Virtual Endoscopy and 3D Reconstruction in the Airways

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Springer

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ISBN 978-3-030-23252-8 ISBN 978-3-030-23253-5 (eBook)
https://doi.org/10.1007/978-3-030-23253-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

New technologies in airway management never cease to amaze me, and it is especially wonderful to be existed in a period when rapid medical advances are changing the clinical practice landscape with reassuring certainty and frequency—having seen the world around me slowly transition from 2D to 3D imaging and even 4D in certain cases! It was only a matter of time before clinicians would find themselves needing 3D imaging on a regular basis.

In less than 10 years, virtual endoscopy and 3D reconstruction have spread all around the world, and the diffusion of this technique may be traced through the increasing number of published papers in the literature. I have personally kept in touch with the major advances in the field and have used virtual endoscopy for many of my patients. Having been in the field of airway management for 20 years, I can confidently attest to its robustness and efficacy in managing hitherto impossible to intubate patients.

From my experience and those of my colleagues, we have gathered a lot of knowledge and wisdom on the subject, and I am delighted to present the first edition of our book *Virtual Endoscopy and 3D Reconstruction in the Airways.*

While this book is mainly intended for anesthesia trainees and consultants, we believe it would be well suited for intensive care physicians, emergency physicians, radiologists, ORL-HNS surgeons, maxillofacial surgeons , pulmonologists, paramedical staff, and medical students.

The content includes a brief review of the fundamental airway anatomy and moves onto radiologic and virtual 3D evaluation of normal and diseased airways. The discussion also deals with the use of this technology in oral, nasal, maxillofacial, and skull base surgeries. We also discuss about 3D virtual endoscopy in ICU settings, augmented reality visualization in pulmonary

interventions, and implications of 3D printing on airway management. There is a section on challenging cases derived from real patient experiences in our hospital. The book ends with future perspectives and recommendations.

While we did our best to prevent any misinformation of any form, we would urge our readers to inform us of any such error, including spelling or contextual errors. We also would advise that this book certainly does not replace professional or expert guidance and consultation.

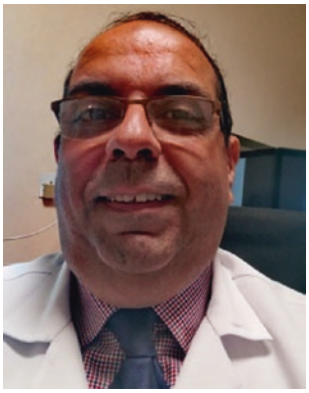
I am much thankful to my wife, sons, and daughter for their continuous help in all stages of this book.

I would also like to thank Dr. Hanan Mawlana for her constant support while editing this unique book and to all the participating authors for their contribution.

Thank you and enjoy your book!

Doha, Qatar Nabil A. Shallik

Preface



Ever since the dawn of time, mankind has brought forth innumerable innovations, and the medical field is a prime example. As a radiologist, I firmly believe that an image is worth a thousand words, as the saying goes, and this could not be more true with the advent of 3D reconstructions, volume rendering techniques, and virtual endoscopy (VE). In today's world, it is difficult to imagine living without technology. Some of the newest innovations today were either in the realm of fiction years ago or were just a seed in someone's mind, ready to evolve into something far greater.

Computer-aided diagnosis (CAD), coupled with VE, can inevitably aid in providing better healthcare.

3D printing can be done for difficult and complicated cases, as surgeons will have a physical model of the pathology to have a clear approach to proceed with the surgery, and can be a great tool to use when teaching junior colleagues.

Many people consider 3D imaging and VE as difficult tasks; however, when well practiced, it is considered a great asset with limitless clinical value.

In some respects, the workstation of a radiologist is their own high-end video games console, just like Sony's PlayStation 4 capable of rendering millions of high-fidelity imaging metadata, as well as providing aesthetically pleasing and clear information.

I am inviting all our colleagues to practice the 3D imaging and VRT techniques which are considered fun with great clinical impact and value; please enjoy.

Doha, Qatar — Abbas H. Moustafa

Preface

Within a fast-changing world like ours, very detailed descriptions are often important. To get autonomous cars running perfectly, you need detailed maps and instructions to navigate the cars through a jungle of obstacles.

So too, the future of surgery lies with automatization; through automatization, we seek to get a safe and stable product free of human error. Automatization provides potential to extract consistent and standardized information from patients, such as genetic profiles for pharmacokinetic modelling and dexterous robots as surgeons and anesthesiologists to be handled by experts of course! However, for automatization in anesthesiology, absolute accuracy and meticulous detail of anatomy are needed, which would have to be even more precise than the detailed maps we need to drive autonomous cars. To make robots that intubate patients, we first need even more precise understanding and detail of the anatomy of the airway. This book can bring us to that future of automatization!

Let us start first by minimizing dangerous situations, such as "cannot intubate/cannot ventilate," which can be accomplished through better training programs, better tools, and better understanding of the airway.

Different angles from different specialists give us better understanding about the airway. A book about the anatomy of the airway is therefore essential.

Hopefully, all will read this book with pleasure. I congratulate every author for the effort they put in and the other editors especially Dr. Nabil for their patience and endurance.

Happy reading.

Doha, Qatar — Marco A. E. Marcus

Acknowledgments

The preparation of the *Virtual Endoscopy and 3D Reconstruction in the Airways* book has required the help and cooperation of many. To each individual, we acknowledge our debt of gratitude. It has been both an honor and a privilege to have worked with all of the authors who are expert anesthesiologists, radiologists, surgeons, and technologists from across the world.

First and foremost, we would like to extend our gratitude to Mr. Samir R. Khiste, a radiology technologist who did a great job in 3-D reconstruction of our clinical cases. Also, we would like to thank Dr. Serag Kamel for editing the diagrams and photos for normal anatomy chapter and to Dr. Abderrazak Sahraoui for his talent in photography of our 3-D printed projects.

The staff at Springer have contributed in countless ways, with competence, patience, and hard work, particularly Ms. Reshmi Rema and Mr. Andrea Ridolfi who kept us on task and played a pivotal role in the quality of the final written text.

We especially wish to express our deep appreciation to the Anesthesia, ICU, and Perioperative Medicine Department and Clinical Radiology & Medical Imaging Department, both at Hamad Medical Corporation, Doha, Qatar; without their relationships, we would not have become the editors of this book.

Lastly, we would like to thank from the bottom of our hearts our God for helping us make this work feasible and our families whose understanding, forbearance, and support made this book possible.

Contents

Abbreviations

2-D	Two-dimensional
2-D MPR	Two-dimensional multi-planar reconstructions
3-D	Three-dimensional
4-D	Four-dimensional
A & E	Accident and emergency
ABS	Acrylonitrile butadiene styrene
AD	Arytenoid dislocation
AP	Anteroposterior
AR	Augmented reality
AS	Aortic stenosis
AS	Arytenoid subluxation
ASA	American Society of Anesthesiologists
ATLS	Advanced trauma life support
BI	Bronchus intermedius
BMI	Body mass index
BPF	Bronchopleural fistula
C-MPR	Curved multi-planar reconstruction protocol
CAD	Computer-aided design
CAS	Computer-assisted surgery
CFD	Computational fluid dynamics
CMF	Cranio-maxillofacial surgery
CN	Cranial nerve
CoCr	Cobalt chromium
CPAP	Continuous positive airway pressure
CSF	Cerebrospinal fluid
CT	Computed tomography
CTM	Cricothyroid membrane
CV	Cervical vertebrae
DED	Directed energy deposition
DICOM	Digital imaging and communications in medicine
DISH	Diffuse idiopathic skeletal hyperostosis
DLP	Direct light processing
DO	Distraction osteogenesis
DOD	Drop on demand
EBM	Electron beam melting
FBA	Foreign body aspiration
FDM	Fused deposition material

FESS	Functional endoscopic sinus surgery
FOB	Fiber-optic bronchoscopy
FT	Flexible tracheobronchoscopy
GE	General electric
HU	Hounsfield units
IGS	Image-guided surgery
IIG	Inter-incisor gap
IJV	Internal jugular vein
IV	Intravenous
IVS	Interactive virtual simulation
LMA	Laryngeal mask airway
MDCT	Multi-detector computed tomography
MDCT (VB)	Multi-detector computed tomography virtual bronchoscopy
MinIPs	Minimum intensity projections
MIP	Maximum intensity projection
MPR	Multi-planar reformations
MPR	Multi-planar reconstruction
MPRs	Multi-planar reformations
MRI	Magnetic resonance imaging
NAP4	The Fourth National Audit Project
NiTi	Nickle titanium
OAP	Obstructing airway pathology
OPG	Orthopantomogram
OR	Operating room
OSA	Obstructive sleep apnea
PACS	Patient archive and communication system
PBF	Powder bed fusion
PEEK	Polyether ether ketone
PET/CT	Positron emission tomography-computed tomography
PFR	PaO_2-to-FiO_2 ratios
PLA	Polylactic acid
SARI	Simplified airway risk index
SGD	Supraglottic device
SHS	Selective heat sintering
SII	Smoke inhalation injury
SLA	Stereolithography apparatus
SLS	Selective laser sintering
SSD	Shaded surface display
STL	Standard tessellation language
T-B	Tracheal-bronchial
TBI	Tracheobronchial injury
TEF	Tracheoesophageal fistula
TM	Tympanic membrane
TMD	Thyro-mental distance
TMJ	Temporomandibular joint
TMJA	Temporomandibular joint ankylosis
TMVR	Transcatheter mitral valve repair
TEF/TOF	Tracheo-osophageal Fistula

TPN	Total parenteral nutrition
TTP	Tissue transparent projection/Tissue transition projection
US	Ultrasound
UV	Ultraviolet
VB	Virtual bronchoscopy
VE	Virtual endoscopy
VPI	Velopharyngeal insufficiency
VR	Virtual reality
VRT	Volume rendering techniques
VSP	Virtual surgical planning
WHO	World Health Organization

List of Videos

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