversibility of likely causes that require resuscitation
- Description of potential interventions and their consequences
- Chances of successful resuscitation including differences between outcomes to witnessed and unwitnessed arrests
- Ranges of outcomes with and without resuscitation
- Responses to iatrogenic events
- Intended and possible venues and types of postoperative care
- Use of postoperative trials of therapy
- Postoperative timing and mechanisms for reinstitution of previous limitations of LSMT
- Establishment of an agreement through a goal-directed approach or revocation of the do-not-resuscitate order for the perioperative period
- Documentation

institute is made when the etiology of the event is known. This model encourages the ethically redoubtable strategy of trialing therapies. A trial of chest compressions that do not achieve specific goals provides evidence that continuing the therapy would be inconsistent with the goals of end-of-life care. Witnessed arrests in the operating room often have a better outcome than unwitnessed arrests due to the more immediate intervention and the greater likelihood that the cause of the arrest is known.

Most decision makers choose to use a goal-directed approach that authorizes temporary therapeutic interventions to manage quickly and easily reversible events, but reject those interventions that will likely result in permanent sequelae, such as neurologic impairment, from receiving potentially LSMT. For example, a brief bradyarrhythmia that responds to intravenous epinephrine and chest compressions would be consistent with the authorization to treat events that are temporary, easily reversible, and unlikely to have significant sequelae. On the other hand, if the bradyarrhythmia resulted in an extended resuscitation, continued therapy would require unacceptable burdens that in any case would be unlikely to achieve the patient's return to previous functional status. In that case, it would be appropriate to cease resuscitation efforts.

This common goal-directed preference can be documented as "The patient desires resuscitative efforts during surgery (and in the postanesthesia care unit (PACU)) only if the adverse events are believed to be both temporary and reversible in the clinical judgment of the attending anesthesiologists and surgeons."

The goal-directed approach requires determining when the child returns to their previous status for LSMT. Given that the goal-directed approach requires intimate knowledge and that it is intended to respond to the vicissitudes of anesthesia and surgery, the perioperative agreement is often discontinued when the patient is discharged from the PACU.

Clinicians should also discuss whether to try a postoperative trial of therapy before concluding that the burdens of continuing therapy outweigh the benefits. A trial of therapy allows decision makers and clinicians to determine how well a treatment achieves a defined agreed-upon goal, rather than presuming whether the therapy would work [3]. Trials may be limited by time or other factors. Trials permit children to tolerate a relatively small amount of burden, such as brief mechanical ventilation, to see if it would accomplish their defined goals. This information guides further decision making with greater certainty of burdens and benefits.

In pediatrics, precisely defining and documenting postoperative plans is often less essential, because parents are often available in the postoperative period to make decisions regarding therapy. Parents are often cognitively capable of participating in discussions of withdrawal of therapy because they have already grappled with analyzing the benefits and burdens of end-of-life care. The presence of parents permits greater trials of perioperative resuscitation while still respecting the decision to limit the burdens. However, developmentally appropriate conversations with the patient are essential when a child is able to participate in these discussions. A child's preferences should be incorporated into decision making similar to obtaining assent.

Resist the hegemonic instinct to overreact to iatrogenic events. Decision makers chose to limit care because they do not want the burden of undesirable outcomes. Iatrogenic issues do not supersede agreed-upon preferences for limitations on potentially LSMT unless knowledge of the event makes the associated burdens and benefits of treatment consistent with the agreed-upon plan.

That said, putting aside personal feelings about an iatrogenic event is hard. But children and families care about how they are, not how they got there.

## Physician orders for life-sustaining treatment

A physician order for life-sustaining treatment (POLST) promotes the honoring of resuscitation preferences by giving the preferences the power of a physician order. This order is valid across in- and out-of-hospital locations [36]. As compared to other advance directives, which can be prepared without professional medical guidance, POLSTs ensure the advice of a physician on how to achieve end-of-life care preferences. POLSTs document preferences for LSMT, other medical interventions, and management of artificial nutrition [37]. POLST documents appear to improve communication and honoring of preferences, particularly across settings [38–40].

Perhaps the biggest impediment to POLSTs is physician unfamiliarity [41]. From the perioperative clinician's point of view, it should be taken as if the child has a duly authorized limitation of LSMT. It should thus undergo required reconsideration.

## Barriers to honoring perioperative limitations on life-sustaining treatment

Although honoring limitations on LSMT is improving in the main, clinicians still poorly honor end-of-life care preferences [36,42,43]. Clinicians remain inadequately informed about policies, law, and ethics, hindered by sabotaging systems and poisoned by lore and misinformation [44–48].

Insufficient early identification and communication about a child who needs a perioperative reconsideration of LSMT, such as one with a POLST, limits the ability to find the right clinicians, have a robust discussion, and reach an agreement satisfactory to the child, family, and clinicians. Children having minor surgery or those who have not had a preoperative visit are more likely to remain unidentified until the day of surgery.

Lore and break room gossip reinforce the incorrect perception that honoring perioperative limitations on LSMT may result in being sued [49]. Statutes that address requirements for limitations on LSMT often include immunity provisions that protect clinicians from liability. Given the right of children to avoid inappropriate treatment, and the lack of judgments against clinicians who honor properly documented LSMT, the risk of honoring limitations on LSMT is likely to be lower than the risk of not honoring it.

Barriers that are less obvious include the natural desire to avoid most risk, particularly what is incorrectly perceived as a significant risk for little benefit [49]. Many clinicians like to avoid ambiguous situations in which they

have little experience making judgments and in which they are more prone to private or public criticism. These concerns can lead to anticipatory regret, letting an uninformed or overactive imagination create a fictional horrifying outcome that makes honoring limitations too risky. Clinicians overcome these honest but inappropriate feelings by reality testing with experts, seeking to become more skilled in these areas, and remembering that clinicians serve patients.

## Potentially inappropriate interventions

Most of the confusion surrounding the concept of futility comes from imprecise terminology. Futile therapy should be viewed as treatments that cannot accomplish a specific physiological goal. In that sense, dilemmas about whether to use futile therapy rarely arise. Interventions with a low likelihood of success, on the other hand, may be considered potentially inappropriate but they cannot be considered futile. An intervention may be considered potentially inappropriate if there is "no reasonable expectation" that a significant defined endpoint will be reached, the burdens to the child, feasibility, or, at times, cost [50].

At the clinician level, discussions about inappropriate interventions center on the benefits and burdens to the child. Qualitative and quantitative considerations should be defined carefully and clinicians should explain whether the information used to form the estimation is based upon intuition, clinical experience, or rigorous and sufficiently relevant scientific studies. Complicating matters is the dubiety in predicting the likelihood and range of outcomes of therapeutic interventions in very young children. In the end, in the absence of national standards, decision making for a child regarding inappropriate care should be based on the benefits and burdens on the child and not on cost [51]. Hospitals should have established processes for resolving conflicts [52].

Perioperative clinicians encounter cases that seem to be inappropriate treatments. Aside from differences in core values and beliefs, parents have other influences that encourage them to seek seemingly inappropriate care (Box 1.3). Understanding these factors helps clinicians be empathetic.

**Box 1.3:** Why are we doing this case? Factors that affect parental desire to seek seemingly inappropriate care

Parents seek seemingly inappropriate care for personal, familial, and societal reasons. These latent factors influence decision making.

- Unrealistic expectations about prognosis or effectiveness of treatment
  - Previously incorrect prognoses about their child ("Won't live past age 2")
  - Local rumors about "miraculous" cures
  - Public stories about "miraculous" cures
- Influence/disapproval from insufficiently informed family
  - Fear of damaging personal reputation in their community
  - Fear of subtle ostracism
  - Internal or external pressure not to damage family reputation
- Guilt
  - Responsible for previous actions (e.g. left with "irresponsible" relative)
  - Responsible for "delaying" treatment because they "missed' something
  - Vague but wholly wrong feeling that it was their fault
  - Emotional overtones of "causing death"
- Mistrust of clinicians, hospitals, or medical systems
  - Personal disturbing individual interactions
  - Legitimate and illegitimate stories and events engendering distrust
  - Coming from communities that have experienced organizational prejudice (e.g. racial, gender, ethnic, socioeconomic, etc.)
- Inadequate education/guidance from clinicians
  - No clearly identified clinician coordinating care
  - Inadequate communication among clinicians
  - No process to address LSMT with family
  - Breakdown of communication among family and clinicians
  - Well-meaning but poorly considered comment by a peripheral clinician (sometimes medical student) on to which families latch

LSMT, life-sustaining medical treatment.

## What would you do in my situation?

Parents may ask clinicians what they would do in the same situation. Clinicians should attempt to determine what the parent is asking before directly answering this question.

If they are asking for help making a decision, either because of difficulty managing the complexity of information or because of uncertainty, it is important to clarify the goals or values of the parents. Clinicians can then answer the question, "If that were my goal, I would do this, because…." Explaining why allows parents to apply their own values to the reasoning.

If parents are unsure about how to weigh competing values, it is appropriate for clinicians to share their values, with the caveat that many other approaches are acceptable and that the parents' values take priority. Clinicians can explain that to parents: "My job is to help you make one of the several reasonable choices that fits your values. Let's discuss how we can apply your values to this decision."

If parents are looking for reassurance for a reasonable decision that is not the one the clinician would have chosen, clinicians can respond by affirming both the appropriateness of the decision and the naturalness of feeling uncertain [53]. Admitting uncertainty about the "right" thing to do confirms to the parents the difficulty of the decision.

## Organ procurement after cardiac death

In organ procurement after death by neurological criteria, the child is declared dead before going to the operating room. In organ procurement after cardiac (or circulatory) death (DCD), a child in whom the decision has been made to withdraw potentially LSMT is brought to the operating room and then treatment is withdrawn. If the child is declared dead by cardiac status within a pre-established time, organ procurement proceeds. Although widely accepted, concerns about DCD include whether the dying process is altered by interventions to facilitate organ procurement. See Chapter 30 for more information about organ donation after cardiac death.

## KEY POINTS: FORGOING POTENTIALLY LIFE-SUSTAINING TREATMENT

- Children have the same right as adults to limit potentially LSMT, but predictions about the likelihoods and range of outcomes are less reliable
- Orders for limitations for LSMT must be reconsidered for the perioperative period. They may be honored under a goal-directed approach
- Trials of therapy increase the likelihood of honoring preferences for end-of-life care. Trials allow decision makers to test the assumption that a treatment may achieve specific goals while permitting it to be withdrawn if the treatment becomes too burdensome
- Desires for what appear to be inappropriate treatment come from values, beliefs, perceptions, personal experience, and community history
- Work with children and families to apply their values to decision making

## Special circumstances in pediatric anesthesia

### Research in pediatric patients

The anesthesiologist Henry K. Beecher was one of the first to recognize that research in pediatric patients requires greater oversight than research in adults [54]. Research subjects requiring surrogate consent are vulnerable to abuse. Pediatric research exposes children to unknown risks of long-term harm because research interventions occur during growth and development of the child [55].

The increased risk of harm and lack of direct benefit to the child increase the obligation to obtain the developmentally appropriate assent from the child. This obligation is not always met, particularly in diseases that have a strong emotional overlay, like cancer [56,57]. Assent may be waived if there is the prospect of direct benefit to the child that is available only through participation in research. Although undesirable, assent also may be waived if the study exposes the child to no more than minimal risks or if the study could not sensibly proceed without the waiver [50,51].

Federal guidelines define four categories of pediatric research (Box 1.4). The hallmark of these categories is that potential benefits must increase commensurate with potential risks. Most controversy about pediatric research concerns the interpretations of minimal risk and minor increase over minimal risk [52].

*Minimal risk* is defined as "the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests" [58,59].

The common interpretation is that minimal risk refers to risks encountered by healthy children in a safe environment, such as playing sports and riding in a car [59,60]. A previous competing interpretation, now out of favor, used the more relative interpretation of basing the standard of "daily life" on the events to which children enrolled in the research are routinely exposed. In other words, if a child enrolled in the study routinely receives lumbar punctures as part of therapy, then it may be acceptable to expose a child to the risk of a lumbar puncture for study purposes.

The category "*greater than minimal risk* and no prospect of direct benefit to individual subjects, but likely to yield generalizable knowledge about the subject's disorder or condition … which is of vital importance" defines when it is acceptable to expose a child to what is called "minor increase over minimal risk" [58]. "*Minor increase over minimal risk*" has been interpreted as pain, discomfort, or stress that is transient, reversible, and not severe [61]. Risk assessment is based on the combined exposure to risks throughout the study and the relationship between the risks and the patient population. For example, although drawing blood in healthy 15-year-olds may be considered acceptable, drawing blood from 15-year-olds with severe autism spectrum disorder may be unacceptable because their inability to understand may cause intolerable stress [62].

"Condition" is used to mean characteristics "that an established body of scientific or clinical evidence has shown to negatively affect children's health and wellbeing or to increase the risk of developing a health problem in the future" [62]. For example, consider a protocol to assess insulin resistance in obese children who do not have type 2 diabetes. If the investigator presented sufficient scientific support to the institutional review board that obese children are at increased risk of developing diabetes because of their obesity, then those obese

**Box 1.4:** Federal classifications for pediatric research [50]

1. Research not involving greater than minimal risk.
   a. IRB determines minimal risk
   b. IRB finds and documents that adequate provisions are made for soliciting assent from children and permission from one of their parents
2. Research involving greater than minimal risk but presenting the prospect of direct benefit to the individual subjects.
   a. IRB justifies the risk by the anticipated benefit to the subjects
   b. The relation of the anticipated benefit to the risk is at least as favorable as that presented by available alternative approaches
   c. Adequate provisions for assent and permission from one of the parents
3. Research involving greater than minimal risk and no prospect of direct benefit to individual subjects, but likely to yield generalizable knowledge about the subject's disorder or condition (commonly known as "minor increase over minimal risk").
   a. IRB determines the risk represents a minor increase over minimal risk
   b. The intervention or procedure presents experiences to subjects that are reasonably commensurate with those inherent in their actual or expected medical, dental, psychological, social, or educational situations
   c. The intervention or procedure is likely to yield generalizable knowledge … which is of vital importance for the understanding or amelioration of subject's disorder or condition
   d. Adequate provisions for assent and permission from both of the parents
4. Research not otherwise approvable which presents an opportunity to understand, prevent, or alleviate a serious problem affecting the health or welfare of children.

IRB, institutional review board.

children would be acceptable research subjects for this study. Svelte children would not be acceptable, because they would not be considered at risk for developing diabetes.

Stringent regulations certainly hinder necessary and beneficial research [56,57]. But regulations are often responses to previous transgressions. At some point, relaxation of regulations will reanimate the abuses that beget the regulations. It is difficult to identify that line until it is crossed.

Improving the institutional review board (IRB) process may minimize the inaccurate estimations of risk that hinder appropriate research and permit inappropriate research. An individual's intuition about the risk level of an activity is hampered by cognitive biases, such as familiarity, control of activity, and reversibility of the potential harms [63]. Systematizing evaluation of research risks may reduce inaccurate estimations of risk. One approach is to use a standardized scale to categorize the extent and likelihood of each potential harm and then compare the potential harms with comparative activities [64].

Socioeconomically disadvantaged children are overrepresented in clinical research [65]. Their environments may drive or worsen diseases such as reactive airway disease, and most research is performed in urban hospitals. Children in more economically settled situations get the benefit of the research without bearing proportionate risk. In addition, socioeconomically disadvantaged children and families may be more enticed to participate in research because of the commonly offered relatively inexpensive tokens of gratitude. But to socioeconomically disadvantaged families, what the researcher or IRB perceives as a minor gift can be a strong incentive to participate. See Chapter 4 for additional discussion about research consent and ethics.

## Confidentiality for adolescents

Open discussion, the lynchpin to a successful adolescent–clinician relationship, occurs only when the adolescent believes in the openness and confidentiality of the discussion [66,67]. Confidentiality means the adolescent owns their information, and, as such, it may not be shared without the adolescent's permission [68]. The adolescent's emerging desire for autonomy and their cognitive decision-making abilities make them developmentally ready for this responsibility.

Clinicians are obligated to protect patient information from unauthorized and unnecessary disclosure. With adolescents, confidentiality is crucial for even the anodyne. Adolescents concerned about confidentiality withhold pertinent information and defer necessary treatment [66,67,69]. Clinicians may want to ask sensitive questions without the parents present. Squarely addressing confidentiality concerns often improves truthfulness.

But adolescent confidentiality is not absolute. Honoring an adolescent's preferences for autonomy may compete with the obligation to ensure the adolescent is making a reasonable decision. It is ethically justifiable to breach confidentiality only when complying with reporting statutes or when breaching confidentiality will prevent serious harm to the child or another. These decisions are not obvious, and clinicians should use patient, family, and case characteristics in consultation with ethics or legal consultations to determine the appropriateness of breaching confidentiality.

Confidentiality breaches occur by sloppy and insecure use of medical records and electronic communications, by discussing patients in front of other patients or uninvolved clinicians in public areas like elevators, hallways, and cafeterias, and by clinicians being forced to have public discussions with patients or families because of inadequate private facilities, such as in the family waiting room. The most common breaches were to clinicians uninvolved in patient care about patients' sexual activities, mental or other stigmatizing illnesses, and racial or ethnic backgrounds [70].

## The pregnant adolescent

Hospitals and clinicians should have a defined approach to the preoperative adolescent who has a positive pregnancy test. As described previously, this information is the adolescent's and should only be shared with the patient's permission. State statutes may limit clinicians to informing only the adolescent about a positive pregnancy test [71,72]. In addition to ethical principles and practical reasons, these statutes are specifically present to address concerns about child abuse in pregnant adolescents.

Clinicians in possession of sensitive information should encourage the adolescent to share the relevant information with the parents. Involving adolescent specialists or social workers may facilitate communicating with the parents and receiving future care.

The ethical complexity increases logarithmically when pregnant adolescents do not want to inform their parents and it is appropriate to postpone the procedure [73]. Even though clinicians must postpone the case in a manner that does not breach confidentiality, the details of how the postponement is communicated affect the ability to maintain confidentiality. For example, clinicians can issue a terse communiqué to the parents that the procedure will be postponed. While this approach avoids explicit lying, its oddness may confuse parents and trigger a cascade of questions leading to a loss of confidentiality. On the other hand, clinicians may actively deceive, correctly reasoning that because parents have no right to that information, their primary obligation is to preserve confidentiality.

Albeit peculiar in a medical textbook, perhaps a short course in deception is useful [74,75]. Clinicians should try to avoid deception. But, when necessary, as a later resort to maintain confidentiality, it may be the least objectionable approach. It is perhaps easier to mitigate the sting of being deceptive by considering that, ethically, only the patient has the right to that information, and you are doing what is practically necessary to maintain confidentiality.

Clinicians should deceive in ways that will be successful, not require diagnostic or therapeutic interventions, and not unduly worry parents. For example, while intimating about unavailable operating room space and emergency surgeries may be useful, the excuse is rather weak if stated in the morning, when the family could offer to wait until one is available. Using a "new murmur" as an excuse may worry parents and cause unnecessary consultations. More simple deceits, such as postponement due to concerns about inadequate fasting or upper respiratory infections, tend to minimize unintended consequences.

The American Academy of Pediatrics supports confidentiality for adolescents seeking information about having an abortion [76]. Unless restricted by state law, adolescents may have abortions without parental consent. The rules surrounding parental involvement in elective abortions vary by state [71]. States may require either parental consent or notification prior to an elective abortion [71]. To ensure that adolescents can seek an abortion confidentially in states with parental involvement laws, states must have a judicial bypass procedure to preclude parental involvement. In a judicial bypass hearing, the judge interviews the adolescent to determine sufficient maturity to consent for an abortion. Even if the judge determines the adolescent insufficiently mature, the judge may grant permission for the abortion if the judge believes it is in the adolescent's best interest.

### LGBTQI+ patients

Although the number of LGBTQI+ adolescents and the incidence of gender dysphoria are increasing, the specialization of care for these individuals means there is often clinical inexperience. LGBTQI (lesbian, gay, bisexual, transgender, transsexual, queer, intersex) is an insufficient term to describe the variations of preferences for gender identification or no identification. A person's genetic biology is called sex. Gender is a self-identified social construct of how a person presents themselves to those around them. Gender identification is unconstrained, and includes no gender, gender fluid and combined or unnamed genders. Because covering the spectrum would be unwieldy, the "+" is to indicate those unmentioned, without prejudice.

The wholly legitimate issue of gender variation or dysphoria in the prepubescent child is widely misunderstood and not infrequently grotesquely mocked. Different treatments are appropriate. Decisions about more definitive interventions are usually postponed until puberty, given the uncertain natural history [77]. Clinicians must be supportive in following the chosen treatment (e.g. support for gender transition) for their patient.

Being an adolescent is hard. Isolation, prejudice, and even implicit or explicit condemnation from parents and other family make the difficulty of being an LGBTQI+ adolescent unimaginable for those who have not had the experience. Because of these factors, LGBTQI+ children have higher rates of substance abuse, homelessness, suicidal ideation, and physical harm. Reprinted rather widely is part of the 2015 suicide note of Leelay Alcorn, who self-identified as transgender. This note exemplifies the isolation, shame, and pain. "Please don't be sad, it's for the better. The life I would've have lived isn't worth living in… because I'm transgender….I never told anyone and I just continued to do traditionally 'boyish' things to try to fit in." [78].

Clinicians should avoid heteronormative assumptions (asking if someone has a boyfriend or a girlfriend), identify preferred name (often incorrectly identified on records if the name has not been legally changed), identify preferred pronouns or use non-gender pronouns, although in conversation with children their name should be used, articulate the purpose of potentially awkward questions, and use genderless language.

**KEY POINTS: SPECIAL CIRCUMSTANCES IN PEDIATRIC ANESTHESIA**

- Adolescents deserve confidentiality for ethical and practical reasons. Clinicians are responsible for maintaining appropriate confidentiality
- Diligently assess yourself for personal but unintended behaviors that may lead to health or healthcare disparities, particularly across race, gender, and socioeconomic status. Develop strategies to minimize these actions
- Be cautious about seemingly innocuous language that makes presumptions that may hurt or shame adolescents

## Professionalism in pediatric anesthesia

### Advocacy and good citizenship

Physicians owe their ability to train, practice, and thrive to society's largesse. The implicit social contract therefore obligates physicians to manage matters within their sphere of influence, with a special obligation to address issues that "directly influence individuals' health" in the physician's community [79,80]. Community may refer to a physical location or a type of patient to whom the physician is particularly obligated. Pediatric anesthesiologists have a special obligation to further pediatric healthcare [81,82].

Pediatric anesthesiologists fulfill obligations to society by participating in activities that are consistent with the individual's "expertise, interests and situations" (Fig. 1.1) [80]. Pediatric clinicians in particular should address the healthcare disparities of quality of care and access to care seen across socioeconomic, racial, gender, geographical, and other cohorts that lead to the health disparities in morbidity and mortality [83,84].

### Safety and quality care initiatives

Clinicians must work to improve safety. Clinically, clinicians need to actively support safety initiatives that seek to improve care such as the procedural time out and the Clean Hands Count initiative. Ignoring or bypassing inefficient, impractical, or harmful policies prevents developing a functional policy and leads to a dysfunctional culture of clinicians choosing which rules to follow [85]. Clinicians need to bring unsuccessful policies to leadership, who must be willing to honestly discuss and address concerns without blaming clinicians or demeaning them by declaring "try harder." Even one brush-off by leadership will chill future communication from the front lines.

Clinicians should do their best to improve care by reporting near misses or other potential risks. Clinicians are suspicious (sometimes rightly) of the trumpeted "blame free" approach to reporting potential errors or near misses [86]. To fulfill professional obligations of identifying potential risks, suspicious clinicians should reality test their perception or find a different way to highlight the risk. System flaws that lead to medical errors can only be identified by honest reporting and by participating in root cause analyses.

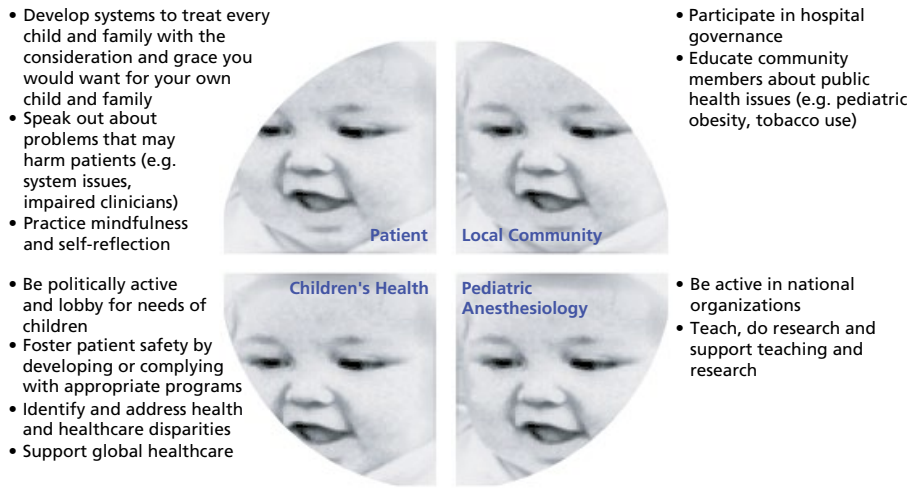


**Figure 1.1** Obligations of pediatric anesthesiologists. Pediatric anesthesiologists are obligated to these four communities. Individual anesthesiologists are not expected to fulfill every obligation. "Units" of anesthesiologists such as private practice groups, academic departments, and state societies should fulfill these obligations collectively. A few examples are given.

## Disclosure and apology

Although viscerally seductive, hiding medical errors violates informed consent principles, destroys trust when the error is inevitably revealed, and leads to legal action [87]. To be sure, it is understandable to want to hide a medical error. Clinicians foresee mercurial treatment by the hospital or legal system, do not receive adequate psychosocial support, and are inadequately educated about how to manage these conversations [88].

Children and parents wish to be informed about medical errors. Proper disclosure and apology can improve trust, communication, and respect and may give them a greater sense of control, which some research suggests may lead to better outcomes [89]. They also wish to receive appropriate apologies, even if it makes them more anxious.

Thoughtful full disclosure should commence upon recognition of the problem. Wise clinicians unskilled in disclosure and apology involve an expert. The expert can prepare clinicians by rehearsing process and content and by providing support for the clinician. The expert can arrange for continuing communication and provide emotional support for the family. Clinicians who make errors, sometimes referred to as "second victims" [90], may be understandably rattled and may not be able to provide emotional support. Clinicians should share what is known as quickly as reasonably possible, but they should not make assumptions about what is not known, particularly about fault. Decision makers should be informed about the medical implications of the event and any necessary treatment. Because disclosure is a process over time, the child and family should be given a contact person skilled in disclosure and apology who will be available to answer questions, arrange meetings, explain the results of the investigation, and describe plans to prevent comparable events.

Most arguments against apology about and disclosure of errors center on increasing the risk of being successfully sued and on protecting the patient from unnecessary anxiety regarding the event or future care. Upon examination, these arguments are weak. An apology is an expression of regret or sorrow. A sincere apology followed by actions consistent with regret is invaluable; an insincere apology is costly. Even though more than half the states have laws prohibiting the admission of apology or sympathy as evidence of wrongdoing, it is conceivable that an apology may increase the risk of being sued or losing a suit. But the best protection against being sued is a good patient–doctor relationship [16]. Hiding, dissembling, or being indifferent about an event destroys trust and galvanizes a lawsuit much more than a sincere apology.

For example, some recommend apologizing for the effect on the child but not taking responsibility for the actual event. This apology is appropriate for a rash caused by an appropriately administered antibiotic. But it seems bizarre not to take responsibility when a clinician errantly administers a neuromuscular blocking agent instead of an anti-cholinesterase agent when attempting to antagonize muscle relaxation. Although an investigation should be done to assess for system flaws that contributed to the error, not taking responsibility in that case (unless there was a good reason) would likely aggravate parents.

Parents are naturally sensitive about the perioperative experiences of their children. Clinicians should consider apologizing or at least sympathizing about unpleasant experiences such as multiple, painful attempts to insert an intravenous catheter or an out-of-control inhalation induction of anesthesia. These discussions can include an acknowledgment that it was a bad experience and recommendations for the future. For example, a clinician could say, "I am sorry the intravenous catheter took so many sticks," and "Next time, we should probably give oral sedation prior to attempting the intravenous catheter." These comments simply acknowledge what happened, express regret, and educate the family for the future.

"Communication-and-resolution," a transparent disclosure of injury or error presented with appropriate compensation, can lead to improved relationships with patients and families, better analysis of events to implement improvements, and possibly forestall legal action [91,92]. Defense of appraised care is essential for clinicians to participate in this system [93,94].

## Production pressure

Production pressure is the ubiquitous "internal or external pressure on the anesthetist to keep the operating room schedule moving along speedily" [95]. As a consequence, clinicians may feel pressure to curtail preoperative discussions, inadvisably proceed with cases, or prematurely extubate the trachea to speed turnover. Clinicians should be aware of pressures to provide anesthesia inconsistent with their level of skill or to permit surgery in inappropriate settings. For example, the "routine" tonsillectomy for a child with achondroplasia may be too complex for some clinicians or some surgery centers. Clinicians have an obligation to their patients and to themselves only to provide care for which they are competent and to recognize when economic and administrative pressures induce them to do otherwise.

## Suspicion of child maltreatment

Physicians are legally obligated to report even the suspicion of child maltreatment and may be criminally liable for not reporting it. It is natural to downplay concerns because of a hesitancy to inform authorities, particularly if the parents are from a socioeconomic class similar to the physician's. But child abuse should never be minimized as a one-time event. Early intervention minimizes disastrous consequences.

Children may be physically abused, sexually abused, emotionally abused, and neglected [96]. Clinicians may be the first to recognize child abuse because evidence of abuse frequently occurs on the arms, hands, head, face, neck, and mouth. Signs of abuse include bruises or burns in shapes of objects, injuries that fit a biomechanical model (e.g. a handprint), fractures in infants, and developmentally inappropriate injures that are not explained by the offered history. Child abuse might occur in the hospital during diagnostic or therapeutic care. Children with chronic cognitive delays or physical limitations are more prone to abuse [97]. Munchausen by proxy syndrome is a type of abuse in which parents either cause or fictionalize clinical problems in their children. The signs and symptoms of the resultant diseases are often difficult to explain coherently.

### KEY POINTS: PROFESSIONALISM IN PEDIATRIC ANESTHESIA

- Pediatric clinicians have a societal responsibility to improve children's health through supporting professional or lay efforts in local, national, or international communities
- Disclose and apologize for medical errors promptly, factually, blamelessly, and with colleagues trained in disclosure and apology. Remember that clinicians are the "second victims" and deserve grace. Put in place systems to identify and support "second victims"
- Reject production pressure by treating each child as if they were your own

### CASE STUDY

This case study is designed: (1) to emphasize that superficially defining cases such as "a 17-year-old wants to refuse transfusion therapy" overlooks relevant complexities; (2) to examine the process and relevant factors in determining maturity for medical decision making in an adolescent; (3) to provide an example of how dilemmas may be evaluated; and (4) to provide an example of the content in an ethics consultation. Characteristics of consultations include clarifying medical issues, identifying stakeholders and their relative extent of influence, defining the ethical questions and issues, and providing an assessment and recommendation.

#### Summary

Candace is a 17-year-old who has a rare type of rhabdomyosarcoma. She presents for resection of a tumor intertwined with major blood vessels. Candace is a Jehovah's Witness and wants to refuse receiving transfusion therapy during and after the resection of the tumor.

#### Medical questions

This type of rhabdomyosarcoma is too rare to reliably predict outcome. The best guess, though, is a 5-year survival of 5–10%. While there is a low likelihood of significant bleeding during the operation, the position of major blood vessels presents the possibility of sudden, rapid, and substantial bleeding.

#### Family

Candace is the daughter of Linda and Larry. Through a friend, Larry began exploring the Jehovah's Witness community 9 years ago and became baptized as a Jehovah's Witness 6 years ago. Linda describes herself as spiritual but has no interest in organized religion. She very much supports the authority of Candace's decision making.

Candace "was very skeptical the first month of learning about [the Jehovah's Witness religion]. I had friends who had 'found' religion … but it never made sense to me." Jehovah's Witness "made sense to me, in an easy to understand manner. This is it, this is the right religion." Following thorough study, at age 14 she chose to become a baptized member to show her dedication to being a Jehovah's Witness.

Candace leads an active high school life. She is a starting wing on the field hockey team, and she frequently participates in school theater productions. She leads bible study and weekly youth group meetings. She is an accomplished public speaker, speaking to groups "over 100 people" about being a Jehovah's Witness.

Linda and Larry like the person Candace has become. Candace, Linda, and Larry share decision making about family matters. They have the normal disputes about things like curfew.

Candace is an active participant in her care. She asks appropriate and extensive questions about options and short- and long-term implications.

In private discussions with Candace, she emphasized that she did not want to die. However, because she believes that Bible and God forbid taking blood, receiving blood would fill her with incredible guilt and sadness because she had disappointed her God. While she was concerned that taking blood would separate her from God, her primary concern was the overwhelming sense of failing her God. When asked whether being transfused forcibly or while unconscious would ease her conscience, she answered that she would feel the same because she had actively put herself in a position in which she could involuntarily receive blood. She equated being transfused forcibly while unconscious as "rape." She stated in a factual and calm way that "if I woke up and found I was getting blood, I would rip it out of my arm."

Candace coherently articulates her religious and spiritual faith. Her beliefs are consistent with the teachings of her chosen faith community. She views herself as able to reason and be responsible for acting on personal moral judgments. She can imagine separating from the Jehovah's Witness community if guided so by her conscience.

**Ethical questions**

1. If individuals of majority age have the right to refuse potentially life-sustaining transfusion therapy, do minors have this right?
2. What characteristics and criteria can be used to determine whether a minor possesses sufficient decision-making capacity and maturity to make this decision?
3. What issues should be discussed to ensure that their desired blood therapy wishes are followed?

Maturing adolescents are granted increasing authority in decision making. Relevant characteristics that give evidence of adolescent maturity and decision-making capacity include an understanding of their options and associated consequences, an internally coherent rationale, an ability to articulate their positions, an intellectual and emotional freedom to entertain alternate perspectives, and an indication of mature relationships with older individuals. Not all characteristics need to be present for an adolescent to be considered mature. The threshold for the evidence necessary to have decision-making capacity for a specific decision increases as the consequences of the decision increase.

Legitimate concerns about adolescents being overly influenced by short-term consequences should not be tainted by less relevant concerns that preferences may change as adolescents become older. Mature individuals are able to change their minds based on experience and evidence. That adolescents may change their mind as they mature does not invalidate current choices inasmuch as sufficient decision-making capacity is present.

Pragmatism affects considerations about whether to force adolescents to receive undesired healthcare. Adolescents are most capable of physical protest, either by yanking intravenous catheters or by not presenting for therapy. For example, Billy Best, a 16-year-old with Hodgkin lymphoma, ran away so that he would not have to complete his chemotherapy regimen [98].

**Assessment**

The ethics advisory committee believes that Candace meets the requirements of being a mature individual with substantial decision-making capacity who understands the gravity of her choice. Her active participation outside the Jehovah's Witness community indicates a wider view of the world rather than a more narrow view that may be present with exposure only to the Jehovah's Witness community. Given her beliefs and her extensive missionary and teaching activities, we believe that she has thoughtfully chosen to become a Jehovah's Witness. She has a loving and comprehensive relationship with her parents. Although her refusal of potentially life-sustaining therapy may lead to significant morbidity or death, we believe she exceeds the criteria to make these decisions.

**Recommendations**

1. The ethics committee believes that Candace should be considered primary decision maker.
2. We are aware that the surgeon requests a court order permitting Candace to be able to consent for refusal of potentially life-sustaining transfusion therapy. We encourage Candace and her family to seek as much information about this process as possible, including the process of seeking this status, the possible drawback of pursuing and securing mature minor status, the role of the parents after achieving this status, and the use of healthcare proxies. A court order may minimize chances that wayward individuals may transfuse Candace.
3. To ensure fidelity in regard to the hospital's implicit promise to honor her preferences, a cadre of clinicians committed to honoring Candace's wishes must be identified. Necessary clinicians include operating room nurses and technicians, anesthesiologists, trainee anesthesiologists, certified registered nurse anesthetists, surgeons, and postoperative nurses and physicians, particularly ICU physicians. Arrangements must be made to ensure willing clinicians in case of an emergent re-operation. The needs of these clinicians (e.g. to meet Candace) should be met.
4. This consultation is solely advisory. Our comments are restricted to the ethical interpretation of the issues facing Candace, her family, and the care team. You may wish to contact the Office of Legal Counsel for their input on existing regulations as well.

*Postscript*: A court order granted Candace the authority to make decisions about transfusion therapy. In informal conversation later, the judge declared that one of the primary considerations aside from Candace's maturity was the very low likelihood of survival. If her possible survival had been higher, they would have been much less likely to grant Candace the legal authority to make decisions about transfusion therapy.

## Annotated references

*A full reference list can be found in the Wiley Companion Digital Edition of this title (see inside front cover for login instructions).*


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CHAPTER 2

# History of Pediatric Anesthesia

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## Introduction

History is different when written by people who were there at the time compared to that written more recently by people who rely on information derived from other sources. Insights into the use of clinical signs and acumen by older anesthesiologists, many of whom also had good technical skills unaided by modern equipment (for example, difficult and blind nasal intubation and locating nerves when injecting local anesthetics), help one to appreciate the developments that have taken place and how they managed before.

This chapter will mention events in the first hundred years of anesthesia but will cover mainly 1950–2000, the period of greatest change in children's anesthesia.

## The beginning of anesthesia as a specialty and the first drugs used, 1842–1921

The first anesthetic agents had all been experimented with as party inhalations and observed to relieve pain when the inhalers were accidentally injured. Humphrey Davy had made the observation that led him to remark in 1799 that nitrous oxide might be useful to relieve surgical pain where no great effusion of blood took place. In 1824 Henry Hill Hickman thought that a gaseous inhalation might have the desired effect but selected ineffective carbon dioxide.

In 1844 Horace Wells, a dentist in Hartford, Connecticut, tried nitrous oxide successfully in his practice for extractions. Subsequently his public demonstration failed because his patient cried out, although he claimed he felt no pain.

Ether was used in 1842 by Crawford Long in Georgia to anesthetize several patients for surgical procedures, including children. As he did not report his cases for several years, until after William Morton performed his successful public demonstration with ether in Boston in 1846, he has not been given his due credit for inventing anesthesia. Neither has the chemist, William Clark, who had a tooth extracted painlessly as an experiment, after ether frolics, in January 1842.

The speed with which the news travelled around the world was remarkable considering the rate of sea travel at the time. William T.G. Morton's first successful public demonstration of anesthesia was held in Boston on 16 October 1846. The first anesthetics were given in Britain on 16 December and in Australia by Pugh (surgical) on 7 June 1847 and Belassario (dental) in Sydney about the same time.

In 1847 James Young Simpson, Professor of Midwifery in Edinburgh, introduced chloroform as an anesthetic, having previously used it and ether at dinner parties to exhilarate his guests. So the three agents that were to dominate anesthesia for the next century had been introduced. Later, ethyl chloride was often used for induction because of its rapid onset and short duration of action. It was first introduced in 1848 but did not come into general use until 1895. Embley reviewed its pharmacology in 1906 [1,2].

*Gregory's Pediatric Anesthesia*, Sixth Edition. Edited by Dean B. Andropoulos and George A. Gregory.

**Figure 2.1** Pediatric Schimmelbusch masks (left), with gauze insert in the middle. Chadborne's modification is shown on the far right.

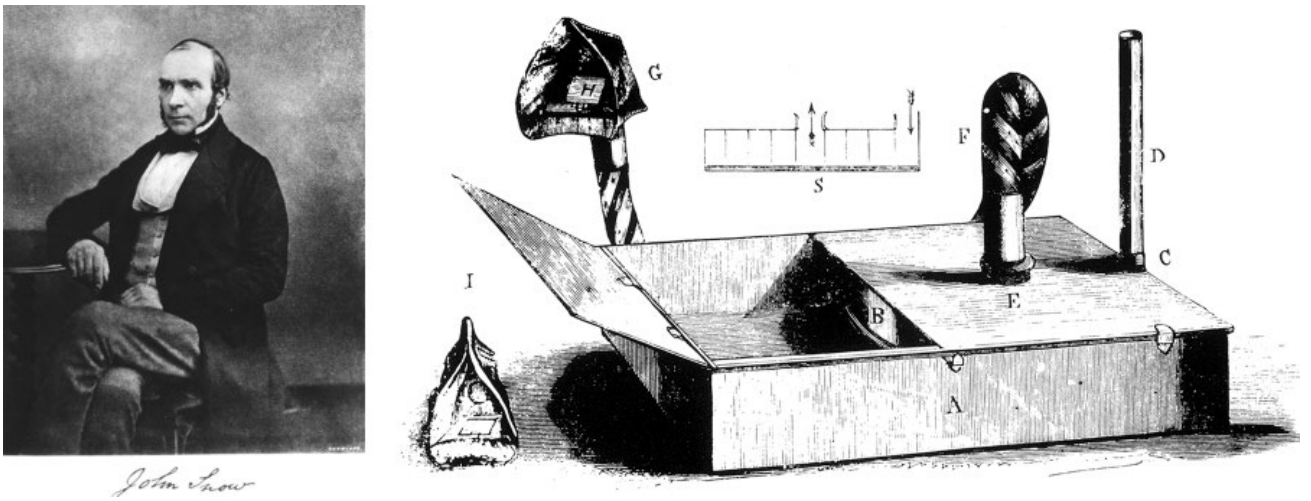


**Figure 2.2** John Snow and his inhaler showing the waterbath (right).

These anesthetics were administered in many cases by open drop on to a handkerchief or on to gauze, which was later held in a wire frame such as the Schimmelbusch mask [3] (Fig. 2.1).

Ether was regarded as a relatively safe anesthetic. It has sympathomimetic properties, which sustain cardiovascular stability, and is a very potent bronchodilator that was used successfully to treat status asthmaticus before specific bronchodilators were available. It also produced secretions that liquefied sticky mucus so that it could be more easily sucked out. Secretions were usually a nuisance during anesthesia but could be controlled with atropine or hyoscine – a major reason for including these drugs in premedication. The smell was unpleasant and many children were sick but most often only vomited once. Guedel developed a scale of eye signs and breathing patterns which is a useful guide to the patient's depth of anesthesia during ether administration.

Ether is flammable. Electrical plugs were placed higher than 5 feet (150 cm) to minimize the possibility of ignition or explosion because ether is heavier than air. Ethylene was a weak anesthetic gas like nitrous oxide. Its use was limited because it was flammable and lighter than air and was dangerous with these electrical installations. Ether has continued to be used in many less affluent countries because it is cheap and relatively safe and simple to administer by trained nurses and medical assistants. These people provide an important service, particularly in many parts of Africa where medically trained personnel are scarce.

John Snow (Fig. 2.2) in London soon became the expert in the administration of anesthetics. He built a vaporizer that took into account several principles of vaporization of ether: baffles increased contact time between liquid and gas so that more vapor was taken up, and a warm waterbath surrounded it to prevent the liquid from cooling too quickly on vaporization. Snow also kept meticulous records of his cases and published large series with both ether and chloroform without fatalities. He recorded 145 cases of infants under 1 year who received chloroform, the youngest being 10 days old [4]. Many of these were for operations on cleft lip. He emphasized the importance of avoiding high concentrations. With chloroform he did not exceed 2%. He also noted that the effects of chloroform came on more rapidly in infants and children than in adults.

There was much discussion about the choice between ether and chloroform. The latter was sweet-smelling and caused less vomiting but was associated with more deaths, mostly cardiac but some due to liver failure. In 1896 there were 85 deaths in England, of which 65 occurred before surgery began. These statistics led the first anesthetist at the Melbourne Hospital, Edward Henry Embley (Fig. 2.3), to undertake a huge study on 284 dogs which showed that death was due to cardiac failure rather than respiratory failure as suggested by the Hyderabad Commissions in India. He also showed that some protection was offered by vagal section or atropine. Another feature of the study was that half the animals received

**Figure 2.3** Edward Henry Embley.

morphine and curare 40 years before curare's introduction into clinical anesthesia. The animals were ventilated via tracheostomy prior to the administration of chloroform. The results were published in 20 pages of the *British Medical Journal* in April 1902 [5]. In 1905 Embley published another major paper on ethyl chloride, used for over half a century to induce anesthesia. Embley was appointed as lecturer in anesthetics at Melbourne University in 1901. He must have been one of the earliest academic appointments in anaesthesia in the world.

The first recorded death with chloroform was that of Hannah Greener, a 15-year-old girl who succumbed during induction like so many others afterwards [6]. It was probably because her heart, sensitized by chloroform, was exposed to high levels of circulating catecholamines (she was very anxious). After the development of the electrocardiogram (ECG) by Levy in 1911 it was shown that this combination could cause ventricular fibrillation. There were no defibrillators then.

## Premedication

The purpose of premedication was to reduce patient anxiety and thereby reduce the amount of anesthetic drugs needed, and to reduce secretions, particularly with ether (atropine or hyoscine). Forty years ago heavy premedication with an opiate, atropine, or hyoscine with or without a hypnotic was often used. Children did not like injections and nurses did not like giving them so there was a change to oral (or nasal) administration in about the 1980s. Now, with increasing parental involvement and more day-of-surgery admissions, many anesthesiologists rarely use premedication. It has been shown that preschool children are as calm when their parents are present as with premedication if they are not there [7].

## Local anesthesia

The discovery of the local anesthetic properties of cocaine on the eye by Koller in 1884 led to the development of other local anesthetic drugs such as amylocaine (1904) and procaine (1905).

Local and regional anesthesia was developed initially by surgeons. August Bier in Germany performed spinal anesthesia and had two children among his first six patients (1898) [8]. Spinal anesthesia became popular in some centers and, by 1907, 2000 cases were reported from France and another 1000 by Bier's group in Germany.

In 1920 Gaston Labat, a French surgeon, spent a year at the Mayo Clinic teaching regional anesthesia and writing his well-known book *Regional Anesthesia: Its Techniques and Clinical Applications* [9].

Fidel Pages (Madrid, 1921) introduced epidurals [10]. Mario Dogliotti (Turin, Italy, 1933) has been credited with popularizing this technique [11].

### KEY POINTS: THE BEGINNING OF ANESTHESIA

- Crawford Long in Georgia used ether in the first recorded anesthetics starting in 1842, including children
- Horace Wells first used nitrous oxide for dental extraction in 1844 in Hartford, Connecticut
- William T.G. Morton staged the first successful public demonstration of anesthesia, with ether, in 1846 in Boston
- James Young Simpson introduced chloroform as an anesthetic for labor and delivery in 1847 in Edinburgh, Scotland

## Early regional anesthesia in children, 1909–1933

Papers relating specifically to regional anesthesia in children began to appear in the early twentieth century. In 1909–10 Tyrell Grey, Medical Superintendent of Great Ormond Street Hospital for Sick Children in London, published three papers on spinal anesthesia in children, each covering 100 cases [12]. The patients were not anesthetized but comforted by a nurse who knew them. Spread of the local anesthetic was controlled by increasing specific gravity of amylocaine with glucose. The patient benefits were absolute anesthesia, no surgical shock, analgesia was localized to the area of the block, and postoperative vomiting was minimal. The surgical advantages were good operating conditions, easy access to the abdomen, the gut was contracted, the surgery was quicker, and the spinal anesthesia could be administered by the surgeon himself. There was less pain and feeding could be started sooner.

In 1945 Etherington-Wilson was well known for the use of baricity in determining the height of spinal block. He included 30 patients between 16 days and 3 years of age when describing his methods of calculating dosage in a series of 1600 patients [13]. Successful experience with spinal anesthesia was also reported by Stephen and Slater in Montreal (1949) [14] and Leigh and Belton [15].

If one knew this and had read the positive reports of its use in sick infants it should not be surprising that many years later Abajian et al advocated spinal anesthesia as an effective form of anesthesia in neonates and premature infants, especially as it does not cause hypotension in that age group [16,17]. A major problem of general anesthesia in this age group was postoperative apnea. This can be largely overcome by retaining less diffusible nitrogen in the lungs by inhaling air, thus stabilizing the alveoli. Déry et al demonstrated the importance of this in maintaining functional residual capacity in adults [18]. The same applies to infants and babies but, although effective, the method has not been widely practiced in neonates.

In 1920 Farr, in Minneapolis, reported 129 spinals in children with nine failures. Many were for pyloromyotomies [19]. In 1932 Marian from Bucharest, Romania, reported 653 spinals in children, mainly with 4% procaine, with 15 failures [20]. Interest continued and spread. In 1935, Balacesco, also from Bucharest reported 1241 spinals in children with good results – only some older children (older than 15 years) had headaches. He used amylocaine and later 4% procaine [21].

Spinals were used in children as young as 2 weeks of age in Toronto by 1933 [22]. They had also done four thoracic cases. The patients were mostly premedicated with pentobarbitone and morphine, and the needle was inserted at L4–5 as it had been recognized that the spinal cord reached lower in infants but, conveniently, the intercristal line between the iliac crests at the level where the needle was inserted, was also a segment lower than in older children. Junkin, in Toronto, made two important observations: that hypotension was less than in adults and headaches were uncommon in children [22].

Caudals were introduced for cystoscopies and urethral surgery in children 4–14 years old by Meredith Campbell (1933) [23]. In 1936 Sievers reported the use of peridural block for cystoscopy [24].

Harry Curwen in Durban, South Africa, presented a paper on caudal anesthesia in 92 neonates in 1950 [25]. Armando Fortuna led the development of regional anesthesia in Brazil. He wrote several papers relating to caudal anesthesia and its safety, even in poor-risk children, and then produced a good historical review of regional anesthesia in children in 2000 [26,27].

By the 1970s caudal anesthesia was being used in several parts of the world including Australia, Britain, France, and Mexico [28–31].

The French Paediatric Anaesthetic Society, ADARPEF, analyzed 224,409 cases done with regional or local blocks: 50% were caudals [32]. There were eight dural perforations, four accidental spinals, two inadvertent vascular injections with convulsions, and one rectal penetration. Another reported complication is syringe swap and the incorrect drug being given. This can be disastrous if a toxic substance is injected. The same society later published another review of 24,005 cases (1982–91), mostly caudals followed by lumbar epidurals and spinals [33]. This paper caused some concern because there were five patients with serious neurological sequelae, three of whom died. They were all less than 2 months old. Three had tetraplegia, one had hemiplegia, and one had cardiac arrest with brain damage. Dalens et al suggested that the injection of air could cause problems [34], as it did in some of these catastrophes [35].

When large numbers of failures are recorded (25%) [21] or there are many serious complications it suggests that the knowledge of technique or dose was inadequate or the operators were careless [36]. For example, textbooks previously described performing femoral nerve block by fanwise injection lateral to the femoral artery. It is more accurate to insert a short beveled needle vertically lateral to the femoral artery and feel the resistance of two "pops" as the needle penetrates fascia lata and fascia iliaca. If it is easy to inject, the tip is in the correct place [37]. Otherwise withdraw the needle with pressure on the syringe plunger until it is easy to inject – occasionally the two fascial layers are fused. The other aid to finding depth is that there is resistance to injection while the needle tip is in muscle but it is easy to inject into spaces where nerves often lie [38].

### KEY POINTS: EARLY REGIONAL ANESTHESIA IN CHILDREN

- Tyrell Grey of Great Ormond Street Hospital in London published three papers on spinal anesthesia in children in 1909–10
- In the 1920s and 1930s there were four major case series of spinal anesthesia in children in over 2000 patients
- The first caudal anesthetics in children were reported by Meredith Campbell in 1933

## Delivery systems and anesthetic machines, 1916–1937

Many varieties of inhalers were developed before gas, oxygen, and ether machines such as the one produced by Gwathmey came into being in the early twentieth century. Edmund Boyle, at St. Bartholomews Hospital (Barts) in London, dissatisfied with the older methods of anesthesia, obtained a Gwathmey machine from the United States in 1916. As it developed gas leakage problems at joints he decided to make his own machine beginning about 1917. Initially this provided oxygen, nitrous oxide, and ether. This continued to develop as the Boyle machine, which became widely used around the world [39]. In the United States Forreger and then Heidbrink machines were developed. As all these progressed, flowmeters and vaporizers improved and became more accurate. By the 1950s Lucien Morris had developed the copper kettle vaporizer [40] and Cyprane had made the Fluotec with split gas flow and temperature compensation to provide accurate lower concentrations of halothane. It was then modified for other agents [41].

Another important addition was carbon dioxide absorption with soda lime, introduced in a circle system by Dennis Jackson (1915) [42]. Waters developed the to and fro system using his canister which had a small pediatric version [43]. These avoided the use of high gas flows and were particularly useful with cyclopropane which was an expensive and explosive agent. It also required special flow meters.

Anesthetic machines such as the Boyle evolved, and variations remained in use for six to eight decades (Fig. 2.4). Jeffrey Cooper in Boston designed a brilliant delivery system with electronic feedback safety features [44] which suffered commercial suppression. Rod Westhorpe (see Fig. 2.11H) and colleagues in Melbourne produced a machine with many ergonomic features such as height adjustment, sloping light emitting diode (LED), flow meters, and gas delivery from either side (Fig. 2.5). It did not get past prototype development before the new concept workstations were introduced which combined anesthesia delivery, ventilator, and monitors. They were revolutionary.

## Pediatric anesthesia delivery systems

For infants and small children low-resistance circuits were desirable to minimize work of breathing. In 1937 Philip Ayre (Fig. 2.6) introduced his T piece which had the advantages of low resistance (no valves), simplicity, and allowing controlled ventilation away from the operative field in patients who were intubated, particularly for cleft lip and palate and neuro surgery. His original T piece was part of an older Philips circuit which had a gas delivery tube entering the side but turning a right angle to face the expired gas flow. He recognized that the patients did better this way because the flow creates slight resistance to expiratory flow which would tend to keep the alveoli open – actually it was a form of continuous positive airway pressure (CPAP). Unfortunately when the T piece was manufactured it was made with the fresh gas flow tube entering at right angles. About 40 years later an acute-angled fresh gas inflow was made and Portex made a similar device in plastic, thus restoring the original benefit of slight CPAP.

The volume of the expiratory limb of the T piece should exceed tidal volume to avoid air dilution. For controlled ventilation the expiratory limb is occluded to force fresh gas into the lungs. The tidal volume then depends on the fresh gas flow rate and the duration of occlusion (flow generator).

Ayre was an unusual man: he had alopecia, wore a ginger wig, and had had a cleft lip and palate repair which left him with a honking voice that mesmerized the children during induction. He gave about 2000 anesthetics while he was still a medical student [45]!

Later, Jackson Rees from Liverpool, England, added an open-ended bag to increase versatility (Fig. 2.7). With spontaneous ventilation it acted as a respiratory monitor but it could

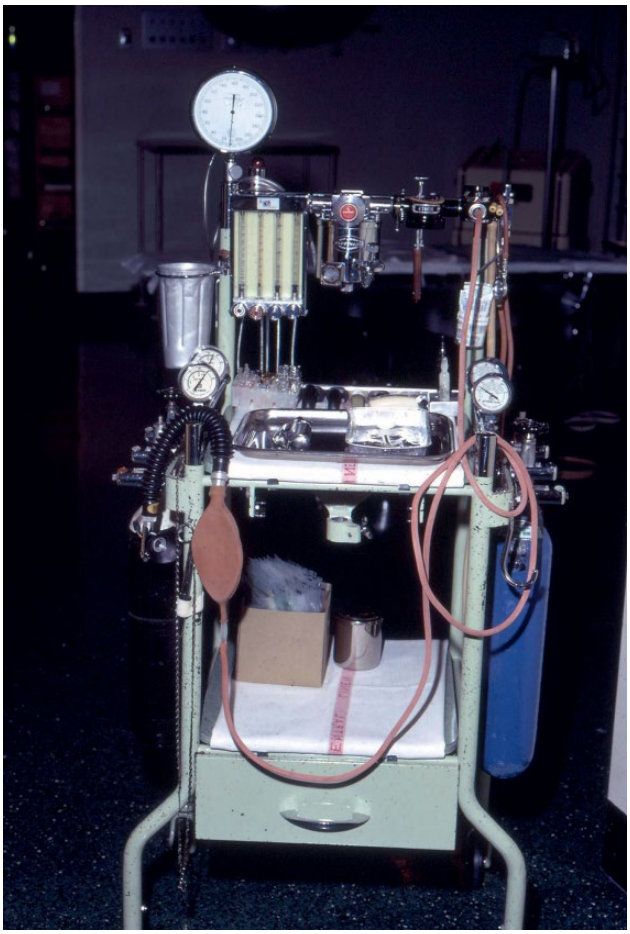

**Figure 2.4** CIG Boyle machine, 1963.

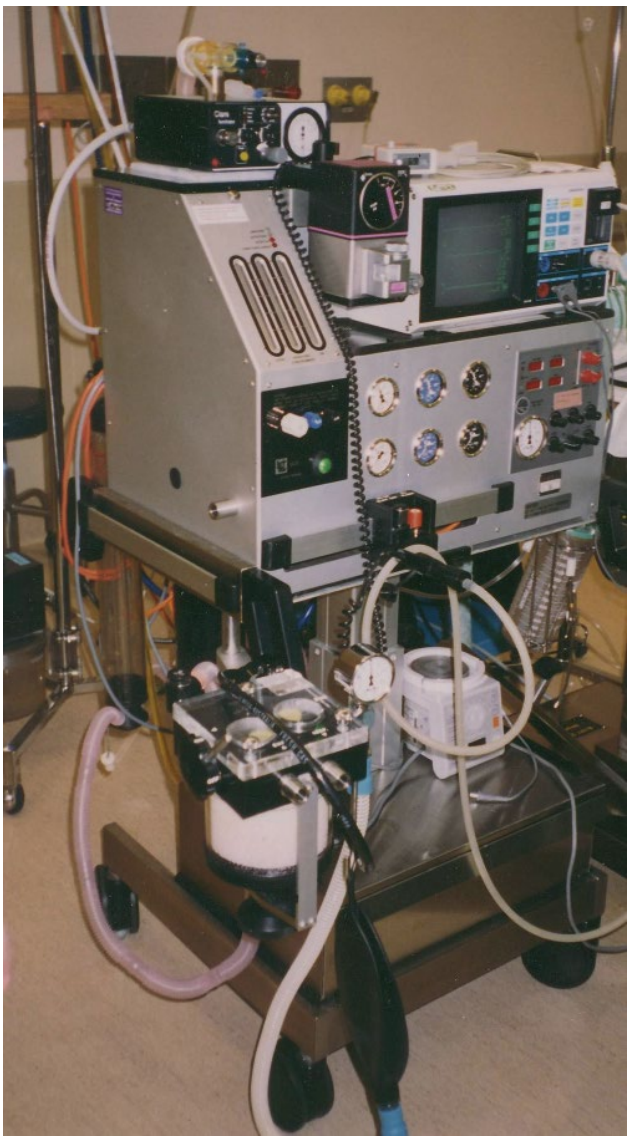

**Figure 2.5** Ergonomic anesthetic machine with Claire ventilator and monitor on top.

**Figure 2.6** Philip Ayre, Newcastle upon Tyne, England.

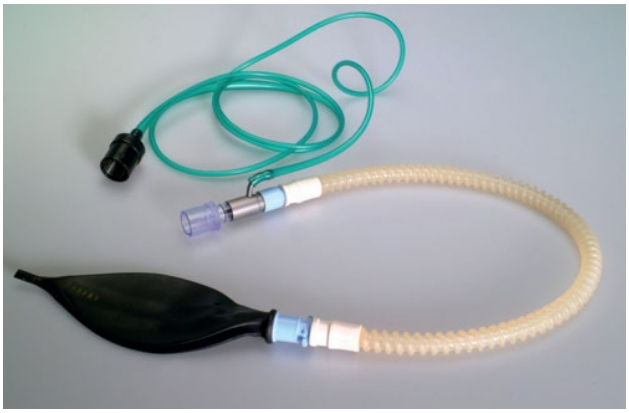

**Figure 2.7** Jackson Rees T piece modification with his prolonged intubation tube attached.

be used for controlled ventilation as demonstrated in Figure 2.8. It was important to use three fingers to squeeze the bag because using four caused thenar muscle fatigue.

Other low-resistance devices used more in North America were the Lewis–Leigh and Stephen–Slater one-way valves. They allowed fresh gas to flow to the patient but during expiration a flap valve stopped the inflow and directed the gas out of the circuit.

The Bloomquist pediatric circle with miniaturized soda lime canisters and narrow tubing were used in North America, while Ian McDonald in Melbourne made a similar miniature circuit. They had valves which increased work of breathing and so were better used with controlled ventilation. The circle system conserved the expensive gas, cyclopropane, and reduced the risk of fire.

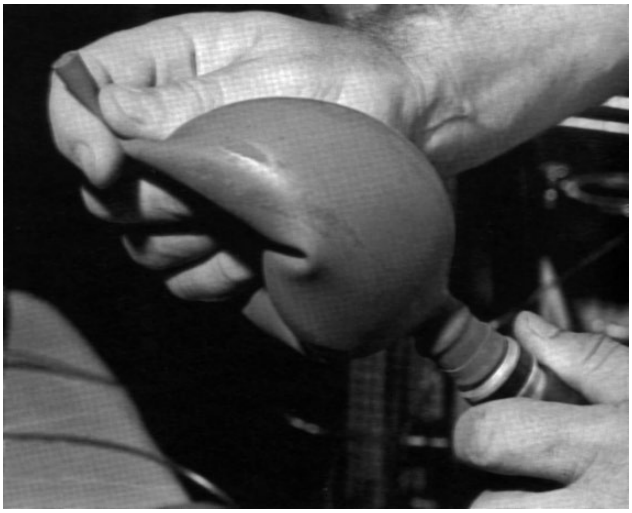

**Figure 2.8** Ventilating with the open-ended bag of the Jackson Rees T piece. Three movements are required. (1) Close open end with thumb and index finger. (2) Squeeze bag with the other three fingers (shown). (3) Stop squeezing and allow expiration.

### KEY POINTS: DELIVERY SYSTEMS AND ANESTHETIC MACHINES

- Anesthesia machines delivering oxygen, nitrous oxide, and ether were developed as early as 1916–17
- Carbon dioxide absorption with soda lime was introduced by Jackson in 1915
- The Ayre T piece was introduced in 1937 specifically for pediatrics

## New drugs in the 1930s, 1940s, and 1950s

Several new anesthetic drugs were introduced in this period. Cinchocaine/dibucaine (1929) was a longer-acting local anesthetic which was widely used to extend spinal anesthesia. Vara-Lopez from Burgos, Spain, reported 438 spinals in children using cinchocaine/dibucaine in 1942 [46].

The short-acting barbiturates, hexobarbital and thiopental, were introduced in 1932 and 1934. Although many continued to induce anesthesia using inhaled agents, thiopentone was the favored intravenous induction agent for over 60 years. There were circumstances in which the usual dose (about 5 mg/kg) needed to be modified. It was often avoided in neonates but could be used in small doses – 2–3 mg/kg. The infant dose was higher and declined after 2 years with age [47,48]. Premedication reduces anxiety and the sympathetic response. An anxious child will have an increased cardiac output and muscle blood flow with proportionately less of the cardiac output going to the brain so that more drug is needed to induce anesthesia. The opposite situation prevails when the patient is hypovolemic, usually due to blood loss. If the usual dose is given, the concentration in the reduced blood volume is greater and a greater proportion of cardiac output and the drug goes to the brain and heart. Onset of anesthesia is quicker and myocardial depression is more likely to occur.

Cyclopropane is a gas, discovered in Toronto but introduced to clinical anesthesia by Waters in 1934 [49]. It was not only flammable but explosive. There was an explosion in Chile that killed five staff and the patient. Cyclopropane had a low blood:gas solubility (0.47) and provided rapid induction and emergence. Deep anesthesia could be reached quickly and the muscles relaxed so that patients could be intubated and good operative conditions achieved. This facilitated the development of thoracic surgery before muscle relaxants were introduced. Cyclopropane had sympathomimetic properties so that blood pressure was maintained even when some blood had been lost. The downside was hypotension when the vasoconstrictive action wore off.

Cyclopropane was popular for children because of the rapid, smooth induction. In inexperienced hands laryngeal spasm during emergence could be a problem but after three or four spasms one soon learnt how to deal with that complication – *continuous* positive pressure on the bag full of oxygen would force oxygen into the patient with the slightest opening of the vocal cords. It was a matter of timing whether one extubated the child while still deeply anesthetized or nearly awake. Ralph Waters taught to turn on nitrous oxide and discontinue cyclopropane near the end of an anesthetic to reduce the tendency to spasm. The use of cyclopropane declined after the introduction of halothane.

Trichloroethylene (Trilene) was a dry cleaning agent. Langton Hewer, in London, introduced it as an anesthetic in 1941. It had several good points including low cost, potent analgesia (good for obstetrics and peripheral procedures), and non-flammability. Its minimum alveolar concentration (MAC) was 0.17%. Unlike other inhalational agents it was a poor hypnotic and increased muscle tone, resulting in rapid shallow breathing (like restrictive lung disease). Unlike other inhalation anesthetics it increased consumption of non-depolarizing muscle relaxants when used with them. This was thought to be due to an effect on muscle spindles increasing muscle tone which reduced chest wall compliance.

Trichloroethylene was found to have neurotoxic effects when used with soda lime which, in those days, contained 5% potassium hydroxide [50]. The exothermic reaction of this compound with carbon dioxide produced toxic breakdown products, affecting most commonly the trigeminal nerve. Potassium hydroxide was later replaced with sodium, calcium, or barium hydroxide in soda or baralyme (80% calcium hydroxide and 20% barium hydroxide) which were safer.

Trichloroethylene was used in a few pediatric centers as an adjunct in neurosurgery, as an agent which did not cause cardiovascular changes during cardiac catheterization, and in primitive situations where it could even be used instead of nitrous oxide which, being a gas, was too expensive or not readily available in less affluent countries.

High concentrations had to be avoided otherwise rigidity, prolonged sleep, and a high incidence of postoperative vomiting occurred, especially if narcotics were used as well. One could just detect the smell when 1 MAC was delivered. Trichloroethylene was very cheap but it was discontinued when the manufacturing plant needed to be replaced.

Lidocaine (lignocaine) was synthesized by Lofgren and Lundquist in Sweden in 1946. It became widely used. Despite its shorter action (about 1½ h) it was used by infusion, if necessary, for longer cases in less affluent countries where cost mattered and new drugs were too expensive. About 18 years later it was found to have antiarrhythmic effects on the heart.

More recently longer-lasting local anesthetics such as bupivacaine were introduced (1963) which led to a rekindling of interest in nerve blocks and regional anesthesia. Although newer agents with claimed advantages have been introduced, bupivacaine was safely used thousands of times by keeping to safe doses (3 mg/kg) and avoiding intravascular injection. Moore suggested convulsions were unlikely below plasma levels of 4 μg/mL. He recorded 5.1–5.4 μg/mL in one case [51]. In another report 7.5 μg/mL was recorded during unexpected convulsions because the plunger of the syringe was pulled back to ascertain the absence of blood. The 12-year-old patient was ventilated with oxygen until she recovered. Although a decrease in heart sounds occurred, indicating a transient decrease in cardiac output, no dysrhythmias were detected [52].

### KEY POINTS: NEW DRUGS IN THE 1930S, 1940S, AND 1950S

- Cyclopropane was introduced into practice by Waters in 1933
- Trichloroethylene was first used by Hewer in 1941
- Lidocaine was synthesized by Lofgren and Lundquist in 1946

## Neonatal anatomical and physiological factors in relation to anesthesia and monitoring

There are some important anatomical points relevant to ventilation of infants and small children [53]. Looking at a chest radiograph, small infants' ribs are more horizontal which prevents an increase in antero-posterior diameter, also, lacking the bucket handle movement of older children and adults prevents increases in transverse chest diameter. The consequence is that a baby's tidal volume is more dependent on diaphragmatic movement. Anything that splints the diaphragm such as air in the stomach or abdominal distension diminishes tidal volume. Gentle ventilation will avoid stomach distension.

In tracheo-esophageal fistula, positive pressure ventilation, if used, must be gentle (low pressure), particularly if a lower esophageal fistula is large. In the early years (1960s) the size was sometimes estimated by the air in the fistula on a lateral chest radiograph. If it was more than 2 mm across, it indicated that inflating the stomach was a potential hazard.

Another observation when looking at a neonatal chest radiograph is that the left bronchus comes off the trachea at a greater angle (47°) than the right bronchus (30°) [54]. Adriani and Griggs [55] stated in 1954 that the angles were equal, a point that was assiduously reproduced in textbooks for many years.

When an endotracheal tube is inserted too far, it is usually on the right side. Many people think this is because the right bronchus is in a more direct line from the trachea or that the right bronchus and lung are larger, but it is mainly due to the fact that the tip of the bevel of the tube is on the right. The

practical implication is to turn the tube so that the point of the bevel is on the left if one is aiming for left endobronchial intubation. In the days before endoscopic placement of tubes was available these were important points for the anesthesiologist to know.

Anesthetic dead space must be kept to a minimum and hence the Rendell-Baker–Soucek low dead space mask was developed. Some anesthesiologists cut endotracheal tubes to reduce dead space but this is unnecessary and even undesirable when controlled ventilation is used because of the tendency to overventilate.

Babies breathe faster and have more rapid heart rates so that more oxygen is delivered to the tissues to satisfy their higher metabolic rate and oxygen consumption. Cardiac output is heart rate dependent because stroke volume varies little. Also, the heart rate slows in response to hypoxia (unlike adults) so that cardiac output is adversely affected.

Fifty years ago monitoring was simple and depended more on observation of clinical signs. Anesthesiologists could glean most of the essential information from these. The pulse would indicate rate, rhythm, volume, and character (e.g. bounding, soft).

The stethoscope, either precordial or esophageal, provided valuable information about ventilation and correct placement of the tube as well as heart rate, rhythm, and intensity of heart sounds. The last are created by heart valve closure and will be softer if stroke volume or myocardial contractility is reduced. The sounds give a sensitive indication of changing cardiac output (provided the stethoscope has not become loose) and, more recently, it is a quick way of telling whether a falling oxygen saturation is a patient or probe attachment problem.

Capillary refill was a useful indicator of peripheral perfusion. It would decrease when there was blood loss and with cold temperatures. Skin color could indicate adequacy of hemoglobin; for example, if it was low, the skin exhibited pallor. Cyanosis was a rather late sign of hypoxia, particularly if the hemoglobin was low. This is why the introduction of the pulse oximeter was such an important development in anesthesia.

Over the years fluid and electrolyte therapy has improved. Initially it was felt that babies needed to be kept hydrated and needed glucose for energy. Pediatricians gave 5% glucose in water or 4% glucose in 1/5 normal saline which provided inadequate sodium resulting in hyponatremia.

An important difference between neonates and small infants compared to older children is that the extracellular (ECF) and smaller intracellular (ICF) fluid compartments are larger, which makes them sicker than older patients if they become dehydrated (easy loss from ECF and less fluid in the ICF to buffer losses in the ECF) (Fig. 2.9).

The kidneys, including the cortical nephrons which control sodium reabsorption, are not fully developed at birth. While much water is reabsorbed in the proximal tubules, the urine osmolality (700 mOsm/L in neonates compared with 1400 mOsm/L in adults) is adjusted by water reabsorption in the loops of Henle where interstitial urea is less (nitrogen is being used for tissue building). This information was only reported in the 1960s and early 70s.

Nowadays a balanced electrolyte solution (e.g. Hartmann's, lactated Ringer's) is a commonly used intraoperative fluid in children. Normally the stress of surgery will ensure an adequate blood sugar level in children. Some glucose may be added to the intravenous fluids in premature babies because glucose and glycogen storage may be insufficient at birth. Neonates require less fluid during the first few days. One calculation for daily fluid requirement was:

- 0–7 days: day of life/7 × 100 mL/kg
- 0–6 months: 100 mL/kg
- 1–13 years: weight (kg) – age (years) × 90 mL/kg.

Total parenteral nutrition (TPN) was a concept developed in the 1970s, advocated because it shortened length of stay in ICUs by providing essential calories, nutrients, and fluids. The savings offset the cost of TPN.

Heat loss may be greater because infants have large heads that contribute to their greater surface area:body weight ratio. They are poorly insulated with less subcutaneous fat, they do not shiver, and they have a narrower thermoneutral range, i.e. ambient temperature where heat loss is minimal. Steps such as a warming blanket beneath the baby on the operating table, wrapping in foil, warmed humidification, and the use of overhead heaters were used to prevent cooling. Before these steps were taken, outcomes of surgery were less favorable.

There have been many developments in physiology, some of which also affect the handling of drugs, which impact on pediatric anesthesia. A better understanding of these has helped improve the care of children and the results of surgery.

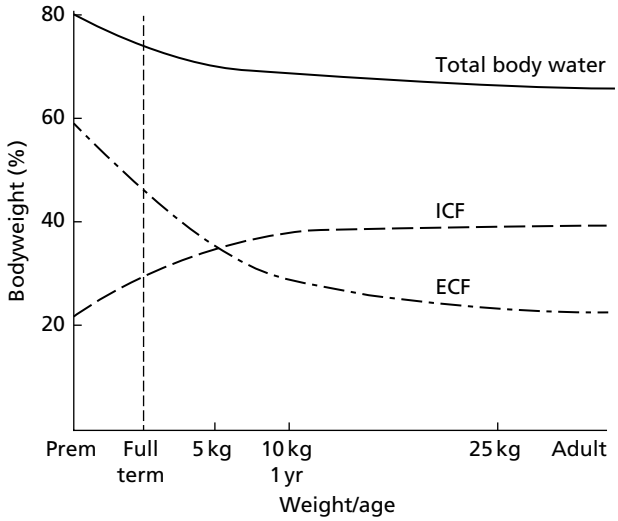


**Figure 2.9** Changes in intracellular and extracellular fluid compartments (ICF and ECF) during the first months of life. *Source:* Adapted from Cheek [125] and Friis-Hansen [126].

## KEY POINTS: NEONATAL ANATOMICAL AND PHYSIOLOGICAL FACTORS

- Small infants' ribs are more horizontal, preventing "bucket handle" movement and making tidal volume more dependent on the diaphragm
- In early years monitoring was by clinical observation only: skin color, capillary refill, pulse
- Balanced electrolyte solutions, preservation of body temperature, and neonatal pharmacology have contributed significantly to survival in neonatal anesthesia

## Early anesthesiologists interested in children: pediatric anesthesia emerges into the specialist era, 1920s to 1950s

During the transitional years (1920–1950) when doctors who gave anesthetics first began to take a special interest in children, particularly babies, changes began to occur mainly in some of the more progressive children's hospitals. Pediatric surgery was beginning to expand but success was only possible when anesthesia improved and there was still a long way to go.

Pediatric anesthesia refers to anesthesia for children of all ages. In the first 100 years it was part of the amalgam of anesthesia generally, with few references to studies in children who were regarded as miniature adults. Few doctors devoted their practice to anesthesia, mostly doing some general practice as well. Before World War II few people took a special interest in children's anesthetics. In countries like Canada, Britain, Australia, and New Zealand, doctors, sometimes young and inexperienced, gave the anesthetics while in the USA and Europe nurses were often involved. Betty Lank was one who made an outstanding contribution, working with Robert Gross in Boston for 20 years from 1936.

### Canada

Charles Harold (Robby) Robson (Fig. 2.10A) [56,57] came from British Columbia. He graduated in medicine at McGill in Montreal in 1913. He interned at Montreal General and trained in anesthesia at Royal Victoria Hospital before going to France in World War I, later becoming Senior Consultant Anesthetist to the Canadian Army.

In 1919 he returned to Canada and became Chief Anesthetist at the Hospital for Sick Children (HSC), Toronto, where he remained until he retired in 1951. Adenotonsillectomy constituted about a third of cases. Anesthesia was mainly open drop ethyl chloride and ether. Robson had a special skill of tactile intubation when necessary – he used his fingers to guide the tube into the trachea. He became Clinical Demonstrator in 1935, published one paper on "anesthesia for children" in 1936 and made a movie on the hazards of the immediate postoperative period. He was a frequent speaker on pediatric anesthesia and trained a generation of anesthesiologists, including five who became department heads. He was probably the first pediatric anesthetist to have such a major influence on the field and has been called the grandfather of pediatric anesthesia in Canada.

In 1927, Charles Junkin joined the staff of HSC but like many doctors involved with anesthesia in those days he anesthetized adults and children and also did general practice. In 1945 he became a full-time pediatric anesthetist and went on to become Chief from 1951 to 1960 [58].

At the conclusion of World War II the department was enlarged by better trained and more experienced full-time anesthetists coming back from the war, such as Norman Park, who was joined by others in Toronto including Code Smith, a wonderful pharmacology teacher who made the subject more interesting by discussing structure–action relationships of drugs (notably barbiturates and local anesthetics). This made the subject easier to follow and remember. He was mainly a neuroanesthetist.

Digby Leigh (Fig. 2.10B) [58], also from British Columbia, graduated in Montreal (McGill) in 1932. He began surgical training until Wesley Bourne, later the first Professor of Anesthesia in Montreal and Canada, persuaded him to change to anesthesia. He spent three years with the legendary Ralph Waters at Madison, Wisconsin, the first Professor of Anesthesia in the USA (1937), before returning to become Chief at the Montreal Children's Hospital in 1940. He developed a non-rebreathing valve and an infant circle absorber so that cyclopropane could be administered in a closed circuit.

During the war, Leigh with Wesley Bourne and Harold Griffiths (later first President of the World Federation of Societies of Anaesthesia – WFSA) each organized 3-month anesthesia courses for doctors in the armed forces before they went overseas. Many of these trainees went on to become part of the rapid expansion of specialists after the war. Digby Leigh established the Montreal Diploma of Anesthesia course which set the pattern for training in Canada. In 1947 he moved to Vancouver where he set up a department which supplied the total service for Vancouver General and Children's Hospitals. Among those who went with him was Eric Webb, a brilliant clinical teacher who also inspired an interest in the history of anesthesia among trainees. Leigh later went to Lagos, Nigeria, as part of a Canadian initiative to help establish training in that country. Others who accompanied Leigh were Horace Graves, Harold Kester, John Poole, and Herb Randall. The last also trained with Waters and had a limited practice until he was 92 (possibly the oldest anesthesiologist still to practice).

Leigh produced the first textbook on pediatric anesthesia in North America with Kay Belton, Supervisor of Pediatric Anesthesia at Vancouver General Hospital (1949) [59]. It is an interesting book, first discussing the care of the child in hospital, and later including a chapter on local anesthetic blocks including caudals and spinals, which were used in about 10% of their cases.

In 1954 Digby Leigh moved to Los Angeles Children's Hospital, having failed in his request for a separate department and chair of anesthesia in Vancouver. He started the annual weekend courses on pediatric anesthesia that were run for many years by Wayne Herbert. Later his idea of half-day release for teaching trainees was taken to Australia. His influence on teaching and training both generally and in pediatrics was immense. He was regarded as father of pediatric anesthesia in Canada.

C.R. Stephen followed Leigh as chief at Montreal Children's Hospital until 1950, when his colleague H.M. Slater succeeded him when he moved to Duke, North Carolina [57]. They had developed the Stephen–Slater non-rebreathing valve.

Children's hospital anesthetic departments and major hospitals with separate pediatric sections began to acquire more and more full-time pediatric anesthesiologists although in many places general anesthesiologists performed children's anesthetics as part of their practice. The full-timers were largely responsible for leading the way in the advances in the specialty, which was developing from the 1950s onwards.

In 1954 Ruston, working in Hamilton, Ontario, reported on epidural anesthesia for Infants and children, and 10 years later updated their experience [59,60].

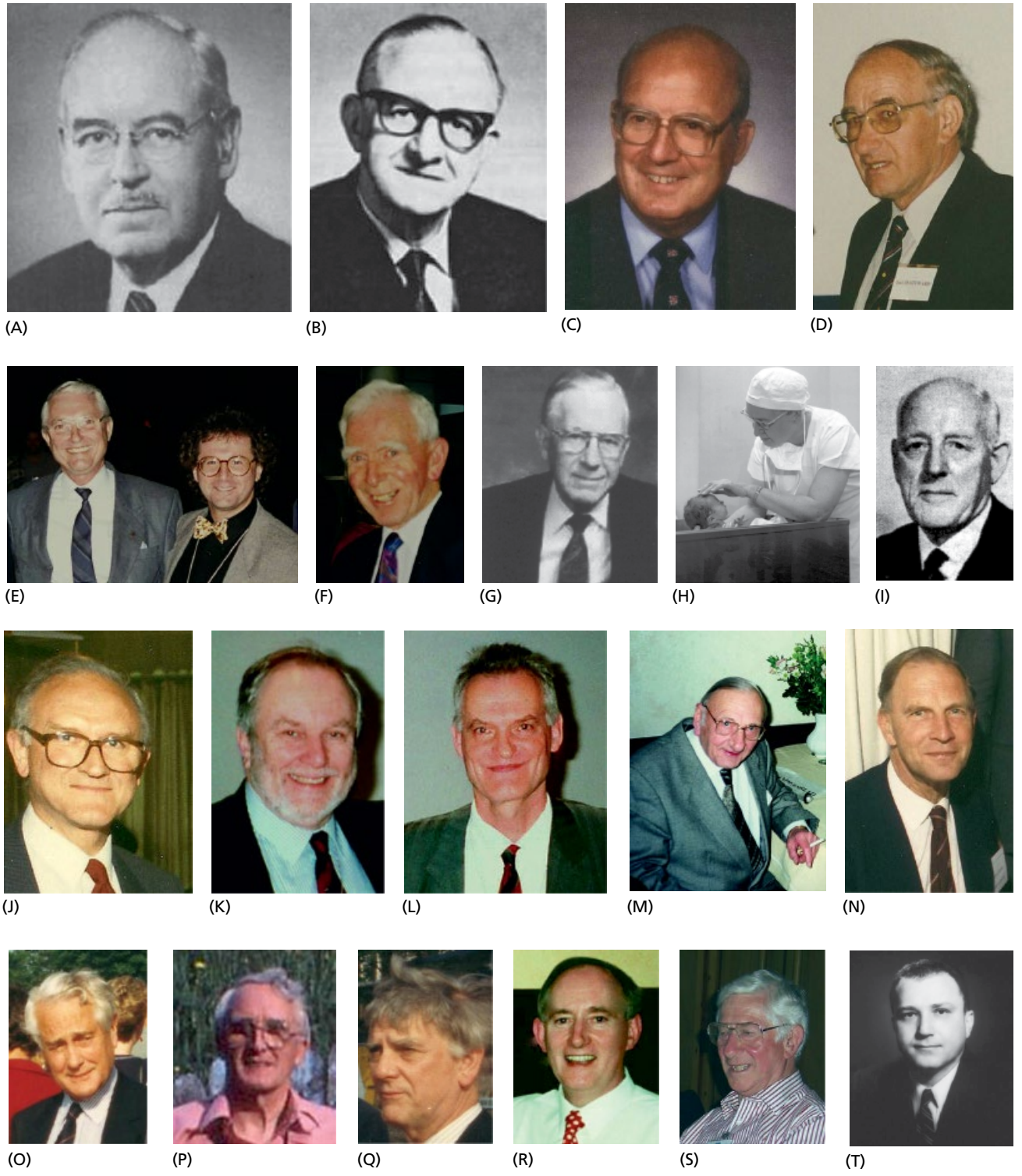


**Figure 2.10** Prominent pediatric anesthetists: Canada, USA, and Britain. (A) Charles Robson, Toronto; (B) Digby Leigh, Montreal, Vancouver, Los Angeles; (C) Alan Conn, Toronto; (D) David Steward; Toronto, Vancouver, Los Angeles; (E) Robert Creighton (left), Jerrold Lerman (right), Toronto; (F) Tom McCaughey, Winnipeg; (G) Robert Smith, Boston; (H) Virginia Apgar, Columbia, New York City; (I) Robert Cope, London; (J) William Glover, London; (K) David Hatch, London; (L) Ted Sumner, London; (M) G. Jackson Rees, Liverpool; (N) Gordon Bush, Liverpool; (O) Gerry Black, Belfast; (P) Harold Love, Belfast; (Q) Peter Morris, Manchester; (R) George Meakin, Manchester; (S) Ted Armitage, Brighton; (T) Arthur Keats, Houston, TX.

During the 1960s and 1970s the next group of leading contributors in Canada included Alan Conn (Fig. 2.10C), Chief at HSC Toronto, who went on to become Chief of Intensive Care with a special interest in near drowning. He was succeeded by David Steward (Fig. 2.10D), who was a very active teacher and editor of his well-known *Handbook of Pediatric Anesthesia*. One of his interests was anesthesia for ex-premature infants. He later opened up Vancouver Children's Hospital before concluding his clinical career as Chief at Los Angeles Children's Hospital. He was succeeded by Bob Creighton and

then Jerry Lerman (Fig. 2.10E), who was an enthusiastic researcher.

Many others specialized in the field. Jeremy Sloan was a cardiac anesthetist at HSC who came from South Africa. Later he contributed to international standards committees. Harold Davenport was chief at the Montreal Children's Hospital before moving to Vancouver for a short period. He then returned to England. He authored a small book about pediatric anesthesia. Tom McCaughey (Fig. 2.10F) became well known as chief at Winnipeg Children's Hospital.

## United States of America

Robert Smith (Fig. 2.10G) [4], after war service in Europe where he became involved in anesthesia, was appointed Chief of Anesthesia at the Boston Children's Hospital in 1946. Previously anesthesia at this hospital had been given by nurses including Betty Lank, who made special equipment such as small blood pressure cuffs and masks for infants and children. Smith was interested in patient safety and was an advocate of the use of appropriately sized endotracheal tubes and of wrapping babies to prevent heat loss. In the 1950s he pioneered the use of the precordial stethoscope.

Robert Smith was a great teacher and trained people from all over the world. He had a calm demeanor and never roused antagonism. He produced a famous, comprehensive book in 1959 called *Anesthesia for Infants and Children*. He was regarded as the father of pediatric anesthesia in the USA [61].

Virginia Apgar (Fig. 2.10H), having trained with Ralph Waters, became Director of Anesthesia at the Babies Hospital in New York in 1938. Following her research on neonatal resuscitation she became known around the world for the APGAR scoring system (1953) which she developed to assess the condition of babies at birth and soon afterwards: skin color, pulse, reflex irritability, muscle tone, and respiration each scored as 0, 1 or 2. It was simple and had predictive value – a score below 5 indicated that the baby was in trouble. Later in her career she moved to Johns Hopkins University where she took an interest in birth defects [62].

There were others who contributed to the development of pediatric anesthesia such as Robert McQuiston at Chicago Children's Hospital and Herbert Rackow and Ernest Salanitre at the Babies Hospital at Columbia Presbyterian Medical Center in New York [63]. They established departments that advanced training and practice of pediatric anesthesia after World War II. The latter had research interests in the uptake and elimination of inhalational agents and the risk of cardiac arrest in infants and children.

Margot Demming was the first full-time pediatric anesthesiologist in Philadelphia. She observed that infants required higher concentrations of inhalational agents than adults [64]. Many others followed such as Jack Downes, also in Philadelphia, who was involved in the early days of intensive care [65]. Some places benefitted by the immigration of established pediatric anesthesiologists like Digby Leigh and C.R. Stephen from Canada, and elsewhere.

## United Kingdom

In Britain, Great Ormond Street Hospital for Sick Children in London appointed Robert Cope as head anesthetist in 1937 (Fig. 2.10I) [66]. Others joined him such as Sheila Anderson, Bill Glover (Fig. 2.10J), and later David Hatch (Fig. 2.10K) who became the first Professor of Paediatric Anaesthesia in the United Kingdom. David Hatch, with Ted Sumner (Fig. 2.10L), produced a valuable book on neonatal anaesthesia.

Liverpool became influential later when people like Jackson Rees (Fig. 2.10M), Gordon Bush (Fig. 2.10N; the first editor of *Pediatric Anesthesia*), Alan Stead, and Tony Nightingale joined the group there. People from many parts of the world gained experience with them. Britain had many children's hospitals, and places like Glasgow (Douglas Arthur, Roddie McNicol – nerve blocks, especially the anterior approach to the sciatic nerve), Belfast (Harold Love, Fig. 2.10O; Gerry Black, Fig. 2.10P), Manchester (Peter Morris (Fig. 2.10Q), George Meakin (Fig. 2.10R) – muscle relaxants in children), Birmingham (Susan Jones) and others developed good reputations as their staff became well known. Even places like Brighton contributed through the work on caudal anaesthesia by Ted Armitage (Fig. 2.10S) and, in Derby, by Brian Kay. Many of the leaders became President of the Association of Paediatric Anaesthetists.

Jackson Rees was an enthusiast who was well recognized for his teaching, research, and constant search for new ideas [67]. He was largely responsible for the Liverpool technique: thiopental, d-tubocurarine, and rapid ventilation with nitrous oxide and oxygen. Many people incorrectly described it as hyperventilation but the method as he performed it was very rapid, small breaths ventilated with the bag he attached to the T piece on which he kept a slight positive pressure. Unwittingly he was using high-frequency ventilation and positive end-expiratory pressure (PEEP) long before the value of these were appreciated. He was guest lecturer to the Australian Society of Anaesthetists and ran a 2-week course in Melbourne in 1963. During his visit he saw the work with prolonged nasotracheal intubation, with ventilation if needed, that had developed in Adelaide [68] and Melbourne [69]. He returned to Liverpool via Toronto and conveyed his enthusiasm for what he had seen. He began pediatric intensive care in Liverpool and developed his special complex tube for nasal intubation.

In 1973 Britain led the way in Europe when the Association of Paediatric Anaesthetists of Great Britain and Ireland (APA) was formed. They had foreign members who were leaders in Europe and the rest of the world who were well represented at their meetings before other regular meetings had started [70]. These became an important step in building the bonds between pediatric anesthesiologists.

## Australia

In Australia a handful of the more experienced general anesthetists took care of most of the babies and pediatric cases needing special care before and during World War II. These included Gilbert Brown (first President of the ASA – Australian Society of Anaesthetists) and Mary Burnell (Fig. 2.11A) who established pediatric anesthesia at the Adelaide Children's Hospital (later President of ASA and Dean of the Faculty of