Electrodiagnostic Studies

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OVERVIEW OF ELECTRODIAGNOSTIC TESTS

Electrophysiology is the study of the electrical properties of biologic cells and tissues. It involves the measurement of voltage change or electric current on a wide variety of scales from single ion channel proteins to neurons firing in whole organs, such as the heart measuring the integrity of the conduction system. Electrodiagnostic tests are electrophysiologic studies of the electrical activity and conduction system of nerves and muscles at rest and during activity. These diagnostic tests provide significant evidence- based data for best-practice interventions in the treatment and management of abnormalities in nerves and muscles. Electrodiagnostic tests help provide specific data about the location and underlying causative factors of these abnormalities that routine diagnostic tests cannot differentiate.

There are few complications in electrodiagnostic tests. Noninvasive surface electrodes have rare complications. Patients are instructed not to wear lotion for 24 hours before the test. A complication might be an irritation or allergy to the adhesive of the electrode. Invasive complications are usually limited to the invasive procedure itself, such as insertion site infection and bleeding. A consent form is signed by patients after instruction is given about the procedure, complications, and follow-up care. The electrophysiology function of the target system area is usually produced in a graph format that requires a specialist to interpret. Most tests are conducted in an electrophysiology lab and interpreted by a trained specialist or electrophysiology physician. A disadvantage of electrodiagnostic tests is faculty interpretations of data caused by artifacts and an untrained reader of the test. The following summarizes common tests[1] in this graph format:

1. Electroantennography for the olfactory receptors in arthropods
2. Electrocardiography for the heart
3. Electrocorticography for the cerebral cortex
4. Electroencephalography for the brain

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5. Electromyography for the muscles
6. Electro-oculography for the eyes
7. Polysomnography, the gold standard diagnostic test for obstructive sleep apnea
8. Electroretinography for the retina

CARDIAC ELECTRODIAGNOSTIC STUDIES

Electrocardiography (ECG) is a common noninvasive electrodiagnostic test that records the electrical activity of the heart over time using skin electrodes. The ECG measures the overall rhythm of the heart in different parts of the heart muscle. It is a powerful diagnostic tool to diagnose abnormal rhythms of the heart. In myocardial infarction, the ECG can identify damaged heart muscle, ischemia, injury, or infarct. It can also identify electrolyte and drug level abnormalities. A 12 lead ECG is usually preliminary to most tests performed. It is used as a baseline diagnostic tool for identification of rhythms, and is often used as a comparison of pretest and posttest changes. A disadvantage of an ECG is that it cannot measure the pumping ability of the heart, and faculty interpretations can be made because of artifacts and an untrained reader of the electrocardiograph.[2]

Invasive cardiac electrophysiology diagnostic tests are used for diagnosis and treatment of cardiac rhythm disorders. Invasive cardiac electrophysiology procedures involve the introduction of an electrode catheter percutaneously from a peripheral vein or artery into the cardiac chamber of sinuses. These electrode catheters evaluate the performance of programmed electrical stimulation of the heart.[3] These electrophysiologic studies are used for seven primary diagnostic reasons:

1. Accurate diagnosis and management of bradyarrhythmias and tachyarrhythmias
2. Diagnosis of unknown etiology for syncope episodes
3. Determination of the prognosis of the cardiac rhythm disorder
4. Identification of risk factors for sudden cardiac death
5. Evidence-based data generation for primary prevention interventions, such as permanent pacemaker or defibrillator implantation
6. Electrophysiology data for drug-management decisions regarding antiarrhythmic drug therapy
7. Electrophysiology feasibility data for nonpharmacologic management of cardiac rhythm disorders, such as ablation or antiarrhythmic surgery.[3]

Invasive cardiac electrophysiology studies are usually performed in an electrophysiology laboratory using intravenous conscious sedation. The lab staff usually consists of an electrophysiologist physician, circulator nurse, nurse anesthetist, and another physician or technician. One of the staff continuously monitors patients' heart rhythm, and is able to defibrillate using a biphasic external defibrillator if needed. Multipolar intracardiac electrode catheters are positioned in the heart using the Seldinger technique to place multiple venous accesses. The femoral vascular access is the most common approach. Typical placement positions for the multipolar intracardiac electrode catheters include the right atrium (evaluate sinoatrial node function and atrioventricular conduction), right ventricle (useful site for adding premature stimuli during programmed ventricular stimulation), tricuspid annulus (record potential from the bundle of His), and coronary sinus (evaluate left atrial activation).[3]

Baseline recordings are obtained during the electrophysiology testing. The baseline recordings include several surface electrocardiograms and several intracardiac electrograms that are recorded simultaneously including the atrium, bundle of His, and ventricle. The electrophysiology diagnostic test measures four basic intervals that

reflect the integrity of the conduction system under resting conditions.[3] The following list overviews these baseline measurements:

- PA interval is measured from the onset of the earliest P wave to the onset of the atrial deflection on the bundle of His recording. The normal range is 20 to 60 milliseconds. Prolonged PA times suggest abnormal atrial conduction such as first degree atrioventricular block.[3]
- AH interval measures the atrioventricular (AV) nodal conduction and is measured from the earliest deflection of the atrial recording to the earliest onset of the His bundle deflection. The normal range is 50 to 120 milliseconds. A short AH interval suggests abnormal AV nodal conduction which includes causative factors such as increased sympathetic tone and enhanced AV nodal conduction related to pregnancy and steroid use. A long-AH interval suggests abnormal AV nodal conduction that includes causative factors, such as enhanced vagal tone; intrinsic disease; and negative dromotropic drugs, such as amiodarone, digoxin, beta blockers, and calcium channel blockers.[3]
- His bundle of electrograms duration measures conduction through the short length of compact His bundle. The normal range is 15 to 25 milliseconds. Short and long His-bundle intervals suggest abnormalities in the His bundle conduction.[3]
- HV interval measures the conduction time through the distal His- Purkinje tissue and is measured from the onset of the His-bundle deflection to the earliest ventricular activation. The normal range is 35 to 55 milliseconds. A short-HV interval suggests ventricular preexcitation, such as premature ventricular contraction or an accelerated idioventricular rhythm.[3]

After completion of the baseline recordings, pacing is performed with the intracardiac electrode catheters with programmed electrical stimulation to assess AV conduction and to induce supraventricular and ventricular arrhythmias. Premature beats can be introduced by burst pacing and programmed electrical stimulation at various fixed-cycle lengths to investigate the electrophysiology of the tachycardia.[3] Complications of invasive electrophysiology studies are rare. Serious complications are usually related to the catheterization process of veins and arteries with a complication rate of approximately 2%.[3] Complications associated with percutaneous catheterization include pain, adverse drug reaction, infection/sepsis at the catheterization site, excessive bleeding, hematoma formation, thrombophlebitis, pulmonary thromboembolism, arterial damage, aortic dissection, systemic thromboembolism, transient ischemic attack, and stroke.[2] Complications associated with intracardiac catheters and programmed cardiac stimulation include cardiac chamber perforation, coronary sinus perforation, cardiac tamponade, atrial fibrillation, ventricular tachycardia, ventricular fibrillation, myocardial infarction, and right or left bundle branch block.[3] The induction of serious ventricular tachyarrhythmias occurs frequently and can be promptly terminated by overdrive pacing or external countershock.[3] A coronary angiography or echocardiography are recommended before the electrophysiology study in patients at risk for complications, such as patients who have ischemia or heart failure.

Mapping and transcatheter radiofrequency ablation commonly follows invasive cardiac electrophysiology testing in an attempt to alleviate the arrhythmia.[3] Radio frequency catheter ablation is the method of interrupting supraventricular tachycardia. The objective is to interrupt the two competing electrical conduction pathways.[2] A radiofrequency ablation is used to treat atrial fibrillation. Radiofrequency ablation is done in a circular pattern around each pulmonary vein where the lines of conduction abnormality are the contributing factors to atrial fibrillation.[2]

The electrophysiologic procedure begins with a diagnostic electrophysiology study. A catheter with an electrode is positioned at the abnormal pathway then painless radio frequency energy similar to microwave heat is transmitted through the pathway.[2] This ablation process causes coagulation and necrosis in the conduction fibers without destroying the surrounding tissue, which stops the area from conducting the extra impulses, thereby, alleviating the tachycardia.[2] Complications associated with transcatheter radiofrequency ablation include complete heart block; thromboembolism; vascular access problems, such as bleeding, infection, and vascular injury; cardiac trauma, such as myocardial perforation and tamponade; myocardial infarction; cardiac arrhythmias; pericarditis; pulmonary vein stenosis; phrenic nerve paralysis; radiation skin burns; and death.[3]

Cardiac mapping is when the temporal and spatial distributions of electrical potentials generated by the myocardium during normal or abnormal rhythms are identified.[4,5] Cardiac mapping can detect myocardial activation and measures repolarization. Electrophysiologic cardiac mapping, including electroanatomic mapping, and noncontrast endocardial mapping, have replaced intraoperative mapping.[4] Invasive cardiac electrophysiology mapping and ablation is an established clinical technique for the investigation and treatment of cardiac rhythm disorders. Invasive cardiac electrophysiology studies are used to diagnose and treat tachyarrhythmias, such as atrial fibrillation, atrial flutter, supraventricular tachycardia, and ventricular tachycardia.[4]

CASE REPORT: TACHYARRHYTHMIAS

DW, a 54-year-old woman, was recently diagnosed with a myocardial infarction resultant from ventricular tachycardia and right-sided heart failure. An echocardiogram revealed an ejection fraction of 24% with global dyskinesia. She presented to the cardiologist for her 4-week follow-up appointment post-hospitalization. DW reported that she has gained approximately 12 pounds since her second week after discharge and has been extremely fatigued with notable shortness of breath with any activity. Upon assessment, vital signs were stable. DW was dyspneic with an oxygen saturation of 91%. Lung fields displayed bilateral crackles in the bases. Heart tones were audible but distant and muffled. Lower extremities were edematous with three-plus pitting edema bilaterally, ruddy in color and cool to touch. Cardiac monitor revealed a rate of 115 beats per minute and normal sinus rhythm with frequent short runs of supraventricular tachycardia. DW had no evidence of advanced coronary disease. Based upon her recent diagnoses and current assessment findings, DW's cardiologist referred her for electrophysiology studies to review her cardiac conduction pattern.

Electrophysiology had a primary role in the management of DW's ventricular tachycardia. Therapeutic programmed stimulation and burst pacing can induce her ventricular tachycardia to provide electrophysiologic data for management of her ventricular tachycardia. This individualized evidence-based data can confirm her diagnosis and prognosis by determining the mechanism of the arrhythmia, define the hemodynamic instability during her ventricular tachycardia, provide cardiac mapping for transcatheter ablation, provide data for the feasibility of an implantable cardioverter defibrillator (ICD) therapy, and guide antiarrhythmic drug therapy.

Invasive cardiac electrophysiology studies are also used in the treatment of bradyarrhythmias to determine if a permanent pacemaker is needed. Temporary pacemakers are used as an emergency basis to treat symptomatic bradycardia or to override tachydysrhythmias. Bradycardia results from heart block associated with cardiac abnormalities, such as anterior myocardial infarction, and digoxin toxicity. If symptomatic bradycardia continues despite treatment and resolution of cause,

a permanent pacemaker is usually indicated.[2] Implantable cardioverter-defibrillators are used with patients who have life-threatening ventricular dysrhythmias, such as drug-refractory sustained ventricular or ventricular fibrillation. They are also used with a left-ventricular ejection fraction of 30% or less.[2]

Electrodiagnostic impulse formation and conduction intervals provide diagnostic information about the integrity of the conduction system. Sinus node dysfunction and AV conduction orders are the two major categories diagnosed and treated by invasive cardiac electrophysiology studies.[6] In sinus node dysfunction, the person has failure of sinus impulse generation or sinus impulse abnormally conducted to the atrial tissue. Invasive cardiac electrophysiology studies should be used when bradycardia cannot be clearly associated with symptoms or if clinical evidence is borderline, and in conjunction with clinical and noninvasive tests.[6] Atrioventricular conduction disorders have a clinical significance in that they block or delay conduction. Invasive cardiac-electrophysiology studies can identify the location of the site of the AV block, which is usually located within the AV node; within the His bundle (intra-Hisian); and distal to the His bundle (infra-Hisian) in the His-Purkinje system.[6] The AV conduction system can be investigated by identifying AV refractory periods; the response to medications, such as atropine or procainamide; or the response to pacing maneuvers.[6]

Electrophysiologic data is useful in predicting the risk for syncope, complete AV block, and sudden cardiac death. Electrophysiologic data is useful when symptoms are poorly correlated with bradyarrhythmias and when surface tracings cannot identify the site of the block. If patients have tachyarrhythmias or significant cardiac disease, it is important to perform ventricular stimulation with consideration of implantation of dual-chamber or biventricular ICD.[6]

CASE REPORT: BRADYARRHYTHMIAS

NC, a 59-year-of Caucasian man, presented to the emergency department with complaints of intermittent dizziness and had experienced passing out at home three times in the last month. He denied chest pain, but stated that he felt tired and noticed that performing normal activities increased his fatigue. NC's past medical history consisted of a myocardial infarction 3 years ago; a diagnosis of cardiomyopathy 1 year ago with an ejection fraction of 35%; and hypertension for 10 years. Initial assessment of vital signs revealed blood pressure at 158/92 mm Hg, pulse rate of 88 beats per minute, respiratory rate of 22 breaths per minute, temperature of 98.9°F, oxygen saturation of 98%, and cardiac monitor of sinus rhythm 84 beats per minute. Breath sounds were clear to auscultation throughout. Heart tones were audible and regular at present. There were no murmurs or gallops noted. Peripheral pulses were palpable throughout. Extremities were warm to the touch. There was no apparent distress noted. NC was admitted and transferred to the cardiovascular step down unit for further observation.

Upon admission to the cardiovascular step down unit while transferring to the bed from the stretcher, NC complained of dizziness, lightheadedness, and shortness of breath. The client was reassessed immediately with vital signs revealing blood pressure 80/40 mm Hg, pulse rate of 32 beats per minute, respiratory rate of 34 breaths per minute, temperature of 98.2°F, oxygen saturation of 86%, and cardiac monitor of sinus bradycardia with a notable 3-second pause. Rapid response was called, and NC was transferred to the cardiac intensive care unit. NC received oxygen per nasal cannula at 4 l/min, a 500 mL normal saline bolus, atropine 1mg intravenously, and a dopamine, titrate to patient's response drip at 5 mcg/kg/min. Transcutaneous pacing was started. A cardiologist referral was made. Recommendations were made for invasive cardiac electrophysiology studies to determine the feasibility of

a permanent pacemaker after surface tracings could not confidently localize the site of the block.

Electrophysiologic data is helpful in diagnosis and treatment of bradyarrhythmias. The most common indications for pacemaker implantation in the United States are sinus node dysfunction followed by AV block.[7] Invasive cardiac electrophysiology studies can help predict NC's risk for syncope and sudden cardiac death. The electrophysiological studies can also identify the location of the block, response to drug therapy, response to pacing maneuvers, and validate the need for a permanent pacemaker. NC's electrophysiologic data did document the need for her to have a permanent pacemaker.

STRESS TESTING MODALITIES USING ELECTROCARDIOGRAPHY

Exercise and pharmacologic stress testing is an important electrophysiologic testing modality in the evaluation and management of patients who have known or suspected coronary heart disease and the therapeutic effects of cardiac drugs. Exercise tolerance test or stress test is noninvasive. Patients are connected to an electrocardiogram machine while exercising for 3-minute intervals. This activity puts stress on the heart and vascular system. Physical activity produces an increase in myocardial consumption, and if the supply exceeds the demand patients will experience ischemia. This electrodiagnostic test is used to document exercise-induced ischemia and identifies the risk of ischemia-induced activity.[2] If patients are unable to perform, a pharmacologic stress test may be done. Adenosine is a common drug used because it can mimic increased cardiac workload and has a short duration of action.[2] Stress testing can be performed using electrocardiography with imaging, such as with echocardiography and nuclear imaging or without imaging.[8] In nuclear imaging, patients receive an injection of a radiopharmaceutical contrast to assist in the visualization of the heart structures.[2] There are seven common types of exercise and pharmacologic stress tests that are currently in clinical use.[8] **Tables 1–7** overview these tests.[8]

CASE REPORT: EXERCISE CARDIAC STRESS TESTING

SL, a 44-year-old Caucasian man, was admitted through outpatient for an exercise cardiac stress test. He had presented 1 week ago to his primary care physician with complaints of shortness of breath, increased fatigue, chest tightness, and left-arm weakness that radiated from the shoulder area to the hand. SL's past medical history includes being overweight, a positive family history of coronary artery disease, type 2 diabetes mellitus, hypertension, cardiomyopathy, and sleep apnea.

SL's exercise cardiac stress test involved walking on the treadmill. During the exercise stress test, SL's heart rate increased to 168 beats per minute. This heart rate was maintained for 2 minutes. SL experienced slight chest discomfort, 3 out of 10, during the testing that was localized. A radiographic image of the heart was taken before and

Table 1
Treadmill exercise electrocardiography testing

Advantages	Disadvantages
Standard treadmill assessment of ischemia, functional capacity, and prognosis	Lower sensitivity
Stable results in different populations	Does not accurately localize the site or extent of myocardial ischemia

Table 2
Exercise radionuclide myocardial perfusion imaging

Advantages	Disadvantages
Accurate prognosis of extent of CAD	Cost and time commitment
Assessment of left ventricular size	Modest exposure to radiation
Assessment of myocardial viability	Artifact and quality control of trained readers

Abbreviation: CAD, coronary artery disease.

after the test was administered for comparison. When the testing was completed, the cardiologist referred the client to have a cardiac catheterization to further conclude any cardiac involvement.

A cardiac catheterization was scheduled 1week following the exercise cardiac stress test. SL was admitted through outpatient for the procedure. During the procedure, findings indicated that SL had a 90% occlusion of the right coronary artery and an 85% occlusion of the distant left circumflex artery. Angioplasty and one medicated stent to each occluded artery were performed without difficulty. SL was transferred and admitted to the cardiovascular step down unit following the procedure for overnight observation. He was discharged the following morning without notable complications.

Stress testing modalities play a diagnostic role in the treatment and management of coronary artery disease. SL's electrophysiologic testing involved exercise stress with echocardiographic images before and immediately after the peak treadmill exercise was achieved.[9] With echocardiography, cardiac function was evaluated at rest and during exercise. Risk stratification for SL and his ischemia was evaluated. Diagnostic findings provided feasibility data for referral to have a cardiac catheterization.

NERVE CONDUCTION ELECTRODIAGNOSTIC STUDIES

Nerve-conduction studies provide valuable diagnostic information to determine peripheral nervous system function, dysfunction, and disease. Electromyography (EMG or myogram) is a test that checks the health of muscles and the nerves that control the muscles. During this procedure a very thin needle electrode is inserted through the skin into the muscle. The electrode picks up this electrical activity given off by the muscles. This electrical activity is displayed on an oscilloscope.[2] After placement of the electrodes, patients are asked to contract muscles, such as their arm. The presence, size, and shape of the action potential provides information about patients' muscle ability to respond when the nerves are stimulated. There is no special preparation for a nerve conduction test. Patients are instructed to avoid using any creams or lotions on the day of the test, and that they may feel some pain and discomfort when the electrodes are inserted.[2] Patients are also instructed that the muscles may feel tender or bruised for a few days.[2]

Table 3
Thallium versus sestamibi isotopes

Thallium	Sestamibi
Detecting myocardium rest and reinjection	Superior image in obese or female patients
Assessment of pulmonary uptake	Measurement of resting left ventricular function

Table 4
Exercise radionuclide angiography

Advantages	Disadvantages
Risk stratification after myocardial infarction	Cost and limited availability
Good images with obesity and obstructive lung disease	Uses bicycle
Ejection fraction at rest and during exercise	Inaccurate with irregular heart rate Reduced specificity in females and in abnormal left ventricular function

Four primary electrophysiologic studies are used to (1) diagnose focal and generalized disorders of the peripheral nerves; (2) aid in the differentiation of primary nerve and muscle disorders; (3) classify peripheral nerve conduction abnormalities caused by axonal degeneration, demyelination, and conduction block; and (4) provide evidence-based data regarding the clinical course and efficacy of treatment.[10] A stimulating cathode (negative pole) and anode (positive pole) is placed over the nerve. Peripheral-nerve activation occurs when an electrical pulse is generated between them. Surface recording electrodes are used to record the electrical activity resulting from the nerve activation. The recording electrodes are placed over a muscle, a sensory nerve, or a cutaneous nerve distribution. Nerve-conduction studies measure three essential parameters: (1) sensory nerve action potential (SNAP) that assesses the amplitudes, areas, and configurations; (2) compound muscle action potential (CMAPs) that is generated by peripheral nerve stimulation: and (3) sensory and motor nerve conduction velocities.[8] These three measurement parameters are dependent upon the integrity of the largest myelinated fibers.

Four physiologic factors can affect nerve conduction. Nerve conduction varies in regard to specific nerves and nerve segments. For example, nerve conduction velocities are 15% to 20% faster in upper-extremity nerves than in lower-extremity nerves, and sensory conduction is 5% to 10% faster than motor conduction for each mixed nerve segment.[10] Age can affect nerve conduction because there is a negative correlation between age and evoked potential amplitude. This decline can be as much as 50% to 75% for the sensory nerve action potential, which is thought to be related to loss of nerve fibers with aging.[10] Height, weight, and gender also affect nerve conduction. There is a negative correlation between height and evoked potential amplitude especially in the lower extremity nerves. Women have faster conduction velocities than men. Body mass index affects specific nerve segments and thereby SNAP amplitudes are declined.[10]

The three main pathologic mechanisms that affect peripheral nerves are axonal degeneration, demyelination, and conduction block.[10] Nerve-conduction studies identify electropathophysiologic abnormalities that provide objective evidence of efficacy with therapy, such as when to do surgery in the carpal tunnel syndrome and

Table 5
Exercise echocardiography

Advantages	Disadvantages
Information on extent of CAD	Interpretation subjective and nonstandardized
Portable and results immediate	Poor image quality are nondiagnostic
Assesses multiple parameters	Limited number of studies

Abbreviation: CAD, coronary artery disease.

Table 6
Pharmacologic stress testing with dipyridamole or adenosine

Advantages	Disadvantages
CAD assessment without exercise	Cannot assess functional capacity
Drug side effects are rapidly reversed	ECG abnormalities less likely to occur

Abbreviation: CAD, coronary artery disease.

when to use immunosuppressive therapy in polyneuropathies.[10] The American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) recommends that nerve-conduction studies and electromyography be conducted and interpreted at the same time in the majority of test situations because the nerve conduction tests may not determine specific etiologies.[10] The AANEM published a recommended policy manual for electrodiagnostic medicine that includes a coding guide that contains ICD-9-CM codes of relevance to electrodiagnostic medicine.[11] The major complication of nerve-conduction studies is possible electrical injury from stray leakage currents. Patients in the intensive-care setting are at risk for this complication because they are attached to multiple electrical devices plugged into different power outlets. Safety procedures are necessary and the use of ground electrodes in all tests alleviate and minimize electrical leaks.[10]

ELECTRODIAGNOSTIC TESTS FOR LOW BACK PAIN

Low-back pain complaint is found in 84% of adults and is the second most common symptom complaint for physician appointments.[12] Complicated, acute low-back pain, such as nerve-impingement symptoms and fracture, requires diagnostic studies because they could have abnormal nerve function and structure. Common complaints are pain, numbness, tingling, and sensory impairment. Electrodiagnostic testing may be ordered to compliment neuroimaging. EMG is an electrodiagnostic test for evaluating and recording the activation signals of muscles. An electromyography detects the electrical potential generated by muscle cells at rest and with activity. The electromyography produces an electrograms that is read by a neurologic specialist. An electromyography can be ordered using surface electrodes or needle electrodes that are inserted through the skin into the muscle tone. Electrophysiology activity from multiple motor units is typically evaluated. A nerve-conduction test is usually done at the same time. The electromyography provides valuable diagnostic information in the diagnosis and treatment of low-back pain. For example, an EMG is sensitive in detecting disc herniations.[12] EMG is used to diagnose neuropathies and myopathies, such as peripheral neuropathy, alcoholic neuropathy, carpal tunnel syndrome, Guillain-Barré, myasthenia gravis, sciatic nerve dysfunction, and spinal stenosis.[2] Risks are minimal with

Table 7
Dobutamine echocardiography

Advantages	Disadvantages
CAD assessment without exercise	Cannot assess functional capacity
Drug side effects are rapidly reversed	ECG abnormalities less likely to occur
Detects threshold of myocardial ischemia	Labor intensive and requires experienced reader
Assessment of myocardial viability	May cause dangerous ventricular arrhythmias

Abbreviation: CAD, coronary artery disease.

an electromyography, which includes bleeding, infection at the electrode site, and trauma to the muscles that could cause false results in blood tests.[2]

CASE REPORT: NEUROPATHIES

GH, a 54-year-old man, was being evaluated by his primary care provider for a complaint of acute lower-back pain with sensory changes in bilateral lower extremities. The physical complaints included pain in the sacral area and intermittent pain and numbness experienced in the lower legs. Physical evaluation revealed that GH was moderately obese with no obvious signs of trauma or injury. Cardiac system was unremarkable and neurovascular examination was intact and with no reduction of range of motion. History included 15-year insulin-dependent diabetes mellitus that was poorly controlled. There was no history of traumatic injury to the back. X-ray reports concluded that there were no physical abnormalities on examination. Further evaluation of the lower-extremity pain indicated that there was a decrease in sensation for temperature and touch in the legs and feet bilaterally. Reflexes were unremarkable. Pulses were intact and skin color was normal. With no indication that there was a relation between GH's back pain and the lower extremities symptoms, the provider had indication to evaluate the effect that poorly controlled diabetes had on the peripheral nerves. Peripheral neuropathy affects 60% to 70% of people with insulin-dependent diabetes mellitus.[13]

A referral was made for an EMG and a nerve-conduction test. The EMG report found disc herniations and peripheral neuropathy from his complicated diabetes. GH was referred to a neurosurgeon for possible lumbar surgery and to an endocrinologist for possible insulin-pump implantation. Electrophysiological data provided valuable diagnostic data in GH's treatment.

ELECTRODIAGNOSTIC TESTING FOR SEIZURES AND EPILEPSY

Electroencephalography (EEG) is a valuable electrodiagnostic test in evaluating patients who have a possible seizure disorder. An EEG is a recording of the brain's spontaneous electrical activity over a short period of time usually 30 to 45 minutes. Electrodes are attached to the scalp with recording wires attached to a machine that records electrical impulses of brain activity. The results can be printed or displayed on a computer screen. Epileptic activity creates clear abnormalities on a standard EEG study. An example of an abnormal epileptiform activity includes interictal epileptiform discharges (IED), periodic lateralized epileptiform discharges, and generalized periodic epileptiform discharges.[13] A normal routine EEG is only 20% to 24% sensitive to IED, whereas follow-up EEG of four or more is 80% to 90% sensitive to IED.[13] The EEG duration can also affect sensitivity. An overnight EEG or mobile EEG over several days can have a higher yield of IED up to 81%.[13] Increased sensitivity also occurs when an EEG is done within 24 hours of the seizure. Specialized techniques can increase sensitivity to IED and help with classification and diagnosis of seizure or epilepsy, such as hyperventilation, photic stimulation, sleep deprivation, induced sleep, and medication withdrawal.[13] There is a wide variation in how EEGs are interpreted. A specialist is required to interpret the EEG to prevent benign patterns being misinterpreted as epileptiform.[13]

ELECTRODIAGNOSTIC STUDY FOR OBSTRUCTIVE SLEEP APNEA IN ADULTS

Laboratory hallmarks of obstructive sleep apnea in adults are periodic apneas and hypopneas during sleep, episodic flow-limited breaths, and multiple arousals during

sleep.[14] Daytime somnolence is a common feature. Obstructive sleep apnea is usually suspected when patients have excessive daytime sleepiness with witnessed apneas and snoring.[15] A polysomnography is the gold standard diagnostic test for obstructive sleep apnea.[15] Patients sleep while connected to numerous monitoring devices and a technologist records physiologic variables. The following list overviews the physiologic variables[15]:

- Sleep stages (Electroencephalographic activity [EEG], eye movements [electrooculograms], and electromyographic activity [EMG] are recorded to identify the stages of sleep.)[15]
- Respiratory sleep (Indices are derived from polysomnograhic data that includes apnea index, apnea-hypopnea index, respiratory index, and snoring.)[15]
- Oxygen saturation (Pulse oximetry is used to monitor arterial oxyhemoglobin saturation.)[15]
- Electrocardiogram (Detection of arrhythmias during sleep.)[15]
- Body position (Position sensor is used to document patients' position and changes in position.)[15]
- Limb movements (An EMG of the anterior tibialis of both legs is monitored to identify limb movements during sleep.)[15]

Complications of a polysomnography are rare. The most common complication is skin irritation caused by adhesive used to attach electrodes to patients. Inconveniences are reported, such as difficulty sleeping in the laboratory setting, strange surroundings, discomfort related to the monitoring equipment, and time needed to spend the night at the sleep clinic.[15] Education of patients before a polysomnography include advisement not to consume alcohol or caffeine and to continue their usual medications on the night of the PSG, including sleep aids.[15]

SUMMARY

This article overviews electrodiagnostic tests that provide evidence-based data in the treatment and management of abnormalities in nerves and muscles. There is a focused review on cardiac tests, nerve-conduction tests, low-back pain tests, seizure and epilepsy tests, and obstructive sleep apnea electrodiagnostic tests. Case reports demonstrate how these electrophysiologic tests can provide specific data about the location and underlying causative factors of abnormalities in the nerves and muscles that routine diagnostic tests cannot differentiate.

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