

# HANDBOOK OF Interventional Radiologic Procedures

FIFTH EDITION

Krishna Kandarpa  
Lindsay Machan  
Janette D. Durham

 Wolters Kluwer

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HANDBOOK OF  
INTERVENTIONAL  
RADIOLOGIC  
PROCEDURES

5<sup>TH</sup> EDITION



*“Dedicated to the innovative spirit of interventional radiologists.”*

# HANDBOOK OF INTERVENTIONAL RADIOLOGIC PROCEDURES

**Krishna Kandarpa, MD, PhD**

**Lindsay Machan, MD**

**Janette D. Durham, MD**

5<sup>TH</sup> EDITION

 Wolters Kluwer

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## FOREWORD

The field of interventional radiology continues to grow and to change. The scope of care provided by this critical medical discipline has advanced rapidly over the quarter of a century since the very first edition of this *Handbook* in 1989. There are few other disciplines that have changed so much in this brief amount of time. The scope of this change is represented by the table of contents that has expanded to over 100 chapters, and more important, the *Handbook* continues to emphasize not only procedures that have been described in previous editions but also the important expanding roles of endovascular and nonvascular interventional therapies for a multitude of disease states. Reflecting changes in the health care system, important chapters on quality assurance and improvement, risk management, as well as safety—including radiation and infection control—have been included.

More important, discussions on the clinical practice of interventional radiology are addressed, including organizational and operational issues, nursing management, and the practical use and management of pharmacologic therapies.

It is hard to imagine how the *Handbook of Interventional Radiologic Procedures* could possibly improve over prior editions. Since its initial publication, this *Handbook* has become an essential reference for interventionalists at all levels of experience. It will undoubtedly be essential for residents and fellows during their training and should remain an important reference for practitioners who will benefit from the valuable practical information contained in this volume.

The field of interventional radiology continues to evolve as both a clinical and a procedural discipline. The challenges of creating a comprehensive handbook of practical information in a volume that can actually be carried around has become more difficult. Yet the editors and authors have amassed a volume that is brisk and focused in style, extremely well organized and catalogued to make it easy for the reader to get critical information when necessary in the treatment of specific patients. This handbook is a tool in the hands of interventionalists which is as helpful as any of the devices that may be used in specific procedures. In keeping with the times, an updated electronic version for handheld devices is once again provided.

I'm certain that the fifth edition of the *Handbook of Interventional Radiologic Procedures* will become an indispensable tool and resource in the lab coat of all interventional radiologists and staff performing these procedures. I know it will for me.

*Barry T. Katzen, MD*



## PREFACE

From inability to let well alone; from too much zeal for the new and contempt for what is old; from putting knowledge before wisdom, science before art, and cleverness before common sense, from treating patients as cases, and from making the cure of the disease more grievous than the endurance of the same, Good Lord, deliver us.

*Sir Robert Hutchinson*

Correspondence regarding modern treatment in the *British Medical Journal*, March 12, 1953, p. 671.

Interventional radiology remains a vibrant field with evolving and rapidly growing applications due in large part of the ingenuity and creativity of its practitioners. Although it is true that medical necessity may have mothered many inventions, scientific advances and competitive pressures have also done much to motivate this innovational spirit. Future success will depend not only on a continued proactive “innovational” attitude but, more importantly, also on embracing the clinical management of patients, and staying ahead of unrelenting competition. Fortunately, the pace of innovations and the specialty’s acquisition of clinical management skills have necessitated a fifth edition of *Handbook of Interventional Radiologic Procedures*.

This book should be useful not only for practicing interventional radiologists but also for fellows and residents in training, and for those seasoned general radiologists who are several years out from formal training but have retained the skills required for performing interventional procedures. This book will also help interventional nurses and special procedure technologists in performing their own vital tasks more efficiently by enhancing medical knowledge specific to each procedure.

We realize that there is no single way to perform a procedure and do not mean to imply that the descriptions here are the only appropriate ones. The intent is to provide a framework that the interventionalist can use and build on as more experience is gained. As in prior editions, each chapter on procedures has been organized in a consistent outline format to facilitate easy access to specific sections on indications and contraindications, preprocedure preparation, procedural protocol, postprocedure care, and expected outcomes—all toward improving patient safety by preventing complications or managing them appropriately when they do occur. This latter information is especially useful while the procedure is being discussed with the patient before obtaining informed consent. We have—to the best of our ability—corrected mistakes and oversights from prior editions.

We are eternally grateful to the contributors worldwide for their painstaking efforts in creating what we hope will be another successful handbook. We thank Dr. Barry Katzen for kindly writing the foreword. We thank Ryan Shaw and Rebeca Barroso of Wolters Kluwer for guiding us through the process, and most of all for their patience.

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## ABBREVIATIONS

<sup>18</sup> F-FDG	<sup>18</sup> F-fluorodeoxyglucose
2D	Two-dimensional
3D	Three-dimensional
A	Ankle
AAA	Abdominal aortic aneurysm
AASLD	American Association for the Study of Liver Diseases
ABI	Ankle-brachial index
ACA	Anterior cerebral artery
ACAS	Asymptomatic Carotid Atherosclerosis Trial
ACD	Advance care directives
ACE	Angiotensin-converting enzyme
ACLS	Advanced cardiac life support
ACR	American College of Radiology
ACT	Activated clotting time
ADC	Analog-to-digital converter
ADH	Antidiuretic hormone
ADP	Adenosine diphosphate
AE	Adverse events
AECD	Automatic external cardioverter-defibrillator
AF	Atrial fibrillation
AFB	Acid-fast bacilli
AFP	$\alpha$ -Fetoprotein
AGIH	Acute gastrointestinal hemorrhage
AHRQ	Agency for Healthcare Research and Quality
AK	Above-knee
ALS	Amyotrophic lateral sclerosis
AMFPI	Active matrix flat-panel imager
AMI	Acute mesenteric ischemia
AML	Angiomyolipoma
Ao	Aorta
AP	Anteroposterior
APD	All-purpose drainage
APF	Arterioportal fistula
APTT	Activated partial thromboplastin time
ARDS	Adult respiratory distress syndrome
ARNP	Advanced registered nurse practitioner
ASA	Acetylsalicylic acid
ASA	American Society of Anesthesiologists
ASD	Atrial septal defect
ASPECTS	Alberta Stroke Program early computed tomography scan
AT	Anterior tibial

ATIII	Antithrombin III
ATM	Atmospheres
AV	Arteriovenous
A-V	Atrioventricular
AVF	Arteriovenous fistula
AVG	Arteriovenous graft
AVM	Arteriovenous malformation
AVP	Amplatzer Vascular Plug
BAC	Bronchioloalveolar carcinoma
BAE	Bronchial artery embolization
BCLC	Barcelona Clinic Liver Cancer
BE	Balloon expandable
β hCG	Beta human chorionic gonadotropin hormone
BGC	Balloon-guiding catheter
bid	Two times per day
BIPAP	Bi-level positive airway pressure
BLS	Basic life support
BMI	Body mass index
BMS	Bare-metal stents
BMT	Bone marrow transplant
BOT	Balloon occlusion tolerance
BP	Blood pressure
BPH	Benign prostatic hyperplasia
BRTO	Balloon-occluded retrograde transvenous obliteration
BTK	Below-the-knee
BUN	Blood urea nitrogen
BW	Bandwidth
CABG	Coronary artery bypass graft
CAD	Coronary artery disease
CAS	Carotid artery stenting
CASH	Chemotherapy-associated steatohepatitis
CAVATAS	Carotid and Vertebral Artery Transluminal Angioplasty Study
CaVenT	Catheter-directed Venous Thrombolysis
CBC	Complete blood count
CBCT	Cone-beam computed tomography
CBF	Cerebral blood flow
CBV	Cerebral blood volume
CC	Cisterna chyli
CCA	Common carotid artery
CCD	Charge-coupled device
CCS	Canadian Cardiovascular Society
CDC	Centers for Disease Control and Prevention
CDT	Catheter-directed thrombolysis
CEA	Carcinoembryonic antigen; carotid endarterectomy
CFA	Common femoral artery
CFV	Common femoral vein
CHA	Common hepatic artery
CHF	Congestive heart failure

CIA	Common iliac artery
CIN	Contrast-induced nephropathy
CIWA	Clinical Institute Withdrawal Assessment
CKD	Chronic kidney disease
CLABSI	Central line-associated bloodstream infection
CLI	Critical limb ischemia
CMS	Centers for Medicare and Medicaid Services
CNS	Central nervous system
COPD	Chronic obstructive pulmonary disease
COX	Cyclooxygenase
CP	Cerebral protection
CPAP	Continuous positive airway pressure
CPAS	Congenital pulmonary artery stenosis
CPOE	Computerized physician order entry
CPR	Cardiopulmonary resuscitation
CPRF	Curved planar reformats
CPT	Current Procedural Terminology
Cr	Creatinine (serum)
CQI	Continuous quality improvement
CR-BSI	Catheter-related bloodstream infections
CRC	Colorectal cancer
CREST	Carotid Revascularization Endarterectomy versus Stenting Trial
CRP	C-reactive protein
CSF	Cerebrospinal fluid
CsI	Cesium iodide
CT	Computed tomography
CTA	Computed tomographic angiography
cTACE	Conventional transarterial chemoembolization
CTO	Chronic total occlusion
CTP	CT perfusion
CTV	Computed tomography venography
CV	Central venous
CVA	Cerebral vascular accident
CVC	Central venous catheter
CVD	Chronic venous disease
CXR	Chest radiograph; chest xray
D5½NS	5% dextrose, half-normal saline solution
D5W	5% Dextrose solution
DAP	Dose–area product
DAVF	Dural arteriovenous fistula
DCI	Delayed cerebral ischemia
DEB	Drug-eluting bead; drug-eluting balloon
DER	Dual energy radiography
DES	Drug-eluting stent
DH	Degree of hypertrophy
DIC	Disseminated intravascular coagulopathy
DICOM	Digital imaging and communication in medicine
DIPS	Direct intrahepatic portosystemic shunt

DLGJ	Double lumen gastrojejunostomy
DIR	Dose Index Registry; double inversion recovery
DM	Diabetes mellitus
DMSO	Dimethyl sulfoxide
DNI	Do not intubate
DNR	Do not resuscitate
DOQI	Disease Outcomes Quality Initiative
DQE	Detective quantum efficiency
DSA	Digital subtraction angiography
DTPA	Diethylenetriamine pentaacetic acid
DUS	Doppler ultrasound; duplex ultrasound
DVT	Deep vein thrombosis
E&M	Evaluation and Management
EASL	European Association for the Study of the Liver
ECG	Electrocardiogram
ECOG	Eastern Cooperative Oncology Group
ECST	European Carotid Surgery Trial
ED	Emergency department
EDV	End-diastolic velocity
EGFR	Epidermal growth factor receptor
eGFR	Estimated GFR
EIA	External iliac artery
ENT	Ear, nose, and throat
EPD	Embolic protection device
ERCP	Endoscopic retrograde cholangiopancreatography
ERF	Esophagorespiratory fistula
ESBL	Extended-spectrum betalactamase
ESCAPE	Endovascular Treatment for Small Core and Anterior Circulation Proximal Occlusion with Emphasis on Minimizing CT to Recanalization Times
ESI	Epidural steroid injection
ESWL	Extracorporeal shock wave lithotripsy
EUS	Endoscopic ultrasound
EVA-3S	Enderterectomy versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis
EVAR	Endovascular aortic aneurysm repair
EVLV	Endovenous laser treatment
EVOH	Ethylene vinyl alcohol
EXTEND-IA	Extending the Time for Thrombolysis in Emergency Neurological Deficits–Intra-arterial
FB	Foreign body
FDA U.S.	Food and Drug Administration
FDG-PET	Positron emission tomography
FFP	Fresh frozen plasma
FHVP	Free hepatic venous pressure
FLR	Future liver remnant
FNA	Fine needle aspiration
FNH	Focal nodular hyperplasia
FOV	Field-of-view
GA	General anesthesia
GABA	$\gamma$ -Aminobutyric acid

Gd	Gadolinium
GDA	Gastroduodenal artery
GDC	Gugliemi detachable coil
Gd-MRA	Gadolinium enhanced MRA
GFR	Glomerular filtration rate
GI	Gastrointestinal
GJ	Gastrojejunostomy
GP	Glycoprotein
GSV	Greater saphenous vein
GU	Genitourinary
GW	Guidewire
HA	Hepatic artery
HAP	Hepatic artery pseudoaneurysm
HAS	Hepatic artery stenosis
HASTE	Half-Fourier acquisitions with single-shot turbo-spin echo
HAT	Hepatic artery thrombosis
HCC	Hepatocellular carcinoma
HCFMEA	Health Care Failure Mode and Effects Analysis
hCG	Human chorionic gonadotropin
HCl	Hydrochloride
Hct	Hematocrit
HD	Hemodialysis
Hgb	Hemoglobin
HHT	Hereditary hemorrhagic telangiectasia
HIFU	High-intensity focused ultrasound
HIT	Heparin-induced thrombocytopenia
HITT	Heparin-induced thrombocytopenia with thrombosis syndrome
HMPAO	Hexamethylpropyleneamine oxime
HMW	High-molecular-weight
HOCA	High-osmolality contrast agents
HPS	Hepatopulmonary syndrome
HR	Hazard ratio; heart rate
HSG	Hysterosalpingogram
HT	High thigh
HTN	Hypertension
HU	Hounsfield unit
HV	Hepatic venous
HVPG	Hepatic venous pressure gradient
IA	Intra-arterial
IC	Intracranial
ICA	Internal carotid artery
ICBT	Intercostobronchial trunk
ICD-10	International Classification of Diseases, 10th revision
ICH	Intracerebral hemorrhage
ICP	Intracranial pressure
ICSS	International Carotid Stenting Study
ICU	Intensive care unit
ID	Internal diameter



IFU	Instructions for use
IHI	Institute for Healthcare Improvement
IHSS	Idiopathic hypertrophic subaortic stenosis
II	Image intensifier
IIA	Internal iliac artery
IIEF	International Index of Erectile Function
IJ	Internal jugular
IJV	Internal jugular vein
IM	Intramuscular
IMA	Inferior mesenteric artery; internal mammary artery
IMS III	Interventional Management of Stroke III
IMV	Inferior mesenteric vein
INR	International normalized ratio
IO	Interventional oncology
IOM	Institute of Medicine
IPSS	International Prostate Symptom Score
IQR	Interquartile range
IR	Interventional radiology; interventional radiologist
IRE	Irreversible electroporation
ISAT	International Subarachnoid Aneurysm Trial
ISV	Internal spermatic vein
ITT	Intention to treat
IV	Intravenous; intravenously
IVA	Inferior vesical artery
IVC	Inferior vena cava
IVUS	Intravascular ultrasound
J-tube	Jejunostomy
KAP	Kerma–area product
KGR	Kinetic growth rate
KP	Kyphoplasty
K-RAS	Kirsten Rat Sarcoma Viral Oncogene Homolog
KTS	Klippel–Trenaunay syndrome
kVp	Kilovolt peak
KVO	Keep vein open
LA	Left atrial; left atrium
LAD	Left anterior descending
LAO	Left anterior oblique
LCD	Liquid crystal display
LDCT	Low-dose CT
LDH	Lactate dehydrogenase
LDL	Low-density lipoprotein
LFT	Liver function test
LGIB	Lower GI bleeding
LM	Lymphatic malformations
LMA	Laryngeal mask airway
LMWH	Low-molecular-weight heparin
LOCA	Low-osmolality contrast agents
LOCM	Low osmolar contrast medium

LSCA	Left subclavian artery
LSF	Lung shunt fraction
LSN	Last seen normal
LUTS	Lower urinary tract symptoms
LV	Left ventricle; left ventricular
LVEDP	Left ventricular end-diastolic pressure
LVEDV	Left ventricular end-diastolic volume
LVO	Large vessel occlusion
MAA	Macroaggregated albumin
MAC	Monitored anesthesia care
MAO	Monoamine oxidase
MAP	Mean arterial pressure
MBB	Medial branch block
MC	Manual compression
MCA	Middle cerebral artery
mCRC	Metastatic colon cancer
mCTA	Multiphase CTA
MD	Medical doctor
MI	Myocardial infarction
MIP	Maximum intensity projection
MODS	Multiple organ dysfunction syndrome
MPA	Multipurpose shape
MPR	Multiplanar reformations
MR	Magnetic resonance
MRA	Magnetic resonance angiography
MR CLEAN	Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands
MRCP	Magnetic resonance cholangiopancreatography
MRDSA	Magnetic resonance digital subtraction angiography
mRECIST	Modified Response Evaluation Criteria in Solid Tumors
MR RESCUE	Mechanical Retrieval and Recanalization of Stroke Clots Using Embolectomy
MRI	Magnetic resonance imaging
MRV	Magnetic resonance venogram; magnetic resonance venography
mTICI	Modified thrombolysis in cerebral infarction
MTT	Mean transit time
MWA	Microwave ablation
nAC	<i>n</i> -Acetyl cysteine
NaHCO <sub>3</sub>	Sodium bicarbonate
NASCET	North American Symptomatic Carotid Endarterectomy Trial
nBCA	<i>n</i> -Butyl cyanoacrylate
NCCT	Noncontrast computed tomography
NG	Nasogastric
NG-tube	Nasogastric tube
NIH	National Institutes of Health
NIHSS	National Institutes of Health Stroke Scale
NINDS	National Institute of Neurological Disorders and Stroke
NKF-KDOQI	Kidney Disease Outcomes Quality Initiative
NLST	National Lung Screening Trial

NOHAH	Nonocclusive hepatic artery hypoperfusion syndrome
NOMI	Nonocclusive mesenteric ischemia
NPH	Neutral protamine Hagedorn
NPO	Nil per os
NS	Normal saline
NSAID	Nonsteroidal anti-inflammatory drug
NSCLC	Non-small cell lung cancer
NSF	Nephrogenic systemic fibrosis
NTG	Nitroglycerin
NYHA	New York Heart Association
OD	Outer diameter
OP	Outpatient
OPSI	Overwhelming post-splenectomy infection
OR	Operating room
OSA	Obstructive sleep apnea
PA	Physician's assistant; pulmonary artery
PACS	Picture archiving and communication system
PAD	Peripheral arterial disease; pulmonary artery diastolic
PAE	Prostate artery embolization
PAP	Pulmonary arterial pressure
PARTO	Plug-assisted retrograde transvenous obliteration
PAVM	Pulmonary arteriovenous malformation
PBD	Percutaneous biliary drainage
PCA	Patient-controlled analgesia; posterior cerebral artery
PCC	Prothrombin complex concentrate
PCDT	Pharmacomechanical catheter-directed thrombolysis
PCI	Percutaneous coronary intervention
PC-MRA	Phase contrast-MRA
PCN	Percutaneous nephrostomy
PCORI	Patient-Centered Outcomes Research Institute
PCSA	Patient-controlled sedation
PCW	Pulmonary capillary wedge
PCWP	Pulmonary capillary wedge pressure
PD	Peritoneal dialysis
PDCA	Plan-Do-Check-Act
PE	Peroneal; pulmonary embolism/embolus
PEEP	Positive end-expiratory pressure
PEG	Polyethylene glycol
PEM	Polidocanol endovenous microfoam
PERP	Patient entrance reference point
PET	Positron emission tomography
PFO	Patent foramen ovale
PGA	Polyglycolic acid
PGJ	Percutaneous gastrojejunostomy
PIAA	Physicians Insurers Association of America
PICC	Peripherally inserted central catheter
PIOPED	Prospective Investigation of Pulmonary Embolism Diagnosis
PJ	Percutaneous jejunostomy

PMMA	Polymethylmethacrylate
PMT	Percutaneous mechanical thrombectomy
PO	By mouth
PPH	Postpartum hemorrhage
P-PS	Power-pulse spray
pr	Per rectum
PRBC	Packed red blood cell
PRG	Percutaneous radiologic gastrostomy
PSA	Pseudoaneurysm
PSA	Prostate specific antigen
PSD	Peak skin dose
PSV	Peak systolic velocity
PT	Prothrombin time; posterior tibial
PTA	Percutaneous transluminal (balloon) angioplasty
PTC	Percutaneous transhepatic cholangiography
PTD	Percutaneous thrombolytic device
PTFE	Polytetrafluoroethylene
PTRA	Percutaneous transluminal renal angioplasty
PTS	Postthrombotic syndrome
PTT	Partial thromboplastin time
PTX	Pneumothorax
PV	Percutaneous vertebroplasty; portal vein/venous
PVA	Polyvinyl alcohol
PVC	Premature ventricular contraction
PVE	Portal vein embolization
PVR	Pulmonary vascular resistance; pulse volume recording
PVS	Portal vein stenosis
PVT	Portal vein thrombosis
QA	Quality assurance
qEASL	Quantitative European Association for the Study of the Liver
qid	Four times per day
QISS	Quiescent interval single shot
QOL	Quality of life
RA	Right atrium
RAO	Right anterior oblique
RAPTURE	Radiofrequency Ablation of Pulmonary Tumors Response Evaluation
RAS	Renal artery stenosis
RBBB	Right bundle branch block
RBC	Red blood cell
RCA	Root cause analysis
RCC	Renal cell carcinoma
RCT	Randomized controlled trial
RF	Radiofrequency
RFA	Radiofrequency ablation
RHV	Right hepatic vein
RI	Renal insufficiency; resistive index
RIJ	Right internal jugular
RIM	Rösch inferior mesenteric

RN	Registered nurse
ROBOT	Rotational bidirectional thrombectomy
ROI	Region of interest
ROSE	Rapid on site evaluation
RPO	Right posterior oblique
RR	Respiratory rate
RT	Respiratory therapist
rt-PA	Recombinant tissue plasminogen activator
RV	Right ventricle
RVEDP	Right ventricular enddiastolic pressure
RVR	Renal vein renin
SAH	Subarachnoid hemorrhage
SAP	Superabsorbent polymer
SBP	Systolic blood pressure
SBRT	Stereotactic body radiotherapy
SC	Subcutaneous; subclavian
SEER	Surveillance, Epidemiology, and End Results
SEMS	Self-expanding metallic stents
SEV	Superficial epigastric vein
SFA	Superficial femoral artery
sFLR	Standardized future liver remnant
SI	Sacroiliac
SICH	Symptomatic intracranial hemorrhage
SIN	Salpingitis isthmica nodosa
SIR	Society of Interventional Radiology
SIRS	Systemic inflammatory response syndrome
SK	Streptokinase
SMA	Superior mesenteric artery
SMV	Superior mesenteric vein
SNMMI	Society of Nuclear Medicine and Molecular Imaging
SNR	Signal-to-noise ratio
SNRB	Selective nerve root block
SPACE	Stent-supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy
SPECT	Single-photon emission computed tomography
SPGR	Spoiled gradient echo
SPN	Solitary pulmonary nodules
SQ	Subcutaneous
SSFP	Steady state free precession
SSFSE	Single-shot fast spin echo
SSI	Surgical site infection
SSV	Short saphenous vein
STIR	Short T1 inversion recovery
STS	Sodium tetradecyl sulfate
SUV	Standardized uptake value
SVC	Superior vena cava
SVR	Systemic vascular resistance
SVS	Society of Vascular Surgery
SVT	Superficial venous thrombosis