

The Audiologist's Handbook of

**Intraoperative
Neurophysiological
Monitoring**

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**Intraoperative
Neurophysiological
Monitoring**

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PREFACE

My own introduction to the operating room environment happened in 1980, at the University of Alberta in Edmonton, Alberta, Canada. I was interested in investigating the neurophysiology of the auditory evoked middle latency response (MLR), specifically to determine whether it was mostly a myogenic response as suggested by some researchers in those days. An opportunity came along courtesy of cardiothoracic surgeon, Dr. Elliot T. Gelfand, who allowed me to record responses in the operating room while the patient was under a neuromuscular blockade and general anesthesia and undergoing coronary bypass surgery.

To make a long story short, we did demonstrate that the MLR was a neurogenic response (Kileny, Dobson, & Gelfand, 1983). At the same time, however, I noticed that changes in blood pressure or perfusion pressure, when the patient was on bypass, affected the amplitude of the MLR, which made me wonder if monitoring some type of evoked potentials may become useful in providing feedback regarding the patient's central nervous system physiologic status. Later on, I started doing intraoperative monitoring of somatosensory potentials during scoliosis surgery; and then shortly after my arrival to the University of Michigan, I established a neuromonitoring program for neurosurgery and neurotology, initially primarily to provide intraoperative monitoring for acoustic neuroma, and vestibular nerve section surgical procedures.

This book represents my attempt to share some of my experience with audiology colleagues and other health care providers who are interested in or have already ventured into the operating room. This book focuses on cranial

nerve monitoring, and I tried to make it as practical and straightforward as possible. The digital companion version also has some videos illustrating neurophysiologic events occurring during surgical procedures. The initial chapters of the book focus on some basic tenets of electromyography and evoked potential recording and some neuroanatomy. The last two chapters (13 and 14) focus on considerations for establishing a neuromonitoring program and specific protocols. Chapter 14 also includes five specific protocols set up in a table format that could be used step-by-step in the operating room to set up and conduct a neuromonitoring protocol for a specific surgical procedure.

While the primary purpose of this book is to describe cranial nerve intraoperative monitoring most commonly encountered by audiologists, Chapter 11 also includes information about somatosensory evoked potentials that need to be used along with cranial nerve monitoring in lower skull base tumor surgery. Additionally, one of the specific protocols that follows Chapter 14 is for somatosensory evoked potentials.

The book was written with the student, fellow, and relatively novice monitoring clinician in mind. However, individuals beyond a beginner level can also benefit from this book, which is illustrated with cases and appropriate figures to guide the learning and reviewing of intraoperative monitoring applications. While the book was written with the audiologist in mind, individuals training as intraoperative monitoring (IOM) technologists, otolaryngology and neurosurgery residents, and fellows can also benefit from this book.

ACKNOWLEDGMENTS

This book could not have seen the light of day without my having the opportunity to work and collaborate with numerous colleagues. The late neurosurgeon Julian “Buz” Hoff, MD, my great friends the late John L. Kemink, MD, and the late John K. Niparko, MD, as well as the outstanding Malcolm D. Graham MD were early proponents and supporters of this emerging field. I have also benefited from working alongside several other superb Michigan Medicine surgeon colleagues: Drs. Steve Telian, Hussam El-Kashlan, Alex Arts, Greg Basura, B. Gregory Thompson, Oren Sagher, Gregory T. Wolf, Mark Prince, and Carol Bradford, to name a few.

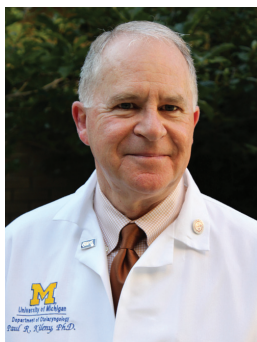
While I contributed to the IOM training of most of my audiology colleagues at Michigan, I ultimately also learned a lot from them. So my thanks go to audiologists Bruce Edwards, Deb Kovach, Greg Mannarelli, Crystal Pitts, and Katie Claytor. Special thanks to our very first Audiology IOM Fellow, Hazel Albertyn, now back home in New Zealand, who contributed to putting together the specific IOM protocols.

Special thanks to my son, Joel L. Kileny, MD for his significant contributions to the anesthesia chapter.

Many thanks to Dianne Hoehn, my assistant for designing some of the graphics and many other contributions to this book.

Finally, to my wife, Leah Kileny, RN, thank you for a lifetime of love and support, and for putting up with my unpredictable schedule, especially in my early “solo” IOM days.

ABOUT THE AUTHOR



Paul R. Kileny, PhD, CCC-A, BCS-IOM, joined the faculty of the University of Michigan Medical School in 1985 and serves as Professor and Academic Program Director of Audiology and Electrophysiology there. He received his Doctorate in Audiology with an emphasis on Neurophysiology from the University of Iowa in 1978. A practicing audiologist, clinical researcher, and administrator at the University of Michigan, Dr. Kileny founded the university's neurophysiologic intraoperative monitoring (IOM) program in 1985. He has published over 150 peer-reviewed journal articles, including many on IOM, and lectures extensively, nationally and internationally. He is a founding fellow of the American Academy of Audiology (AAA), a founding member of the American Audiology Board of Intraoperative Monitoring, and a Fellow of the American Society of Neurophysiological Monitoring. He is an ASHA Fellow and Honors recipient, as well as the recipient of the AAA Career Award in Hearing. He resides with his wife, Leah, in Ann Arbor.

VIDEO LIST

This book comes with the following videos hosted on a PluralPlus companion website. See the inside front cover for instructions on how to access the website.

Video 2–1. This video shows a normal motor unit potential recruitment associated with voluntary muscle contraction. This was recorded with a bipolar, concentric needle electrode.

Video 2–2. This video is an illustration of surgical manipulation (also known as “mechanical”) induced motor unit potential recruitment. It is somewhat similar to motor unit potential recruitment associated with voluntary contraction, but it can appear in different temporal patterns such as bursts, or continuous activation, and should correlate with events in the surgical field.

Video 3–1. This video shows the simultaneous intraoperative, acquisition of auditory brainstem response (ABR; upper traces) and electrocochleography (EcochG; lower traces) during a suboccipital resection of a large cerebellopontine meningioma. While wave V of the ABR is identifiable, its resolution is relatively poor, as opposed to the summing potential and the N1 of the EcochG, which require far less averaging and have a much better resolution. This was recorded with a tympanic membrane electrode.

Video 3–2. This video shows the proper placement of an anti-tragal reference electrode for intraoperative ABR acquisition.

Video 6–1. Insert transducer placement prior to draping, following patient positioning on the operating table.

Video 6–2. Searching for the facial nerve with electrical stimulation in the vicinity of an acoustic neuroma. Note the brief appearance of a compound muscle potential in response when the facial nerve is identified and stimulated. Other areas do not yield a response.

Video 7–1. Facial nerve main trunk stimulation during parotid surgery: compound potentials are present on each one of the four channels (from top to bottom: frontalis, orbicularis oculi, orbicularis oris, mentalis), indicating an intact, fully functioning facial nerve.

Video 9–1. An example of the buildup of the summing and action potentials (SP and AP), with tympanic EcochG recording in a case of superior canal dehiscence; please note the high amplitude of the SP.

Video 10–1. This video illustrates the packing of Teflon between the facial nerve and a blood vessel loop responsible for hemifacial spasm. This is the last stage of the microvascular decompression procedure of the facial nerve to release hemifacial spasm.

Video 14–1. This video is an example of a large electrocautery artifact, as recorded on two free run electromyography channels. These electrical events saturate the amplifiers and, while present, make any type of neuromonitoring unavailable.



This book is dedicated to the memory of Roger A. Ruth, PhD. Roger was a wonderful friend, colleague, father, and husband. He left us way too soon, but made significant contributions to the field of audiology and clinical neurophysiology as teacher, clinician, mentor, and author. This book was supposed to be a collaboration with Roger, but his untimely death prevented those plans. It is a fitting tribute to a beloved friend and colleague.



Introduction to Intraoperative Monitoring

What is intraoperative neurophysiologic monitoring?

Why is there a need for this clinical specialty?

How does one do intraoperative monitoring?

What are potential pitfalls and how does one resolve them?

These are just a few of the questions that arise when the term “intraoperative neuromonitoring” is mentioned. In this book, I will attempt to provide satisfactory answers to those questions and more, so that the book can serve as a basic introduction and provide information about some aspects of neurophysiologic intraoperative monitoring. I hope that the contents of this book will be instructive and that the book will engender sufficient interest and curiosity so that the reader will endeavor to seek additional information about this interesting and clinically effective field. While this book is intended primarily for audiology students and practicing audiologists, I believe that its contents will be of assistance and interest to other health care providers seeking information about intraoperative monitoring.

The earliest form of “intraoperative monitoring” (IOM) was the brainchild of the renowned neurosurgeon Harvey Cushing, who while in medical school contributed to the development of blood pressure monitoring during surgery, and developed the prototype of the flow sheet used to monitor patients’ vital signs during general anesthesia. With some modifications, this type of flow sheet (computerized in recent times) is used to this very day in countless operating rooms all over the world. During the last four of five decades, there has been a remarkable evolution in the efficacy and safety of surgical techniques performed within the proximity and directly on the central and peripheral nervous systems. For instance, as recently as midway during the previous century acoustic neuroma resection was considered to be successful if the tumor was completely resected and the patient survived with minimal or no significant neurological sequelae. The surgery to remove an acoustic neuroma was not focused on the preservation of cranial nerve function. However, with advances in the understanding of the surgical anatomy, developments in instrumentation and in particular the advent of the introduction of the operating microscope and microsurgical technique brought about a burgeoning interest and some success in preservation of neural function.

Acoustic neuroma surgery is but one example of many surgical advances leading to improved functional outcomes along with effective treatment of the disease. In otology and neurotology in particular, refinement in temporal bone surgery has brought about an increased emphasis on preservation of auditory and facial motility functions. Preservation of neural function during surgery presents with a number of challenges, including distorted anatomy (for instance, due to the presence of a tumor), which makes it difficult to identify and trace a specific neural structure, and the difficulty of detecting impending damage to neural structure simply based on visual identification and observation by the surgeon. Therefore, the ability to continuously monitor and provide feedback on the functional (rather than anatomical) status of a neural

structure proves to be very effective in filling the gap left open by observation alone.

Developments in neurodiagnostic techniques, and an increased interest in those techniques by various disciplines, including audiology, also represent an important step in the development and acceptance of intraoperative monitoring, as well as continued improvement of outcomes beyond the contribution of improved and refined microsurgical techniques. One of the landmark contributions to this field was the description and introduction into clinical practice of the auditory brainstem response by Jewett and his colleagues in 1970 (Jewett, Romano, & Williston, 1970). The advent of this robust and repeatable evoked potential regardless of patient state generated a veritable explosion of clinical investigations involving the auditory brainstem response, and ultimately was just one of the first of numerous other neurophysiologic diagnostic techniques used in the clinic, such as various aspects and versions of facial muscle electromyography. The diagnostic applications of these neurophysiologic techniques brought along an understanding of the relationship between specific pathology and changes in the configuration and/or structure of these responses. These steps are absolutely necessary precursors of the more dynamic “interventional” use of these neurophysiologic measures in the operating room.

In the late 1970s to the early 1980s there was convergence of interest in preservation of neural functions when operating in their vicinity, improved microsurgical techniques, and the emergence of intraoperative use of different neuropsychologic techniques (Kileny, Niparko, Shepard, & Kemink, 1988). These neurophysiologic techniques originated from the outpatient, diagnostic domain and were developed to become technically applicable in providing feedback about the neurophysiologic status of neural structures during surgery. In otology and neurotology, along with increasingly sophisticated microsurgical techniques, neurophysiologic intraoperative monitoring has contributed to improved preservation of facial and auditory function following acoustic neuroma resection,

retrolabyrinthine vestibular nerve section, microvascular decompression of cranial nerve V, VII, or VIII, as well as improved facial function preservation when operating on patients with congenital temporal bone anomalies.

At this point it is important to state that intraoperative monitoring is not a substitute for surgical training and skill, but a legitimate adjunct in the surgical armamentarium of those who operate on or in the vicinity of neural structures. It is also important to note that even with improved technology, automated monitoring based on acoustic alarms is not a substitute for the skill, experience, and interactive ability of a skilled clinician who provides moment-by-moment feedback of one or more neural structures. It is safe to assume that no surgical team would consider replacing an anesthesiologist with a series of automated acoustic alarm warnings of changes in blood pressure, heart rate, or other vital functions. By the same token, the same standards and safeguards need to be applied to the administration of intraoperative neurophysiologic monitoring. It is important to avoid instilling a false sense of security in particular in a novice surgeon, and by the same token it is also important to avoid instilling a sense of insecurity if monitored activity is not properly interpreted. For instance, frequent and inappropriate warnings (which are not unusual when automated monitoring is used) will ultimately result in ignoring a true warning or a true alarm when corrective action in the surgical course would be necessary. Just as skill and experience play an important role in surgical techniques, this is equally true regarding the quality of administration of IOM. When all is said and done, constant and meaningful communication between surgical, intraoperative monitoring, anesthesia, and nursing teams in the operating room is the most important aspect of monitoring neural functions, and cannot be substituted by technology. As part and parcel of this, trust is very important, but it bears reminding that trust is earned. The goal of this book is to provide the reader with practical information and knowledge that will assist in building skills in the operating room.