Chapter 2
Electrodiagnosis and the Physical Examination: Casting a Fine Net Widely

"EMG extends the clinical examination"—But to what extent?

Abstract The history of electrodiagnosis displays a mutual dependence on understanding in physics and chemistry as well as in anatomy and histology. The confluence of these knowledge makes up the strength and reliability of the physical examination. This chapter offers a framework in which innovations in the clinical examination and the distinction between provocative and evocative maneuvers in the electrophysiological examination may be evaluated.

Keywords Vitalists · Interactive · Physical examination · Signs · Symptoms · Evocative maneuver · Provocative maneuver · AANEM · Standardization · Specificity · Sensitivity · Pathognomonic

When it was understood that plants grow from seeds, plants became domesticated and agriculture began. When people realized the electrochemical basis of nerve transmission, electrophysiology was born. As the history we have just reviewed demonstrates, electricity was applied as medical treatment for a good many centuries before it came to any diagnostic use. Only after the electrical component of our physiology became understood, could electrodiagnostics have any diagnostic application; just as blood flow must be understood before cardiac auscultation can realistically influence diagnosis.

Summary of the First Chapter and Perspective on the Next

Unsurprisingly, electricity caught human attention due to its effect on us. Soon that attention was focused on how our organisms employ it, and with the Enlightenment as fulcrum, it has catapulted into one of our foremost instruments for self-study: it is recognized as a basic element in animal physiology. Not only EMG but also ECG, EEG, and ENG evoked potentials of every kind record and interpret the "animal electricity" inherent in biological processes. This springs from the work of Galvani. To varying degrees, all imaging studies, all scans and scopes, and almost every

L.M. Fishman, A.N. Wilkins, *Functional Electromyography*,
DOI 10.1007/978-1-60761-020-5_2, © Springer Science+Business Media, LLC 2011

diagnostic device beyond a stethoscope and a reflex hammer, and a tape measure employ the electromagnetic spectrum. This we may trace back to Volta.

As was noted about the late eighteenth Century, ". . . the most striking similarity between electricity and "the nervous principle" was that very little was known about either" [1]. But this naivety ran straight into the Age of Enlightenment, just as it had gained fearsome momentum. We can possibly trace the origin of the antagonistic relationship between the "vitalists" and the scientists back to the medieval view of Life as divine in origin and therefore inscrutable. This may have been a remnant of the Middle Ages that erroneously revived the controversies between Galvani and Volta. So little was known about electricity that declaring it as basic to live movement might have seemed obscurantist . . . and a reference back to what was divinely unknowable: the thunderbolts of the gods. Volta appears to have taken Galvani's approach that way, though actually, the two men were each quite devoted scientists. It may (wrongly) have appeared, during the Enlightenment, that each group was claiming electricity "on their side "—the vitalists asserting that this inexplicable and unknown phenomenon was, like the soul, unreachable, an indefinable *je ne sais quoi*, and something like sacred; and the scientists asserting that this force was easily generated by any man or woman with a piece of amber and a wheel, and might well prove to be as un-spiritual as carbon or oxygen.

Some intellectuals of the time might have seen things in this polarized way. But it was not the actual situation: Luigi Galvani, the physician and anatomist, believed electrical phenomena, no more or less than lightning, were basic to animal functioning, as Volta put it, "animal electricity . . . a kind of electricity inherently linked to life itself, and intrinsic to some animal functions" [2] while Volta himself felt electricity was strictly an inorganic phenomena. Yet both of their extensive life works are empirical, experimental, and open-minded in so many other ways.

In particular, Galvani was not claiming any mysterious unknowability about electricity. On the contrary, he spent his life trying to learn what he could. The chief difference was that Galvani looked at electrical phenomena as a biologist, while Volta thought, experimented, and wrote like a physicist. Their mutual innocence of the electrochemical and membrane-related events of nerve transmission held them apart.

From our vantage point, both men were profoundly correct, and each actually gave great credence to the other. Volta's battery is really an inorganic reconstruction of the torpedo fish; Galvani's measurements were made with an instrument of magnets and wire. Their controversy seems more a shadow of the musty air of the Middle Ages than in the substance of their mutual inquiry.

Relevance to Our Subject

Subsequent investigation and theories explaining their findings have reconciled these two seminal thinkers: yes, live things generate electrical currents that are essential to their functioning, and yes, in highly complex ways, they still obey the fundamental laws of physics. But in a sense, the polarization of "scientific" or

"objective" versus "vital" or "intrinsic to life" still persists in spite of their obvious compatibility. Strict metabolic studies have been seen in contrast to human and animal appetites: B12 injections seem antithetical to cookbooks; signs are carefully differentiated from symptoms, electrophysiological parameters separated from intentional behavior, and body from mind. Yet, contemporary holistic insights incline one in just the opposite direction: you are what you eat, your environment affects the way you feel and behave, including symptoms and signs—functional MRI and event-related-evoked potentials link our very thoughts and perceptions with electrophysiological and vascular events. What you think affects your galvanic skin response, and what you do affects how you feel and what you feel.

Medicine has no current need for amber or the electric eel. Yet in spite of its *therapeutic* antiquity, electro*diagnostic* work dates back only to Du Bois-Reymond and is only 160 years old. We state that "electrodiagnosis is an extension of the physical examination," but the physical examination, like therapeutic use of electricity, goes back thousands of years. Electrodiagnosis has, perhaps, not become fully adapted, not used fully, in extending the physical examination.

Today electrical arrangements are used *therapeutically* more than ever from electroconvulsive therapy and TENS to EMG-operated prosthetic limbs and esophageal speech devices to hearing aids. Each involves understanding human needs and then creating an interface with human electrophysiology to serve them.

Incorporating more "vitalistic," i.e., relevant to actual life considerations in electrophysiological evaluations will only bring more means to bear on our patients' problems. The rest of this book attempts to take a few aspects of the physical examination—used *diagnostically* for many years—and analyze them electrophysiologically, better to understand their pathogenetic mechanisms and devise effective remedies for the conditions they create. We can then use the same electrodiagnostic techniques to document the remedies' efficacy and to design and test better ones.

Developing alongside all types of technological windows into the human body and the soul, with as broad and fanciful a beginning as the first human encounter with amber or the electric fish, has been the use of electrophysiological measures in the physical examination. From earliest times we have made notice of each other and drawn conclusions from our observation: from "Johnny, your lips are blue, you're cold, get out of the water," to the vivid descriptions of people by Jane Austin or Fyodor Dostoyevsky. With electrodiagnostic precision, we can now make just as matter of fact a statement: "Your nerve conductions are all quite slow. You have a neuropathy, let's check your blood sugar."

Today we might say the physical examination has advanced under the skin, with imaging studies that in the case of atomic force microscopy, get inside the bones, functional MRIs that mirror our very processes of thinking and perception, and cardiac stress-testing that measures not just the structure but the behavior of the heart. Still, through the centuries, while physical evidence of pathologic conditions guides more sophisticated inquiry, the motive and procedure are still faithfully reflected in "Get out of the water, Johnny. Your lips are blue." It must apply ultimately to a person's condition, and it must imply, directly or indirectly, its cause and treatment.

The Physical Examination Is Not Just Physical

Essentially, in everything but a perfunctory check-up, the clinician's encounter with a patient is suspicion- or complaint-driven. It focuses on that suspicion or complaint and all future developments spring from it, sometimes in a linear fashion and sometimes surprisingly. There is the time during which the physician or therapist is passive and the patient is active, in which the patient gives, either in writing or in speech, the reason for the first visit. Even at that time, the physician or other clinician starts thinking: what is this like, have I seen it or read about it, or what does it sort of resemble, but not quite?

But symptoms are more sensitive than specific, and there is usually some question about which of a number of pathogenetic processes are causing the patient's suffering. And the critical question is "How can we find out?" The order of things to come is cast by those first clinical moments of reckoning, though the way things proceed may depend on the results of the first probings. But is it all probing?

"You Can Observe a Lot Just by Looking."—*Yogi Berra*

It begins as the patient and clinician meet, a time in which the clinician observes all manner of things about the patient, and the patient does nothing special, and is, from the viewpoint of their meeting, totally passive. It often starts with the knock on the door and the patient striding across the office. This of necessity precedes any further doings, but extends throughout the good physical examination: the physician or nurse or therapist keeps open eyes, ears, nose, and mind, and a sensitive touch. Even the knock can tell you a lot.

This first part is the history (which clearly is also part of the physical) and extends right through every patient–physician encounter.

It Takes Two

Then there is the part generally regarded as the physical examination itself, which is, as we have been saying, part a matter of physician observation of a more or less passive patient: features such as body build, rashes, posture. What overlaps and follows this embodies the uniquely human cooperation that constitutes the heart of every physical examination, the part that is interactive. From the patellar reflex to finger-to-nose-to-finger, the patient and physician are in a sort of dance, whether finely choreographed or ad hoc. On the doctor's part it is based on anatomy, physiology, pathology, and a calculating mind that has been to school; from the patient, it springs from trust and the motivation to learn more about what is and is not wrong and get well. Patellar reflex testing may at first appear involuntary but it is interactive: few people would contest that the patient's contribution to the test is critical to its success. Regardless of the presence or absence of the reflex, the patient is duty-bound to remain still, with quadriceps relaxed.

The interactive physical examination, those aspects of the examination that could not be performed by an observant and sophisticated writer or journalist, are those aspects in which "pure" perception is insufficient, the parts supporting and confirming or ruling out diagnoses. They are, taken together, a rational rather than a merely descriptive task. They may be as directly relevant as testing the bicipital strength of a patient complaining of weakness to Dr. House-like examination of the toenails in episodic fainting.

It is basically knowing how different conditions manifest themselves and looking at the patient for the symptoms and signs that indicate them. When the initial probings do not support diagnosis number 1, then one does not completely forget about it but begins to look for the next most likely diagnosis and so on. The physical examination is a suspicion-guided inquiry, like most inquiries, and requires that the examiner think on his or her feet. The process is inductive rather than deductive, and reasoning about the findings may be somewhat discretionary, but reasoning is not optional.

What are the limits of the physical examination? Instruments like stethoscopes are certainly part of the physical examination. Does the standard MRI test anything that is not physical? Are MRIs then extensions of the physical examination? What about a CBC or bone biopsy? More to the point here, to what extent *is* the EMG an extension of the physical examination?

If all the possible elements in a physical examination were put up on a blackboard, it would make a dizzying array: blood pressure, sensation at the first web spaces, are the gonads descended, do the eyes move in conjunction? Looking at it from that perspective, a medical student might wonder where the examination ends and the lab tests begin. But one might consider the physical examination is something that you do in the patient's presence, and requires the patient's consent, if not cooperation. One might classify what takes place in the physical examination according to the predominant agent. Is the patient's activity salient, or the clinician's, or are they both active?

Analyzing from the patients' point of view, we may divide into three separate columns what doctors and patients do. In some aspects of the physical examination, the clinician is much more active than the patient (passive), in some the patient undertakes the predominantly active role (active), and in some it is more or less 50–50 (interactive). Some common physical examination activities would be easy to classify:

Interactive	Patient Active	Clinician Active
Visual acuity	Cardiac stress test	Skin sensory testing
Muscle testing	Gait analysis	EEG
Pulmonary auscultation	Barium swallow	CT scan
Mental status examination	Tests for dysdiadochokinesis	Clubbing, cyanosis

This is often a matter of degree, of emphasis. Clinicians' activity (or equipment they employ) is essential to muscle testing, but the patient puts in some critical effort too. Cardiac stress testing equipment has to function, but it basically just records

rather than reacting: the patient does most of the work. Therefore, the patient is more the active ingredient in cardiac stress testing, while muscle testing is interactive. People cannot do much at the time to alter a sleep-EEG; therefore, we would have to say that the patient is rather spectacularly passive in that situation. But both the patient and the clinician have to take part in any case.

Veterinarians do use stethoscopes without instructions to the creatures they examine, but human patients cooperate when physicians or nurses listen for the lungs' sounds. Patients had better volunteer whether the pinwheel feels the same at the left shin as the right, but their activity in sensory testing may be limited to just that. The categories given here may have grey edges; nevertheless, as a matter of emphasis, the drift of this tripartite division may be clear by now.

Within this triage, parts of the EMG examination as commonly performed today are of necessity interactive. Determining the findings with partial patient effort and seeking full interference patterns absolutely require patient involvement. Occasionally, by the time needle-testing gets up to the biceps or triceps, patients may pose the question, "Couldn't this test be done under anaesthesia?" and the inevitable answer is "No." Spontaneous activity might be isolated during sleep, but other parts of the needle examination require a conscious patient and definite cooperation. In the succeeding chapters, we propose further patient involvement, chiefly in nerve conduction and H-reflex studies.

Electromyography is a powerful diagnostic tool to evaluate the function and the many dysfunctions of the peripheral nervous system exactly because EMG evaluation serves as a direct extension of the physical examination. It must be taken in that context to be maximally accurate and effective. There are virtually no single wave forms that are pathognomonic of specific disease entities. Rather, there are patterns in the data. Careful history taking and neurological evaluation lead to a differential diagnosis, doing the groundwork for the electrodiagnostics. In this way, electrodiagnosis for each condition is different and at times must be tailored to specific needs and questions that arise in a given patient's assessment.

While symptoms often suggest a great many more diagnoses than are present, and EMG may winnow the list down to a few viable alternatives, the opposite is also true: [3] found a relatively high proportion of individuals who had normal physical examinations and abnormal electrodiagnostic studies. This has been found in MRI examination of the lumbar spine as well [4]. But that is just the point. When MRI finds two different structural anomalies, say, spinal stenosis and herniated nucleus pulposis compressing an exiting root, both at L4-5, one wants to know which is causing the patient's pain! This is where particular maneuvers might help us.

To understand how we do this requires a further distinction: between those aspects of the physical examination that observe or measure what is already present, such as heart rate and temperature, and those that seek to bring out latent features, such as cold calorics or the Hoffmann test: tendencies or propensities that may be quite informative, important, or dangerous, yet are not manifestly present, but rather lurking within the patient's makeup nonetheless. Examples of what is manifestly present at the moment of the examination, and need only be detected, would be positive sharp waves indicating denervation or jitter. Examples

of what is latent, but can be brought out are signs of muscle fatigue by repetitive stimulation in myasthenia gravis or H-reflex enhancement through the Jendrassik maneuver.

We can distinguish between those maneuvers that *bring out, enhance, or evoke* a state of affairs that is currently present but undetectable, such as weakness enhanced by repeated effort or mild spasticity, from those maneuvers that *cause to exist* or *provoke* conditions that are liable to occur but are more liabilities than actualities. These conditions are latent but would not be present at the time of the examination, unless they were brought about by a maneuver.

We can separate those conditions that need enhancement to be detected, or evoked, from those to which the patient is vulnerable, that are not present, but must be provoked. In order to do this we should first separate out *evocative* maneuvers from *provocative* maneuvers as found in the general physical examination.

Evocative maneuvers	What they evoke
Deep breath in pulmonary auscultation	Râles, sounds of pulmonary edema
McMurray test	Pop indicating medial meniscal tear
Hoffmann test	Hoffmann sign suggests spasticity

None of these maneuvers produces anything beyond a response. There are no cases of deep breaths causing pulmonary edema nor of the McMurray or Hoffmann tests bringing about a medial meniscal tear or spasticity. Evocative maneuvers frequently bring out benign and reassuring features of the patient and are frequently useful to rule out diagnoses. Nevertheless, the presence of rales, the occurrence of a pop, and the flexion of adjacent fingers indicate pathology. The nature of these tests is to reveal what is already there at the moment, but is too faint or inaccessible to be observed directly.

There are evocative maneuvers in electrodiagnosis and are as follows:

Evocative maneuvers in EMG	What they evoke in EMG
Jendrassik	Faint but extant H reflex
Partial patient effort	Recruitment pattern
Maximal patient effort	Full recruitment capacity
Repetitive stimulation	Diminishing muscular response

The reflexes are what they are; the recruitment patterns are there, nerve conduction velocity is, under standard conditions, unvarying, but these things need special conditions such as electrical stimuli and sensitive measurement to be observed. The techniques bring out and amplify, image, and in some way measure or “capture” what is present but otherwise difficult to verify. Evocative maneuvers bring something out that is there anyway.

But evocative maneuvers contrast with provocative maneuvers, which bring about a pathological sign or symptom (or fail to bring it about) that is not present at the time, bur rather is incipient, or latent, or sometimes present, but not extant at the time of the examination. They bring something about, and unlike merely evocative maneuvers, which exemplify or picture something that may or may not be pathological, what provocative maneuvers produce (or fail to produce) is always pathological.

Provocative maneuvers	What they provoke
Cardiac stress test	Ischemia, arrhythmias
Empty can test	Pain
Tensilon test	Weakness

There are very many evocative and provocative tests in contemporary Medicine, from arthrograms (evocative) to the Gaenslen maneuver (provocative). There are some provocative maneuvers in electrodiagnosis as well:

Provocative maneuvers in EMG	What they provoke in EMG
Repetitive stimulation But there are not many.	Reduced CMAP

In the rest of this book, we will introduce and attempt to demonstrate the validity of three provocative maneuvers which may be helpful for the clinician, and may further illustrate a valid method for devising other provocative maneuvers in the clinical context as the need for them arises.

Proposed Provocative Maneuvers in Electrodiagnosis

New provocative maneuver	What it provokes	What it means
FAIR test	Delay in H reflex	Sciatic entrapment
Allen test	Delay in PML	Thoracic outlet syndrome
3-min extension	Delay in H reflex	Positional lumbar stenosis

Subsequent chapters will present the case for each one of these maneuvers: the theoretical justification, the practical ways and means of performing them, and the outcome of using these results in treating patients.

Philosophical Reflection of the Yet Unseen

The history of electricity in Medicine from Chapter 1 traces a path toward standardization. Weddell, Feinstein, and Pattle's [5–7] reference manual for researchers and clinicians in 1944 brought a reasonably well-accepted norm that presented a standard for organizing and comparing the practices of a previously heterogeneous assortment of practitioners. Perhaps more to the point, a reference point enabled practitioners if not to establish, then at least to estimate what was normal, what constituted deviations from normal, and what medical conditions were associated with which departures from normal.

Standardization was exactly what was needed in a field born of controversy. From its groping origins, electrophysiology and the study of electricity itself floundered in the dark to learn fundamental truths, the basic behavior of the phenomena at hand from which experimental evidence could be evaluated and understood. Like any science, electrophysiology and indeed the physics of electricity had to establish a concensus before a body of accepted work could grow.

At first there were finely reported but roughly constructed reports on phenomena with torpedo fish, lightning, and frogs. Soon thereafter were experiments with materials and measurements of speed and force, connection with physics, another science in which metrics already existed. Then finer measurements ensued, and with Bernstein, a working theory that fit most of the facts and reconciled some of the apparent contradictions with physics. As familiarity with the phenomena increased, and a tantalizing flurry of speculation about what was going on proliferated, there developed a good deal of near-chaotic investigation and reporting. This led in a Hegelian progression of "thesis–antithesis-synthesis" to a disseminated and accepted compilation of standard procedures and normal values for tests, using straightforward parameters such as millivolts and meters per second. In less than 10 years following Weddell, Feinstein and Pattle's publication, electrodiagnosis grew from a practice that could be considered either exotic diagnostic work or clinical research to a requirement in every department of Physical Medicine and Rehabilitation by 1950.

Like any group of scientists, believing that there is a truth, electrodiagnosticians aimed to advance toward more universal standards of practice, a better measurement of normal, and tighter and tighter margins of error.

John Basmajian's ISEK (the International Society of Electrophysiological Kinesiology), created in 1965, is illustrative of these motives [8]. The later work of Jun Kimura and many others, and the AANEM itself reflect the same goals and themes [9–11]. Compendious volumes and practical handbooks are indispensible for any broad-based human endeavor intended to find truth through the efforts of many researchers and a broad body of work

But in a vital, advancing field, this uniformity must be the basis of further experimentation, a firm basis from which to launch new forays into unknown territory. The standards of practice must function as unvarying paradigms from which innovations

can be objectively judged, but they cannot be used to stifle curiosity, and discourage experimentation which is, by its very nature, less certain in its conclusions. No established work, like a rock foundation, should support efforts at innovation as only it can.

We ask the reader to suspend judgment while examining what we are about to present. Although it definitely has precedent in the evolution of electrodiagnosis, it is new and represents a departure from what is well established using those very well-established principles and values as a guide. As electrodiagnosis is an extension of the physical examination, electrophysiological measurement in provocative maneuvers is presented as an extension of EMG.

We will introduce these maneuvers one by one, and after describing how we have implemented each of them, and the results, we will produce what evidence we can of their clinical utility.

There is another matter that we must consider first, in order to appreciate the need that the first two of these provocative maneuvers fill, that renders these provocative maneuvers more valuable than they might seem to be otherwise. It is to this that we must now turn.

References

1. Schuetze, SM. "The discovery of the action potential." TINS, May, 1983.
2. Piccolino, M. "Animal electricity and the birth of electrophysiology: the legacy of Luigi Galvani." *Brain Res Bull*. 1998;46(July 15 (5):381–407.
3. Lauder, TD, Dillingham, TR, Andary, M, Kumar, S, Pezzin, LE, Stephens, RT, Shannon, S. "Predicting electrodiagnostic outcome in patients with upper limb symptoms: are the history and physical examination helpful?". *Arch Phys MedRehabil*. 2000;81:436–41.
4. Jensen, MC, Brant-Zawadzki, MN, Obuchowski, N, Modic, MT, Malkasian, D, Ross, J. "Magnetic resonance imaging of the lumbar spine in people without back pain." *NEJM*. 1994;331:69–73.
5. Schechter, DC. "Origins of Electrotherapy I." *N.Y. State J. Med.* 1971;71:997–1007.
6. Schechter DC. "Origins of Electrotherapy II." *N.Y. State J. Med*. 1971;71:1114–1124.
7. Licht, S, Ed. Electrodiagnosis and Electromyography. Waverly Press Inc, Baltimore, 1961.
8. Basmajian, JV. "Electromyography Comes of Age." *Science*. 1972 May 12;176(4035):603–9.
9. Kimura, J. 2001. *Electrodiagnosis in Diseases of Nerve and Muscle: Principles and Practice*. Oxford University Press.
10. Perotto, AO, Delagi, EF, Iazetti, J, Morrison, D. 2005. *Anatomical Guide For The Electromyographer: The Limbs And Trunk*. Springer.
11. Braddom, RI, Johnson, EW. "Standardization of H reflex and diagnostic use in S1 radiculopathies." *Arch Phys Med Rehabil*. 1974;55:161–66.

http://www.springer.com/978-1-60761-019-9

Functional Electromyography
Provocative Maneuvers in Electrodiagnosis
Fishman, L.M.; Wilkins, A.N.
2011, XVI, 171 p., Hardcover
ISBN: 978-1-60761-019-9