PRINCIPLES AND PRACTICE OF AVIATION MEDICINE

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Prologue

Aviation is at the heart of world development. Man, with all his physical and mental shortcomings, is at the heart of aviation. But just as modern life is inconceivable without aviation, aviation cannot exist without its weakest link, the human being. The aviation environment, however, is hostile to humans. Soon after the first balloon flights more than 200 years ago, it became clear that man was unable to function and survive at altitude without special protection and support. With the advent of powered flight more than 100 years ago, the need for physiological and medical support became obvious. Doctors supporting the military flight operations of World War I realized that selection criteria had to be developed to reduce the high number of losses of both aircraft and pilots. Following the Peace Conference in Paris in 1919, the first international medical requirements for licensing of aviators were agreed upon, and over the ensuing years these international standards have been further developed. Since then powered flight has evolved considerably and so has the specialty of aviation medicine. The medical standards for licensing of pilots, i.e. the medical requirements an applicant must meet to be accepted for initial training and which all trained and licensed pilots must meet at their regulatory renewal examinations, have always been restrictive and conservative. This is an obvious necessity. The purpose of the requirements is to maintain and secure the high level of safety that characterizes modern aviation — a goal that leaves little

room for experimenting with or relaxing the requirements. However, many medical conditions that were considered permanently disqualifying in the past are now allowed as a result of continuous improvement in our understanding of the physiology of flight, the evolution of evidence-based medicine, and the vast technical advances of recent years in diagnosis and treatment.

All medical standards have three different aspects that always must be considered together. The first is the requirement *per se*, e.g., epilepsy entails unfitness for all classes of medical certification, or blood pressure shall be within normal limits. The second aspect is the method or methods traditionally employed or sometimes prescribed by the Licensing Authority for carrying out the examination. The third aspect is the definitions applied to the requirements. For example, how is epilepsy defined or what are the normal limits for arterial tension? Although most countries have accepted the international standards and recommended practices developed and continually updated by the International Civil Aviation Organization (ICAO), there are still significant differences from one country to another pertaining to the methods of examination. Examining the visual fields of a pilot by confrontational testing with finger movements compared to examining by automated, computerized perimetry provides results on very different levels of reliability. The use of different methods of examination vary from country to country is hardly a surprise; different countries have different cultures, different socio-economical conditions, different prevalences of many diseases, different medical traditions, and different attitudes to the relevance of safety precautions.

Modern civil aviation, however, is international. A modern airliner has the same needs and demands for ground support wherever it happens to be in the world. Almost 200 countries are currently connected with each other by regular commercial flights and none can afford to reject the international community and refuse to provide the infrastructure necessary to ensure the safety of aviation. All signatories to the Convention on International Civil Aviation ("Chicago Convention") of 1944, currently totaling 191 countries, have undertaken to collaborate in securing the highest practicable degree of uniformity in relation to aircraft, aviation personnel, licensing

procedures, etc., including medical certification of pilots and air traffic controllers. Even so, there are still significant differences regarding national approaches to aeromedical certification. To some extent, these differences are related to the influence that military aviation medicine has had upon civil aviation medicine. Also relevant is the comparative level of development that aviation medicine (as a medical specialty) has reached in different countries. While in some countries aviation medicine was a highly-developed medical specialty even before World War II, in other countries aviation medicine is only beginning to establish itself as a recognized specialty.

Most countries have agreed on the need to implement medical requirements for aviation personnel and have adopted the ICAO International Medical Standards and Recommended Practices or developed their own medical standards in accordance with the ICAO provisions. The next step towards uniformity in medical certification must be to help medical examiners and medical assessors worldwide adopt similar methods of examination and similar definitions of diseases and disorders. In particular, agreement on definitions and similar interpretation of the signs and symptoms of diseases and disorders are required if global harmonization in aeromedical certification is to be achieved.

This book contains detailed, experience-based, practical knowledge written to assist aviation medical examiners (AMEs) and other clinicians, as well as medical assessors of the Licensing Authorities, in the often confusing world of medical treatment and aeromedical evaluation of safety-critical aviation personnel such as pilots, cabin crew members, and air traffic controllers. In addition, it provides medical guidelines for physicians who have patients with medical conditions who wish to travel by air. This book is written by AMEs and clinicians from a wide range of medical specialties that are important to the field of aviation medicine. It initially began as a reference book for German physicians who may or may not be AMEs, yet who are involved in the health care of pilots. It has expanded to this current English version to address an international audience in order to provide guidance and advice to colleagues in the practice of clinical aviation medicine. Considering the European background of the authors,

this book represents European points of view and international or European criteria regarding the determination of fitness for duty among civil aviation personnel. It is, nonetheless, an excellent and detailed international guide for medical practitioners in all parts of the world who deal with aircrew members and airline passengers.

Aviation medicine is a scientific discipline that involves the study of the physiological, psychological, operational, and environmental factors that determine the adaptive responses of a human being during flight. With regard to flight crews, the focus is different from that of the "conventional" clinical specialties which primarily deal with abnormal physiology within a normal environment, as it is concerned with normal physiology within an abnormal environment. With regard to passengers, however, conventional and aviation medicine intersect because at times abnormal physiology may be placed within an abnormal environment. This is also the case when it comes to determining exactly to what degree, i.e., with what limitations or restrictions or under what conditions, a pilot with a medical disorder may be able to perform his duties without endangering flight safety. It is to this highly specialized field of clinical aviation medicine that most chapters of the book are dedicated.

Flying represents a hostile environment that imposes a variety of physical, physiological, and psychological demands on human beings who are not genetically adapted to function in such an environment. Promoting the health and well being of aviation personnel worldwide is essential for the safety of all flight operations in civil aviation. It is also very important to recognize the potential consequences that the flight environment can have on those individuals who have pre-existing medical conditions and wish to travel by air or are required to be transported or medically evacuated by aircraft. Therefore, medical practitioners must possess basic knowledge of aviation physiology and medicine in order to make appropriate decisions concerning medical certification of pilots and other flight personnel. Such knowledge is also essential in making the correct decisions concerning the safe medical transport of diseased passengers aboard commercial aircraft or the medical transport (elective or emergency) of patients by air ambulance.

Most university programs that train medical professionals do not include instruction in the basic principles of aviation physiology or medicine. Some countries offer basic and advanced post-graduate training in aviation medicine, but very few offer formal residency programs (specialty) in aviation medicine. Therefore, this book will benefit medical practitioners in many countries that do not have national access to post-graduate training in aviation medicine. It will also be a good source of clinical, aeromedical knowledge for those who are enrolled in post-graduate training programs in aviation medicine.

Any professional publication that contributes to our existing body of knowledge in aviation medicine is very welcome since there are not many up-to-date publications that specifically address the clinical aspects of aviation medicine. Therefore, this book represents an important addition to the international literature on aviation medicine in general, and to its clinical aspects in particular.

The contributing authors' knowledge of aviation medicine, significant clinical experiences, and international professional recognition among colleagues make this book an excellent addition to any aviation medicine practitioner's personal library.

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Preface and Acknowledgement

Aviation medicine is a medical specialty which combines aspects of preventive, occupational, environmental and clinical medicine with the physiology and psychology of man in flight. It is concerned with the health and safety of those who fly, both crew and passengers, as well as the selection and performance of those who hold aviation licences.

This book provides practice-oriented information on evaluation of fitness to fly and medical certification of those who want to acquire or maintain an aviation licence. The focus is on uniform methods of examination and assessment of pilots, both professional and private, cabin crew members, and air traffic controllers. In order to increase the book's clarity and usefulness for practical application, common diseases and disorders are discussed; those rarely encountered in aviation medicine practice are excluded.

A symbolic summary of this book is depicted on the cover by the "aeromedical homunculus." As the area of anatomical representation increases with the complexity of the sensory-motor function, the sensory-motor homunculus represents the connection between different body parts and the corresponding areas in the hemispheres of the brain. The body on the left side is the *motor homunculus*, lying in front of the central sulcus (CS) of the brain. The bigger the body parts in this picture are, the more brainpower is required to control them. The body half on the right is the *sensory homunculus*, lying behind the CS. It is similar to the motor homunculus except that it

depicts how much brain power is dedicated to receiving sensory input from the different body parts. By analogy, the “aeromedical homunculus” in the middle has organs whose relative size symbolizes their aeromedical significance. The dominance of the heart (and therefore of aviation cardiology) makes an extracorporeal depiction necessary. The importance of the eyes and ears (and therefore of aviation ophthalmology and otology) leaves hardly any room for the brain, which — being the most important of all organs — has been moved to the front and given its own, separate space. The gap where the liver should have been alludes to the easily overlooked exogenous and toxic risks.

The different sizes of the organs of the “aeromedical homunculus” are also correlated to the selection of medical topics and the degree of detail and comprehensiveness with which they are treated in the various chapters of the book.

Regarding the significance of clinical aviation medicine, one should not overlook the fact that aviation incidents and accidents have remained relatively constant in recent decades, with human factors causing or contributing to about 80 percent. This gives emphasis to the importance of aviation psychology. The criteria for mental fitness and psychological testing as well as the significance of crew coordination and cockpit resource management are described. A separate chapter deals with the less understood and often underestimated influence of psycho-social stressors. Through disruption of the man-machine interface, the problems of daily life may become a threat to aviation safety. Consequences of head injuries or diseases affecting the brain are sometimes overlooked as licence holders construct facades to hide their loss of flying skills. This is discussed in depth in a chapter on the relevant neuro-psychological conditions and disorders.

An aeromedical book intended for an international readership constantly collides with transcultural issues. In order to minimize the risk inherent in all aviation activities, international regulations (ICAO International Standards and Recommended Practices, SARPs) have been developed and agreed to by virtually all countries in the world. In this context, it is surprising that aviation medicine still exhibits

a large degree of international variation. Each country issues its own aeromedical requirements in accordance with, but not necessarily identical with, the international SARPs of ICAO, but each country has its own aeromedical traditions and a national understanding of the medical problems involved in flying. Even the nomenclature of medical certification is not uniform, e.g. FAA Class 3 medical certification corresponds to JAA Class 2. In addition, there are still national differences with regard to the retirement age for commercial pilots, although the international age limit of 65 years is gaining global acceptance.

The editors are proud to have succeeded in acquiring the cooperation and contributions of several of the leading experts from the various fields of operational aviation medicine. The majority of these experts have for years been engaged in both the clinical and the regulatory aspects of aviation medicine in their capacity as members of the Aviation Medicine Committee of the Federal Minister of Transportation.

The physiological basis for aviation medicine, outlined by two eminent experts, provides the basic theoretical foundation for the following clinical sections.

A chapter on the history of aviation medicine gives the interested reader a stimulating insight into the methodological development of a very specialized field of medicine which, in the words of Dr. Silvio Finkelstein, former Chief of Aviation Medicine Section of ICAO is "invisible but essential."

In addition to the International Standards and Recommended Practices of ICAO, the JAR-FCL 3 medical requirements as well as the FAA rules for licensing are described.

Finally, a chapter on passenger health, written by Dr. Petra Illig, has been added. It deals with several aspects of aviation medicine of importance not only for those who practise aviation medicine but for all medical practitioners who in their daily practice meet people who fly.

Claus Curdt-Christiansen
Jörg Dräger
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Acknowledgment

Petra checking the oil.

The editors are greatly indebted to Dr. Illig for contributing the time-consuming work of translating “Principles and Practice of Aviation Medicine” from German to English, and wish to thank her for her commitment to a project that sometimes seemed unlikely ever to be completed.

Dr. Petra A. Illig, MD, *Senior FAA, Aviation Medical Examiner, Anchorage*

Dr. Petra Illig was born in Germany and immigrated to the United States at the age of four. She obtained her private pilot licence in 1981, a month before she graduated from the University of Washington School of Medicine. Board certified in Emergency Medicine, she worked in that field for 15 years. She became an FAA Aviation Medical Examiner in 1984, and was a Regional Medical Director of Aircrew Health Services for Delta Air Lines from 1998–2001.

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List of Abbreviations, Acronyms and Units

ACC	American College of Cardiology
ACE	angiotensin converting enzyme
AED	automated external defibrillator
AeMC	aeromedical centre
AF	atrial fibrillation
AHA	American Heart Association
AI	aortic insufficiency
AIDS	acquired immuno-deficiency syndrome
AMC	aeromedical center; acceptable means of compliance
AME	authorized medical examiner
AMS	aeromedical section (of the Licensing Authority) ~ CMO's office
ANC	active noise compensation
AP	angina pectoris
AS	aortic stenosis
ASA	acetyl salicylic acid (Aspirin®); atrial septal aneurysm
ASD	atrial septal defect
AsMA	Aerospace Medical Association
AT ₁	angiotensin type 1
ATP	adenosine triphosphate
ATPL	airline transport pilot licence
BPPV	benign positional paroxysmal vertigo
BMI	body mass index

BP	blood pressure
CAA	civil aviation authority
CAB	civil aeronautics board
CABG	coronary artery by-pass graft
CACS	coronary artery calcium score
CAD	coronary artery disease
CAMI	Civil Aerospace Medical Institute (in Oklahoma City)
CCS	Canadian Cardiovascular Society
CCT	cranial CT
CDC	Centers for Disease Control & Prevention (in Atlanta)
CDT	carbohydrate-deficient transferrin
CHD	coronary heart disease
CHF	congestive heart failure
CMO	chief medical officer
CMRI	cardiac MRI
CNS	central nervous system
COPD	chronic obstructive pulmonary disease
CPL	commercial pilot licence
CRM	crew resource management
CRP	C-reactive protein
CT	computerized tomography
CVA	cerebrovascular attack
D	diopetre
DCS	decompression sickness
DES	drug eluting stent
DIWS	document, imaging and workflow system
DNA	deoxyribonucleic acid
DSM-IV	Diagnostic and Statistic Manual of Mental Disorders, 4th Edition (American Psychiatric Association)
DVT	deep vein thrombosis
EASA	European Aviation Safety Agency
EBCT	electron beam computed tomography
EC	European Commission
ECG	electrocardiogram

EEC	electroencephalogram
EEMK	enhanced emergency medical kits
EF	ejection fraction
ENT	ear, nose and throat
ESC	European Society of Cardiology
EU	European Union
EURATOM	European Atomic Energy Community
FAA	Federal Aviation Administration
FCL	flight crew licensing
FFA	free fatty acids
FO	first officer
<i>g</i>	gravity, i.e. the gravitational attraction of the Earth
G	accelerative force (in multiples of <i>g</i>).
γ -GT	gamma-glutamyl-transferase
GND	ground
Gy	gray
HDL	high density lipoprotein
HEPA	high efficiency particulate air filter
hs-CRP	high-sensitivity CRP
Hz	hertz
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization (a specialized agency of the United Nations with HQ in Montreal, Canada)
ICD	implantable cardioverter defibrillator
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th revision (WHO).
ICRP	International Commission on Radiological Protection
IFR	instrument flight rules
IMA	internal mammary artery
INR	international normalized ratio
IPPPSH	International Prospective Primary Prevention Study in Hypertension
IR	implementing rule

ISA	international standard atmosphere
JAA	Joint Aviation Authorities
JAR	Joint Aviation Regulations
K	Kelvin
KeV	kilo electron volt
LA	left atrium
LAD	left anterior descending coronary artery
LBBB	left bundle branch block
LDL	low density lipoprotein
Lp(a)	lipoprotein a
LV	left ventricle
MAR	minimum angle of resolution
MCV	mean corpuscular volume
MEDIF	medical information sheet (IATA)
MET	metabolic equivalent
MeV	mega electron volt
MIDCAB	minimally invasive direct coronary artery by-pass
MRA	magnetic resonance angiogram
MRI	magnetic resonance imaging
MS	mitral stenosis
MSCT	multi-slice CT
MSL	mean sea level
mSv	milli sievert
MVP	mitral valve prolapse
N	newton; north
NOTAM	notification for airmen
NSAID	non-steroidal anti-inflammatory drug
NYHA	New York Heart Association
OML	operational multicrew limitation
OSL	operational single pilot limitation
P	pressure
Pa	pascal
PAC	premature atrial contraction
PBW	phonetically balanced words
PCI	percutaneous coronary intervention
PE	pulmonary emboli

PET	positron emission tomography
PFO	patent foramen ovale
PPL	private pilot licence
PS	pulmonary stenosis
PTCA	percutaneous transluminal coronary angioplasty
PTS	permanent threshold shift
PVC	premature ventricular contraction
R	specific gas constant
RBBB	right bundle branch block
RCA	right coronary artery
RQ	respiratory quotient
RV	right ventricle
SARP	Standards and Recommended Practices (ICAO)
SARS	severe acute respiratory syndrome
SHBG	sex hormone-binding globulin
SJM	St. Jude medical prosthesis
SODA	statement of demonstrated ability
SMR	standard mortality rate
SPECT	single photon emission computed tomography
SSRI	selective serotonin re-uptake inhibitor
SST	super sonic transport
STPD	standard temperature, pressure and air density
T	temperature
TEE	transesophageal echocardiography
TIA	transitory ischemic attack
TTS	temporary treshold shift
TUC	time of useful consciousness
URI	upper respiratory infection
V	volume
VAT	visceral adipose tissue
VF	ventricular fibrillation
VFR	visual flight rules
VOC	volatile organic compounds
VPN	virtual private network
VSD	ventricular septal defect
VLDL	very low density lipoprotein

VT	ventricular tachycardia
WHO	World Health Organization (a specialized agency of the United Nations with HQ in Geneva, Switzerland)
WHR	waist-to-hip ration
WOSCOPS	West of Scotland Coronary Prevention Study
WPW	Wolff-Parkinson-White syndrome
WRIGHT	WHO Research Into Global Hazards of Travel