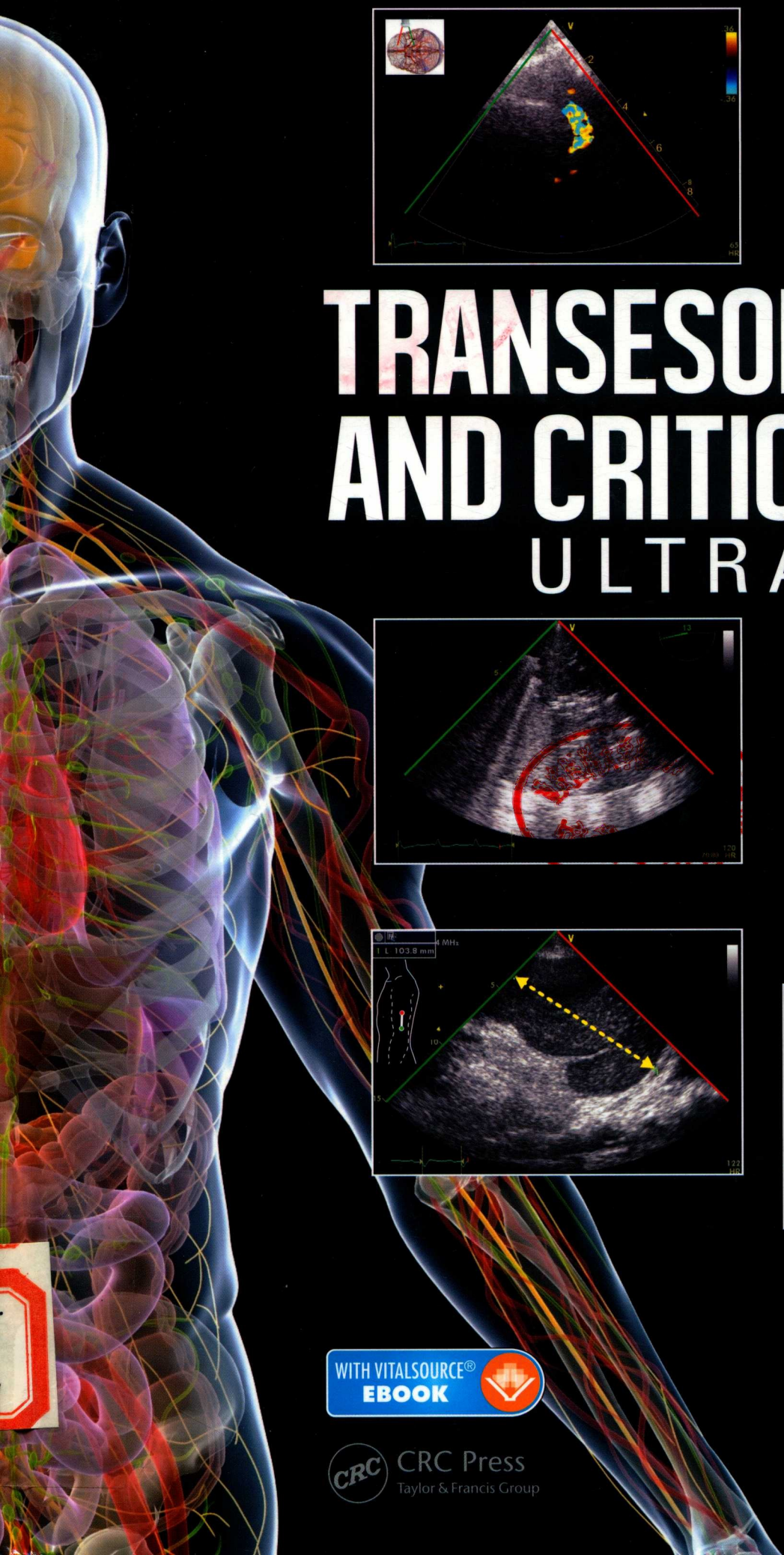

BASIC TRANSESOPHAGEAL AND CRITICAL CARE ULTRASOUND

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BASIC TRANSESOPHAGEAL AND CRITICAL CARE ULTRASOUND

Dedication

This book is dedicated to:

My wife Denise Fréchette and my children Jean-Simon, Gabrielle, and Julien who have supported me with love and patience (André Y Denault)

My parents, Patrick and Lena, and my brother Derek, who have always been supportive (Annette Vegas)

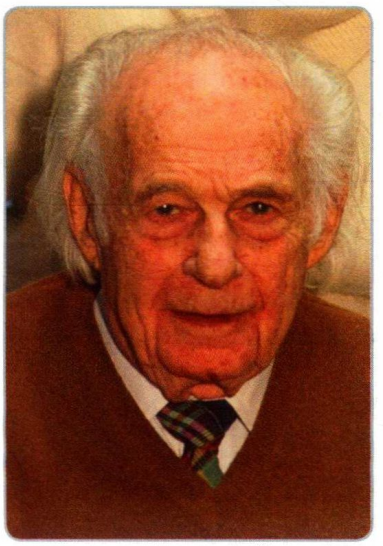
Maude and Julien for their support and inspiration (Yoan Lamarche)

Michèle, Jean-Daniel and Pier-Luc (Jean-Claude Tardif)

Frédéric and Noémie (Pierre Couture)

And above all, our patients for whom we believe that knowledge in the use of bedside ultrasound will improve their care.

The editors would like to thank sincerely Dora and Avrum Morrow and the Richard I Kaufman Endowment Fund in Anesthesia and Critical Care.



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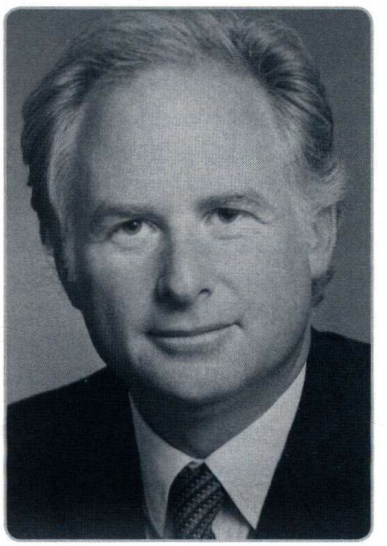

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Foreword

Since I first trained in Critical Care Medicine (CCM) in the mid-1980s at the University of Pittsburgh, where André Denault then followed, the intensive care unit (ICU) has changed dramatically with regards to the acuity, severity and complexity of the patient population. As clinicians at the bedside, the questions we ask are increasingly complex and the answers we seek are more precise. Non-invasive monitoring is more refined and ultrasound (US) technology has become the modern clinician's stethoscope. US monitoring has gone from echocardiography being performed by a cardiologist in the occasional ICU patient two decades ago, to the intensivist obtaining either a focused or comprehensive echocardiogram and performing US examination of the thoracic and abdominal contents, as well as guiding vascular access and monitoring neurological status. Since all the organs of interest to the CCM physician are accessible by US imaging, the scope of practice is rapidly growing in popularity. This is matched only by the challenge we face in mastering the technology, recognizing the limits, interpreting the results and teaching ultrasound to our students, residents, fellows and colleagues.

It is with these objectives in mind that this textbook on US imaging was wonderfully conceived by the team of experts that André has put together. The chapters proceed in more or less the same fashion as US imaging has progressed through the last decades. From basic principles and image acquisition, the reader evolves to transesophageal echocardiography (TEE) and assessing intra-cardiac and extra-cardiac structures and function, as well as all other organs accessible to the TEE platform. The reader then proceeds to transthoracic echocardiography and focused US imaging of the pulmonary and abdominal contents, with a welcome addition regarding brain monitoring. Perioperative and ICU assessments are well dealt with, as are ICU procedures and vascular access in the critically ill patient. Each chapter is rigorously structured and very well referenced with diagrams, intra-operative photographs, illustrations and videos to optimize interactive learning for both the novice, as well as the experienced clinician. Tables and figures abound throughout the text in pragmatic support and as a reminder of concepts, classifications and equations. Last but not least are the chapters dedicated to simulation training and examination, which are of the utmost importance to those involved in structuring US teaching programs and in abiding by society guidelines and recommendations.

Dr Denault and his team are to be complimented for this comprehensive and rigorous effort in mastering US imaging whether in the operating room or the ICU. It is a reflection of where US imaging has come from and where it is going. However, for US imaging to evolve, we must make certain it is well performed, interpreted and leads to appropriate decision making. This book strives to achieve these goals.

Our CCM training program at the University of Montreal believes US imaging is now an obligatory skill to be mastered during fellowship training. Our fellows go through a 3-month structured US training program in order to become proficient in basic US imaging of the heart and other organs through TEE, TTE and focused US examination. This book recreates how our fellows are being trained and as such, is our textbook of reference. Years of clinical observation and correlation with US imaging by clinicians have gone into this book and I am extremely proud of what it has become and what it will achieve.

Jean-Gilles Guimond MD, FRCPC, FCCP
Program Director, Critical Care Medicine
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Preface

In 2005, we published our first Transesophageal Echocardiography Multimedia Manual,[1] which was followed in 2011 by a second edition.[2] These manuals were written to help prepare practising anesthesiologists and trainees in cardiothoracic anesthesia and critical care for the National Board of Echocardiography (NBE) Examination of Special Competence in Advanced Perioperative Transesophageal Echocardiography (TEE). In the second edition, several chapters were dedicated to the role of TEE in non-cardiac surgical applications and in the intensive care unit (ICU). The field of TEE has matured significantly over the last decade. In addition, with the widespread availability of ultrasound, there is a growing interest for the applications of bedside ultrasound in the ICU, non-cardiac operating room, and emergency medicine. Furthermore, training guidelines in basic TEE[3] and in critical care ultrasound were published.[4,5] Certification in both modalities through the NBE and the American College of Chest Physicians (ACCP) have also became available.

The goal of this manual also remains simple: to prepare anesthesiologists, critical care physicians, fellows, and residents for the NBE Basic Perioperative TEE examination and ACCP critical care ultrasonography certification. This book, whose editors and the majority of its authors are from Canadian universities, also covers the Canadian recommendations for critical care ultrasound training and competency.[6] It is the opinion of the editors that all critical care physicians and general anesthesiologists will eventually become trained in both basic TEE and critical care ultrasound. At the Université de Montréal in 2013, the Critical Care Program Director, Dr Jean-Gilles Guimond asked me to initiate comprehensive ultrasound training for all our fellows. This is the manual that we will be using.

The manual is divided in two parts. Part I consisting of Chapters 1 to 12 is dedicated to basic TEE. Part II relates to focused bedside ultrasound and includes Chapters 13 to 19. In Chapter 20, two mock exams inspired by the NBE Basic TEE and the ACCP exam are presented, and additional materials are available from the CRC website: http://www.crcpress.com/product/isbn/9781482237122 In Part I, we introduce for the first time a chapter on extra-cardiac TEE. In addition, in Part II, there is a chapter on ultrasound of the brain. These unconventional areas will become more important in the future as clinicians evaluate not only the etiology of hemodynamic instability, but also the impact on multiple organs such as the kidney, liver, splanchnic perfusion, and brain. This manual is unique because the editors and authors represent several different fields of clinical practice in anesthesia, internal medicine, emergency medicine, and surgery. General anesthesiologists, cardiothoracic anesthesiologists and neuro-anesthesiologists have shared their unique expertise alongside critical care physicians, cardiologists, gastroenterologists, neurologists, emergency medicine specialists, abdominal and thoracic radiologists, and cardiac and thoracic surgeons. I sincerely thank all the authors who have taken the time to contribute to this work.

Such a manual would not have been possible without the support of my four editors. I am very grateful for their contributions. Dr Annette Vegas is a cardiothoracic anesthesiologist with a critical care appointment at the Toronto General Hospital. Annette has been an editor since 2009 and has continuously raised the quality and pertinence of our educational material. She has already published several books in TEE that are carried by ultrasound trainees worldwide. She has contributed to an outstanding free educational website in ultrasound translated into several languages (http://pie.med.utoronto.ca). Her dedication to this manual has been unsurpassed and is remarkable, as it was for the second edition of the TEE manual. Dr Yoan Lamarche is a cardiac surgeon, additionally certified in critical care medicine and TEE, working at both the Montreal Heart Institute (MHI) and Hôpital du Sacré-Coeur. He is the director of the MHI Cardiac Surgical ICU. Yoan's natural leadership, educational skills, common sense, and surgical experience gave this manual clarity and a unique perspective. Dr Jean-Claude Tardif is a cardiologist and the director of the MHI Research Center. Since the perioperative anesthesia TEE program started in 1999 at the MHI, Jean-Claude has strongly supported the Anesthesiology Department in TEE development and expertise. Dr Tardif has played an important role participating in developing our manuals and has also made available the MHI research environment in order to improve the care of our patients in the operating room and the ICU. I met Dr Pierre Couture in 1993 when he returned from Paris after completing his cardiac anesthesia fellowship. We shared a common passion for ultrasound applications and have been working and publishing together ever since. Pierre was our former Chief of Cardiac Anesthesia at the MHI. He has been helping me in all aspects of the manual, completely rewriting some chapters in order to offer the best to our students and readers. His generosity, kindness, amazing TEE knowledge, and teaching skills are well appreciated in our institution.

Several individuals have played a significant role in the creation of this manual. Mr Denis Babin is the webmaster of the Department of Anesthesiology of the Université de Montréal and my research assistant since 1998. I am fortunate to have such an amazing assistant. His diverse talents in computer science, graphic design, database management, and communication provide the key elements that have made all our manuals so appealing. There is not a single figure or video that Denis has not

touched, improved or converted … I often say, "Denis, would you mind 'babinising' this?" Special thanks for the support and advice of my current Chief of Cardiac Anesthesia at the MHI must go to Dr Alain Deschamps. I also thank all my colleagues, anesthesiologists, critical care physicians, cardiac surgeons, and cardiologists at the MHI who have supported and alerted me to interesting cases. Likewise, I thank my critical care colleagues in the ICU of the Centre Hospitalier de l'Université de Montréal.

This work would not have been possible without financial support. I would like to thank especially Dora and Avrum Morrow. Meeting Mr Avrum Morrow in Old Montreal and seeing the Avmor Collection was an unforgettable moment in my life. In 2014, I had the privilege of being chosen for the Richard I Kaufman Endowment Fund in Anesthesia and Critical Care. This support will allow us to continue our educational and research activities for the coming years. My gratitude to the Kaufman family is beyond words. All this support has been completely dependent on the MHI Foundation and its director Mélanie LaCouture. The MHI Foundation has been supporting me every year since 1999 and played a key role in contacting those who are supporting this manual and our future development. Special thanks to Josée Darche from the MHI Foundation. In addition, my appreciation goes to MHI director Dr Denis Roy and to Dr Annie Dore who is responsible for all MHI educational activities, as both have also believed in our initiatives. I am also indebted to the Fondation de l'Association des Anesthésiologistes du Québec and president Dr Gilles Plourde and Mr Joseph Bestravos from Sonosite/Fuji for their generous support. Credit must also be given to Mr Fainman for his generous donation that allowed us to buy the first X-Porte ultrasound system from Sonosite/Fuji in Canada. Several figures in this book came from this equipment.

Dr Robert Amyot, staff cardiologist at the Hôpital du Sacré-Coeur has been an author in our two previous TEE manuals. In 2014 Robert became the president of CAE Healthcare. We acknowledge his support in allowing us to enhance many figures in this manual by extensively using the Vimedix simulator (CAE, Healthcare Canada) to obtain anatomic illustrations and videos. In addition, physicians in Canada have free institutional access to Anatomy.tv powered by Primal Picture (info@primalpictures.com) through Wolters Kluwer Health. This educational site allows clinicians to learn and teach anatomy from a 3D atlas. We are so grateful to both of these companies for allowing us to use their interface throughout the manual.

Finally, many colleagues, residents, and fellows at the MHI have graciously reviewed chapters of this manual, making suggestions and pointing out corrections. I would like to thank all of them which are listed just below.

I hope that you will enjoy reading the 1st Edition of the Basic Transesophageal and Critical Care Ultrasound textbook.

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REFERENCES

1. Denault AY, Couture P, Tardif JC, Buithieu J. *Transesophageal Echocardiography Multimedia Manual: A Perioperative Transdisciplinary Approach*. New York: Marcel Dekker, 2005.
2. Denault AY, Couture P, Vegas A, Buithieu J, Tardif JC. *Transesophageal Echocardiography Multimedia Manual, Second Edition: A Perioperative Transdisciplinary Approach*. New York: Informa Healthcare, 2011.
3. Reeves ST, Finley AC, Skubas NJ, Swaminathan M, Whitley WS, Glas KE, Hahn RT, Shanewise JS, Adams MS, Shernan SK. Basic perioperative transesophageal echocardiography examination: a consensus statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr* 2013; **26**: 443–56.
4. Mayo PH, Beaulieu Y, Doelken P, Feller-Kopman D, Harrod C, Kaplan A, *et al.* American College of Chest Physicians/La Société de Réanimation de Langue Française statement on competence in critical care ultrasonography. *Chest* 2009; **135**: 1050–60.
5. Via G, Hussain A, Wells M, Reardon R, Elbarbary M, Noble VE, *et al.* International evidence-based recommendations for focused cardiac ultrasound. *J Am Soc Echocardiogr* 2014; **27**: 683.
6. Arntfield R, Millington S, Ainsworth C, Arora R, Boyd J, Finlayson G, *et al.* Canadian recommendations for critical care ultrasound training and competency. *Can Respir J* 2014; **21**: 341–45.

Abbreviations

2C	two-chamber
2D	two-dimensional
4C	four-chamber
5C	five-chamber
A	amplitude
A	peak late diastolic TMF or TTF velocity
A	atrial contraction
a′	peak late diastolic mitral or tricuspid annular velocity
A dur	duration of TMF A-wave
A4C	apical four-chamber
AA	apical anterior
AA	axillary artery
AAA	abdominal aortic aneurysm
AAL	anterior axillary line
AC	attenuation coefficient
ACA	anterior cerebral artery
ACC	American College of Cardiology
ACCP	American College of Chest Physicians
ACES	Abdominal Cardiac Evaluation with Sonography in Shock
ACGME	Accreditation Council for Graduate Medical Education
ACLS	advanced cardiac life support
ACoA	anterior communicating artery
Adr	adrenal
Adre	adrenaline
AHA	American Heart Association
AIN	apical inferior
AJV	anterior jugular vein
AL	apical lateral / anterolateral
AL	area-length method
Am	peak late diastolic MAV
AMVL	anterior mitral valve leaflet
Ant	anterior
Ao	aorta
AoV	aortic valve
AP	anterior–posterior
AR	atrial reversal
AR	aortic regurgitation
AR dur	atrial reversal pulmonary venous flow velocity duration
ARDS	acute respiratory distress syndrome
AS	apical septal / anteroseptal
ASA	American Society of Anesthesiologists
aSAH	aneurysmal subarachnoid hemorrhage
Asc Ao	ascending aorta
ASD	atrial septal defect
ASE	American Society of Echocardiography
Asr	late diastolic strain rate
At	peak late diastolic tricuspid annular velocity
AV	axillary vein / aortic valve
AVA	aortic valve area
AVC	aortic valve closure
AVM	arteriovenous malformation
AW	anterior window
BA	basal anterior
BA	basilar artery
BAL	basal anterolateral
BART	Blue Away Red Towards (common color map)
BAS	basal anteroseptal
BHI	breath holding index
BIN	basal inferior
BIL	basal inferolateral
BIS	basal inferoseptal
BSA	body surface area
C	carotid segments
C	propagation speed

CA	carotid artery
CAD	coronary artery disease
CAE	Canadian Aviation Electronics
CAS	carotid angioplasty and stenting
CBF	cerebral blood flow
CBFV	cerebral blood flow velocity
CCA	cerebral circulatory arrest
CCCS	Canadian Critical Care Society
CCE	critical care echocardiography
CCS	Canadian Cardiovascular Society
CCTA	coronary computed tomography angiography
CEA	carotid endarterectomy
CFD	color flow Doppler
CFS	cerebrospinal fluid
CHD	congenital heart disease
cm	centimeter
CME	continuing medical education
CMR	cardiovascular magnetic resonance
CO	cardiac output
CO_2	carbon dioxide
CPB	cardiopulmonary bypass
CPP	cerebral perfusion pressure
CPR	cardiopulmonary resuscitation
CS	coronary sinus
CSA	cross-sectional area
CSE	Canadian Society of Echocardiography
CT	celiac trunk
CT	computed tomography
CTA	computed tomography angiogram
CTP	computed tomography perfusion
CVC	central venous catheters
CVP	central venous pressure
CW	continuous wave
CWD	continuous wave Doppler
CXR	chest radiography
d	diameter
D	diastolic PVF or HVF velocity
D	diastolic
D1	first diagonal
D2	second diagonal
DAP	diastolic arterial pressure
db	decibel
DBP	diastolic blood pressure
DCI	delayed cerebral ischemia
DE-CMR	delayed enhanced cardiovascular magnetic resonance
Des Ao	descending aorta
DF	duty factor
DT	deceleration time
DVT	deep venous thrombosis
E	early diastolic TMF or TTF velocity
E	early filling
e'	peak early diastolic mitral or tricuspid annual velocity
ECA	external carotid artery
ECG	electrocardiogram or electrocardiographic
ECMO	extracorporeal membrane oxygenation
EDA	end-diastolic area
EDV	end-diastolic velocity
EF	ejection fraction
eFAST	extended FAST
EI	eccentricity index
EIV	external iliac vein
Em	early diastolic MAV
ER	emergency room
ERO	effective regurgitant orifice
ESA	end-systolic area

ESLD	end-stage liver disease
Esr	early diastolic strain rate
ET	ejection time
Et	peak early diastolic tricuspid annular velocity
$ETCO_2$	end-tidal carbon dioxide
ETT	endotracheal tube
EUS	endoscopic ultrasound scanning
EV	eustachian valve
EVAR	endovascular repair of aortic aneurysm
f	frequency (Hz)
FA	femoral artery
FAC	fractional area change
FAST	Focused Assessment with Sonography in Trauma
Fd	Doppler frequency shift
FL	false lumen
FO	foramen ovale or fossa ovalis
FP	foramen primum
FS	foramen secundum
FV	femoral vein
FVd	end-diastolic flow velocity
FVm	mean flow velocity
FVR	flow velocity ratio
FVs	systolic flow velocity
FW	frontal window
g	gram
GCCUS	General Critical Care Ultrasound
GE	gastroesophageal
GI	gastrointestinal
GLS	global longitudinal strain
H	horizontal
HAF	hepatic artery flow
HAV	hemiazygos vein
HCM	hypertrophic cardiomyopathy
HITS	hyperintensity thromboembolic signal
HR	heart rate
HU	Hounsfield unit
HV	hepatic vein
HVF	hepatic venous flow
HVLT	half value layer thickness
IN	inferior
IAS	interatrial septum
IA	innominate artery
IABP	intra-aortic balloon pump
ICA	internal carotid artery
ICCU	Imaging Curriculum in Critical Care Ultrasound
ICM	intercostal muscle
ICP	intracranial pressure
ICU	intensive care unit
IJV	internal jugular vein
IL	inferolateral
IMA	internal mammary arteries
IN	inferior
In-Out	inflow-outflow
IOA	lindex of autoregulation
IRC	intensity reflection coefficient
IS	inferoseptal
IVC	inferior vena cava
IVCT	isovolumic contraction time
IVRT	isovolumic relaxation time
IVS	interventricular septum
IVUS	intravascular ultrasound
J	joules
L	lateral
LA	left atrium
LAA	left atrial appendage
LACA	left anterior cerebral artery
LAD	left anterior descending
LAFB	left atrio-femoral bypass
LAP	left atrial pressure
LAX	long-axis
LCC	left coronary cusp
LCCA	left common carotid artery

LCX	left circumflex artery
LGC	lateral gain control
LGE	late-gadolinium-enhancement
LH	left heart
LHV	left hepatic vein
LIJV	left internal jugular vein
LK	left kidney
LLL	left lower lobe
LM	left main
LMCA	left middle cerebral artery
LPV	left portal vein
LSCA	left subclavian artery
LSVC	left-sided superior vena cava
LT	liver transplantation
LTICA	left terminal internal carotid artery
L-to-R	left-to-right
LUL	left upper lobe
LUPV	left upper pulmonary vein
LV	left ventricle or left ventricular
LVD	left ventricular minor-axis diameter
LVEDA	left ventricle end-diastolic area
LVEDD	left ventricle end-diastolic diameter
LVEDP	left ventricular end-diastolic pressure
LVEDV	left ventricle end-diastolic volume
LVEF	left ventricular ejection fraction
LVESA	left ventricular end-systolic area
LVESP	left ventricular end systolic pressure
LVIDd	left ventricular internal diameter at end-diastole
LVOT	left ventricular outflow tract
LVOTO	left ventricular outflow tract obstruction
m	meter
MA	mid-anterior
MAL	mid-anterolateral
MAS	mid-anteroseptal
MAV	mitral annular velocity
Max	maximal
MCA	middle cerebral artery
ME	mid-esophageal
MFV	mean flow velocity
MHV	middle hepatic vein
MI	mechanical index
Mid	middle
MIL	mid-inferolateral
MIN	mid-inferior
MIS	mid-inferoseptal
MLS	midline shift
mm	millimeter
mmHg	millimeter of mercury
M-mode	motion mode
Mn	mean
MOC	maintenance of competence
MOD	method of disk
MPA	main pulmonary artery
MPI	myocardial performance index
MR	mitral regurgitation
MRI	magnetic resonance imaging
ms	millisecond
MS	mitral stenosis
MV	mitral valve
MVA	mitral valve area
MVO	mitral valve opening
MW	middle window
NBE	National Board of Echocardiography
NCC	non-coronary cusp
NL	nipple line
Norad	noradrenaline
NS	not specified
OA	ophthalmic artery
ONSD	optic nerve sheath diameter
OR	operating room
P	power
P	pressure

P1	posterior leaflet
PA	pulmonary artery
PAC	pulmonary artery catheter
$PaCO_2$	arterial carbon dioxide tension
PAEDP	pulmonary artery end-diastolic pressure
PAL	posterior axillary line
Pan	pancreas
PaO_2	arterial oxygen tension
Par	systolic radial blood pressure
PASP	pulmonary artery systolic pressure
PC	pericardial cyst
PCA	posterior cerebral artery
PCoA	posterior communicating artery
PCWP	pulmonary capillary wedge pressure
PD	pulse duration
PE	pericardial effusion
PE	pulmonary embolism
PEA	pulseless electrical activity
PecM	pectoralis muscle
PEEP	positive end-expiratory pressure
PFO	patent foramen ovale
PG	pressure gradient
PHT	pressure half-time
PI	pulsatility index
PICC	peripherally inserted central catheter
PISA	proximal isovelocity surface area
PM	papillary muscle
PMD	power mode Doppler
Pms	mean systemic venous pressure
PMV	prosthetic mitral valve
POCUS	point-of-care ultrasound
Post	posterior
PoVF	portal venous flow
Ppa	pulmonary artery pressure
Ppl	pleural pressure
PR	pulmonary regurgitation
Pra	right atrial pressure
PREDV	pulmonary regurgitation end-diastolic velocity
PRF	pulse repetition frequency
PRI	pulmonary regurgitation index
PRP	pulse repetition period
P_{RV}	right ventricular pressure
PSL	parasternal line
PT	pulmonary trunk
PTE	Perioperative Transesophageal Echocardiography
PV	pulmonic valve
PV	pressure–volume
PVAC	pulmonic valve anterior cusp
PVF	pulmonary venous flow
PVLC	pulmonic valve left cusp
PVR	pulmonary vascular resistance
PW	pulsed-wave
PWD	pulsed-wave Doppler
PWT	posterior wall thickness
PWTd	posterior wall thickness diameter
Py	pylorus
Qp	pulmonary flow
Qs	systemic flow
R	radius
RA	right atrium or right atrial
RAA	right atrial appendage
RACA	right anterior cerebral artery
RAP	right atrial pressure
RCA	right carotid artery
RCA	right coronary artery
RCC	right coronary cusp
RH	right heart
RHV	right hepatic vein
RI	resistance index
RIJV	right internal jugular vein
RLPV	right lower pulmonary vein

RMCA	right middle cerebral artery
RML	right middle lobe
ROSC	return of spontaneous circulation
RPA	right pulmonary artery
RPV	right portal vein
R-to-L	right-to-left
RUL	right upper lobe
RUPV	right upper pulmonary vein
RUSH	Rapid Ultrasound for Shock and Hypotension
RV	right ventricle or right ventricular
RVD	right ventricular diameter
RVEF	right ventricular ejection fraction
RVOT	right ventricular outflow tract
RVOTO	right ventricular outflow tract obstruction
Rvr	resistance to venous return
RVSP	right ventricular systolic pressure
RWMA	regional wall motion abnormalities
RWT	relative wall thickness
S	septal
S	systolic
S	systolic pulmonic or hepatic venous flow velocity
s'	systolic tricuspid annular velocity
S wave	inflow during systole
SAM	systolic anterior motion
SaO_2	oxygen saturation
SAP	systolic arterial pressure
SAX	short-axis
SBP	systolic blood pressure
SC	subcostal
SCA	Society of Cardiovascular Anesthesiologists
SCA	subclavian artery
SCA	Society of Cardiovascular Anesthesiologists
SCD	sickle cell disease
ScO_2	brain saturation
SCT	subcutaneous tissue
SCV	subclavian vein

SD	standard deviation
sec	second
SEC	spontaneous echo contrast
SIRS	systemic inflammatory response syndrome
SL	strain longitudinal
SMA	superior mesenteric artery
SP	septum primum
SPECT	single photon emission computer tomography
SPL	spatial pulse length
SPTA	spatial peak temporal average
SR	strain rate
SS	septum secundum
Ssr	peak systolic strain rate
STJ	sinotubular junction
SV	stroke volume
SVC	superior vena cava
SVF	splenic venous flow
SWT	septal wall thickness
SWTd	septal wall thickness in diastole
SX	sub xyphoid
T	period
TAAA	thoraco-abdominal aortic aneurysm
TAMV	time-averaged mean velocity
TAPSE	tricuspid annular plane systolic excursion
TAV	tricuspid annular velocity
TCCS	transcranial color-coded duplex sonography
TCD	transcranial Doppler
TD	thermodilution
TDI	tissue Doppler imaging
TEE	transesophageal echocardiography
TEVAR	thoracic endovascular aortic repair
TG	transgastric
TGC	time gain compensation
Th	wall thickness
TICA	terminal internal carotid artery
TL	true lumen

TMF	transmitral flow
TPR	total peripheral resistance
TR	tricuspid regurgitation
TS	tricuspid stenosis
TTE	transthoracic echocardiography
TTF	transtricuspid flow
TV	tricuspid valve
TVA	tricuspid valve area
TVAL	tricuspid valve anterior leaflet
TVPL	tricuspid valve posterior leaflet
UE	upper esophageal
US	ultrasound
V	vertical
VA	vertebral arteries
Vaso	vasopressin
VC	vena contracta
Vel	velocity

VIRTUAL	Visual Interactive Resource for Teaching, Understanding and Learning
Vmax	maximum jet velocity
Vmv	mitral valve regurgitant velocity
Vp	flow propagation velocity
Vpeak	peak velocity
VR	venous return
VSD	ventricular septal defect
$Vt_{1/2}$	velocity at the pressure half-time point
VTI	velocity time integral
V_{TR}	peak tricuspid regurgitant velocity
W	watts
WMA	wall motion abnormalities
WMSI	regional wall motion score index
Z	impedance
σ	stress
λ	wavelength