Artifact and Recording Concepts in EEG

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Summary: Artifact is present when electrical potentials that are not brain derived are recorded on the EEG and is commonly encountered during interpretation. Many artifacts obscure the tracing, while others reflect physiologic functions that are crucial for routine visual analysis. Both physiologic and nonphysiologic sources of artifact may act as source of confusion with abnormality and lead to misinterpretation. Identifying the mismatch between potentials that are generated by the brain from activity that does not conform to a realistic head model is the foundation for recognizing artifact. Electroencephalographers are challenged with the task of correct interpretations among the many artifacts that could potentially be misleading, resulting in an incorrect diagnosis and treatment that may adversely impact patient care. Despite advances in digital EEG, artifact identification, recognition, and elimination are essential for correct interpretation of the EEG. The authors discuss recording concepts for interpreting EEG that contains artifact.

Key Words: EEG, Artifacts, Technology, Identification, Misinterpretation.

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The EEG is an electrophysiologic test used to understand the functional properties of the brain. Recording electrical potentials on the EEG that are not brain-derived waveforms represents artifact. Artifact is commonly encountered and is an essential component for routine visual analysis of the EEG (Aurlien et al., 2004). While some artifacts "contaminate" the EEG, others reflect physiologic functions that are crucial for a practical clinical correlation. It is the source (Fig. 1) and context of the generator (Fig. 2) that determine a normal or an abnormal feature in clinical use. Eye movements and the electrocardiogram (EKG) produce important artifacts that denote the level of arousal and define the cerebral−cardiac relationship. Nevertheless, both physiologic and nonphysiologic sources of artifact may act as source of confusion with abnormality and lead to misinterpretation adversely impacting patient care (Benbadis and Tatum, 2003; Krauss et al., 2005). Nonphysiologic artifacts may have multiple sources that require eliminating the interference created by an electrical generator either by manipulating the instruments of recording after the recording or by modifying the environment during the recording. Physiologic generators require recognizing, identifying, and describing the biologic behavior during the EEG when video is not available to permit an electroclinical correlation.

Recording concepts applied to EEG are the foundation for an accurate interpretation and subsequent clinical correlation (Table 1). Because EEG records three-dimensional cerebral sources in two-dimensional fields, the physical and functional factors that govern the believable cerebral fields and polarities of these sources must always be sought to distinguish a physiologic source from artifact. Furthermore, recognizing artifact is a learned experience. It reflects the ability to distinguish a mismatch between an expected electrocerebral potential and one that does not conform to an electrophysiologic head model. Waveforms should be localizable, have proper polarity, and possess an electrical field that has a believable cerebral origin. Alternating polarities that do not conform to a credible field in the absence of a skull defect suggest artifact.

The elimination of undesirable artifact from the EEG first requires the ability to accurately recognize waveforms as artifact. After recognition, source identification is necessary to implement resolution. Therefore, to obtain an optimal EEG recording, it is crucial that the EEG technologist and electroencephalographer function as a team. By working together to recognize, identify, and eliminate artifact, misinterpretation leading to inappropriate treatment (Benbadis and Tatum, 2003) may be averted. It is with patient care in mind that we discuss the challenges that artifact introduces into routine scalp EEG recording.

PRINCIPLES OF DIGITAL RECORDING

Microprocessor technology has ushered in new opportunities for the clinical neurophysiologist. Computer-based technology is available for essentially all neurophysiologic procedures but is especially suited to monitoring the EEG. Digitally based EEG monitoring systems are able to undergo acquisition, analysis, management, transfer, and storage of information in a way that is readily accessible (American Clinical Neurophysiology Society, 2006). Evolution of digital EEG has greatly improved the ability to record and display interpretable EEG but possesses both advantages and disadvantages (Table 2). Specific benefits include the ability to acquire large quantities of information, remontage, and institute software applications, such as spike and seizure detection programs or quantitative EEG capable of compressed spectral analysis (Young and Campbell, 1999). Disadvantages include the need for technical support, maintenance of equipment, unfamiliarity with the system, and greater cost.

Post hoc filtering (Fig. 3), montage selection, adjustment in sensitivity, and alteration of the display speeds enhance the ability to eliminate extracerebral potentials and are not available with analogue technology. Digital machines introduce certain computer-generated artifact that necessitates a facility for use and an understanding of computers. Systems that do not allow an adequate sampling rate "alias" and underrepresent electrical potentials (the Nyquist theorem) by producing signal frequencies that are below the true frequency of the waveforms. Most commercially available digital systems, however, account for this and sample at rates >200 samples per second, making aliasing a rare problem with routine recording. Some digital artifact is unique, such as multiplexing artifact, analogue−digital conversion artifact (i.e., the "sticky bit" seen with infrequent

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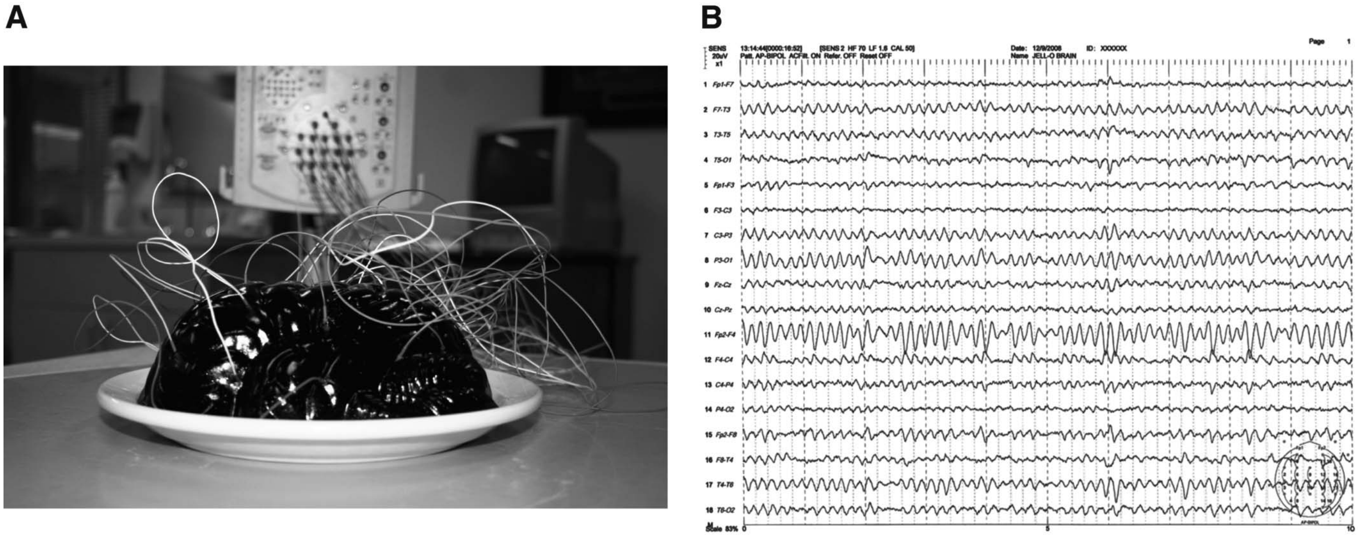

FIG. 1. **A**, Electrodes in a jello mold of the brain. **B**, The EEG of Jello mimicking mild diffuse slowing of the posterior dominant rhythm. Compliments of Ms. Judy Hayton, R.EEGT.

sampling), or "blocking" artifact because of amplifier saturation. These are usually discernible because of the unique and obvious digital artifact characterized by a morphology, polarity, or electrical field that does not conform to a known physiologic generator. With the advent of long-term EEG monitoring such as continuous EEG (cEEG) recording used in the intensive care unit and video-EEG monitoring used in the epilepsy monitoring unit, large volumes of data are acquired to be analyzed that often include substantial artifact (Fig. 4). Despite digitalization of EEG, artifact identification, recognition, and elimination will still be essential tasks of EEG interpretation.

NONPHYSIOLOGIC SOURCES

Extrinsic

Many EEG artifacts are generated by sources or electrical fields that are external to the patient. Some waveforms closely mimic cerebral potentials and appear epileptiform (Fig. 5). Artifacts may be complex and produced during patient movements by compromised electrical connections of the equipment or by faulty electrical connection of the patient to the electrode, such as an *electrode pop*, or appear as a complex repetitive discharge (Fig. 6). However, artifact may arise anywhere between the patient−electrode interface and the recording device. The emergence of artifact becomes increasingly augmented when the sensitivity or the duration of the recording increases.

Artifacts that arise either from the EEG equipment or from the environment are common extrinsic nonphysiologic sources. They may be obtained during routine recording but are more common in hostile environments outside the EEG laboratory, where more electrical currents are present. The most common source is alternating current present in the electrical power supply of nearby devices or outlets (Fig. 7). The EEG amplifiers can create inherent high-frequency noise because of molecular "movement" that occurs

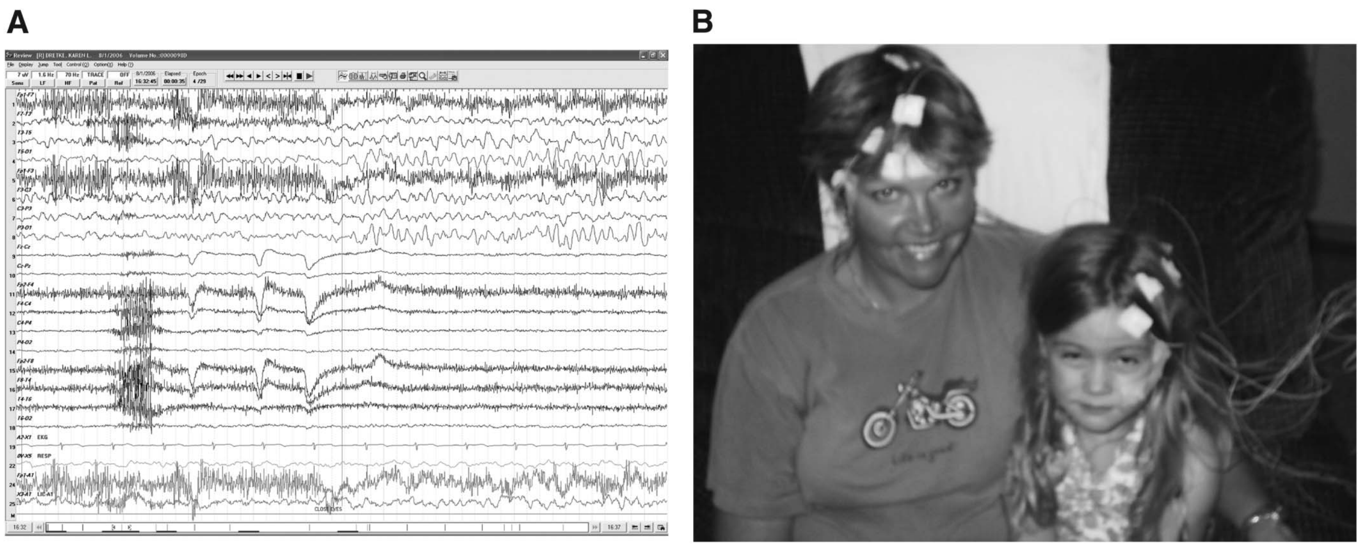

FIG. 2. **A**, Composite awake EEG at first glance appears to demonstrate left hemispheric slowing. However, independently, the sources (**B**) are both normal. Compliments of Ms. Judy Hayton, R.EEGT.

TABLE 1. Recording Concepts Related to Artifact Relative to Specific EEG Features

EEG Feature	Recording Concept
Activity or waveform confined to a single channel	Artifact until proven otherwise. The technologist should check impedances, regel, or replace the electrode to attempt artifact elimination
Complex waveforms and alternating double and triple phase reversals	Suggests artifact: a believable electrographic field that is inherent to all physiologic electrical generators must be present
Activity that appears at the end of a chain in an electrode array or appears in more than 1 noncontiguous head region	Might reflect a distant or an alternate physiologic generator. Application of extracerebral electrodes to regions of movement or proximity to disclose sources as artifact (i.e., eye movements or EMG) will help to localize the generator
Atypical generalized waveforms or potentials	Consider artifact and check the reference electrode, ground, or preamplifier connections to ensure integrity of the recording system
Very high or very slow frequencies < 1 or >70 Hz	Apply filter settings of 1 Hz to reduce low frequencies or notched filters at 60 Hz in the intensive care unit, which may be help reduce artifact
Periodic patterns are encountered in the EEG	Consider as artifact when identical morphology and periodicity occur

TABLE 2. Advantages and Disadvantages of Digitally Recorded Long-Term EEG

Advantages	Disadvantages
Capable of recording, analyzing, and storing large quantities of information	Requires a dedicated technical support team
Able to make post hoc changes in the recording (i.e., montages, filter settings, display, and speed)	Needs regular maintenance of the equipment and calibration
Able to upgrade new software applications (i.e., spike and seizure detection)	False detections of software applications may be cumbersome
Able to perform QEEG with spectrographic analyses	Initial investment cost for equipment and personnel high
Able to perform multimodal monitoring (i.e., several analyses from >1 QEEG applications)	Evolution of technology may make current techniques and software obsolete
Education of personnel for use may be easy with computer experience	Personnel may be unfamiliar with the recording system

QEEG, quantitative EEG.
Adapted from Young and Campbell, 1999.

within the electronic components of machines. This interference is an important artifact for EEG technologists to recognize and often picked up by a loose electrode. Depending on the country standard, 60 cycles per second in the United States (or 50 in Europe) may occur. By identifying 60-Hz artifact, corrective measures to facilitate interpretation may be undertaken. Importantly, ground loops from more than a single ground can be uncovered and eliminated, reflecting a concept that is critically important for patient safety to prevent electrical shock (Fig. 8). In addition, the magnetic fields created by electrical motors result in high-amplitude potentials capable of producing continuous or intermittent interference that mimics abnormal electrocerebral activity. Unique environmental electrical noise externally produced by ventilators, feeding/infusion pumps, and intravenous (IV) drips may create capacitive, inductive,

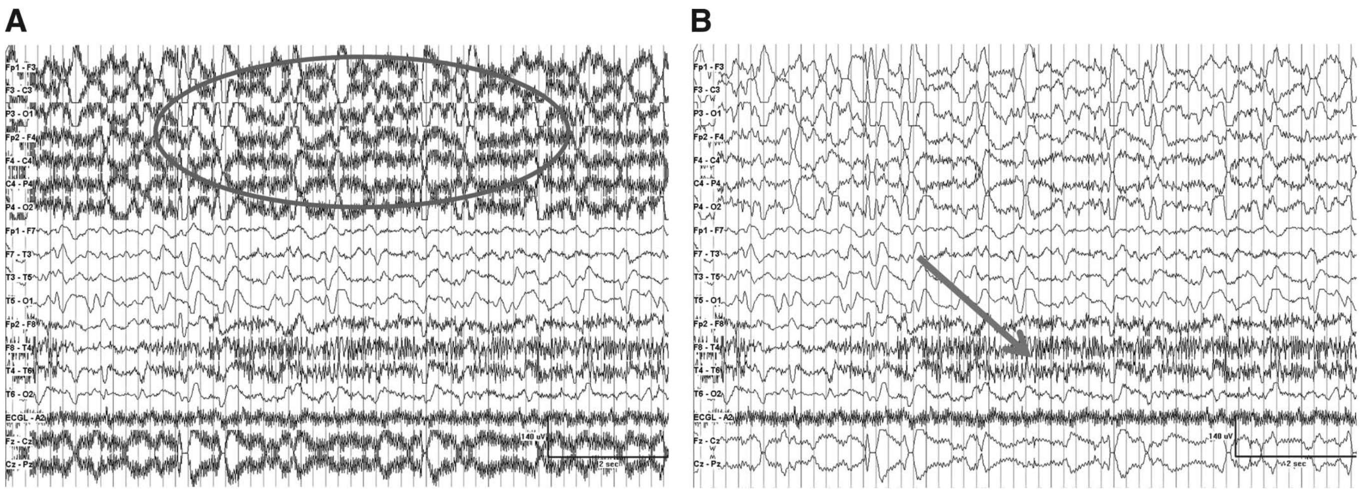

FIG. 3. **A**, Bilateral parasagittal 60-Hz artifact present obscuring a large portion of the tracing (red oval) in a patient with periodic discharges. **B**, Sixty-hertz artifact eliminated after postrecording application of the digital notched filter. Note the multiple electrode artifact evident but the persistent myogenic artifact in the right temporal derivations (blue arrow).

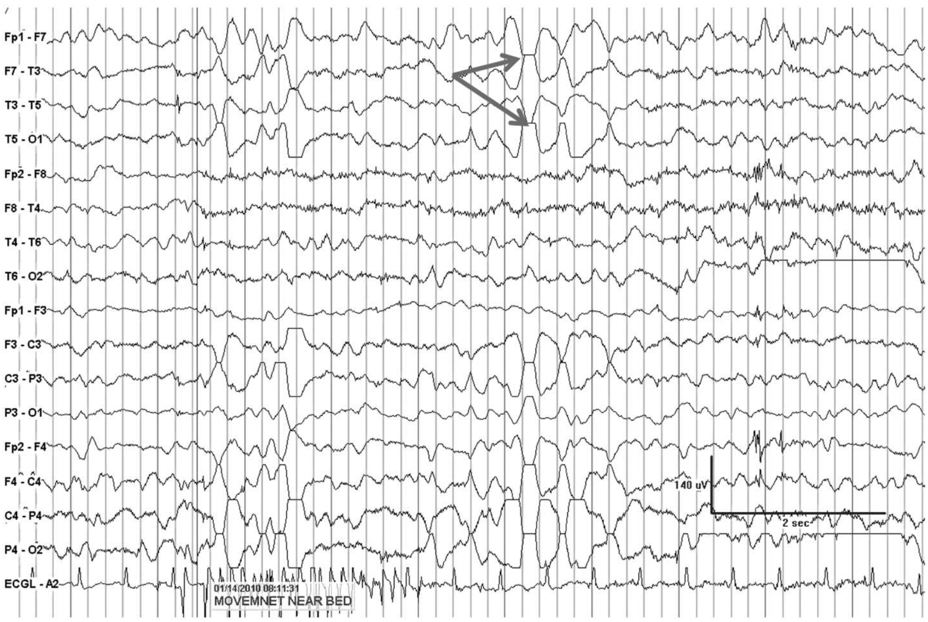

FIG. 4. Continuous EEG sampled from the neurologic intensive care unit before spectrogram interpretation suggesting a possible seizure. Note the double and triple phase reversals in seconds 3, 4, and 7 indicative of multiple electrode artifact.

and electrostatic artifacts not commonly seen on routine recording. Through direct observation, repeat impedance checks, and reapplication of the ground or surface electrodes when disrupted may validate source recognition and quick correction of artifact.

Equipment

The most common artifacts are because of an insecure connection between the *electrodes* and the *machine* (Reilly, 1999). When activity is confined to two channels on a bipolar recording or one channel on a referential recording montage (without an electrical field), the electrode artifact should be suspected and individual electrode impedances should be retested. Similarly, complex waveforms should always raise the suspicion of an artifact. Electrode artifacts are usually recognizable and eliminated by replacing or resecuring an electrode that generates artifact because of a compromised scalp−electrode interface. There may be a notable difference in frequency or amplitude, but if the electrical potentials are localized to a single electrode, then an important concept of recording is that it is to be considered an artifact until proven otherwise. Identifying an impedance >10 kΩ provides the foundation for artifact. Subsequently, changing the electrode pins to "move" the artifact will validate the extracerebral location given that "abnormal" cerebral activity will remain localized to the affected region on the head. By ensuring that an electrical field does not contain double and triple phase reversals that alternate polarity, identifying a nonphysiologic field will facilitate artifact recognition (Fig. 4). Adjacent channels may be "bridged" by electrolytic gel smeared between adjacent recording sites. The "salt bridge" is recognizable by adjacent channels appearing with very low amplitudes because ions freely travel

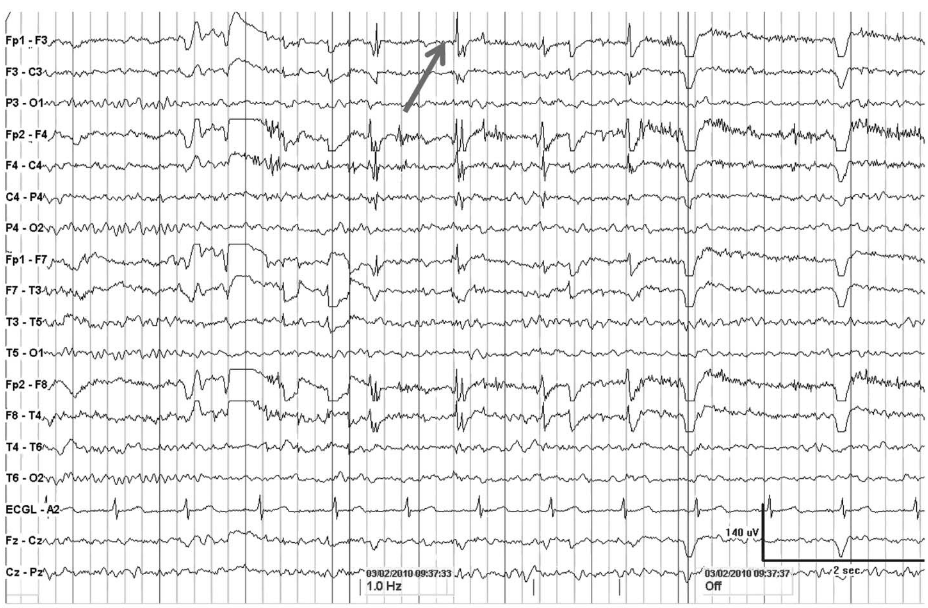

FIG. 5. Repetitive "spikes" and "polyspikes" in the anterior head regions because of a photoelectric effect during intermittent photic stimulation reflecting a "pseudo −photoparoxysmal response."

FIG. 6. A complex waveform simulating a focal seizure at F8 because of a single high-impedance electrode during intermittent photic stimulation. Intermittent "spikes" detected by the computer remitted after electrode reapplication.

between the electrodes and in essence zero out the recorded differences between the electrocerebral activities.

High-impedance electrodes are especially common during EEG recordings in the intensive care unit and operating room, known as electrically "hostile environments." Interference from nearby power lines can introduce "noise" into the biologic signals. By abrading the skin and with adequate use of electrolyte gel, a scalp–electrode biologic resistance (impedance) may be minimized. If there is an electrode mismatch of >5 kΩ through either limited abrasion (the epidermis has high impedance) or incomplete electrode contact with the scalp, then the discordant input to the amplifiers facilitates a greater risk for 60-cycle artifact. When diffuse 60-Hz artifact is encountered, then the integrity of the ground should be reassessed. In addition, ensuring proper patient–machine connections ensures that the integrity of patient safety has not been compromised. Supplemental use of filters, including a 60-Hz notched filter, can be applied to diminish artifact at discrete bandwidths during post hoc review.

Environment

Nonphysiologic artifact requires locating the source when possible, either by adjusting the instruments of recording or by modifying the environment where EEG is recorded. Environmental artifacts remain some of the most difficult to eliminate despite identification and correct source recognition. Many are beyond the technologist's control to adjust. Inductive, electrostatic, and capacitive artifacts may occur during the course of acquiring EEG from the patient through essential electrical wires that monitor other functions in addition to the EEG machine (Klem, 2003). Radio frequencies from nearby mechanical pumps or electrical devices in special care units can introduce intermittent or continuous high-frequency artifact. Electrical motors in beds, adjacent IV machines, tube feeding delivery systems, or other devices may create artifact that is difficult to identify or alter (Fig. 9). Inductive artifact may occur from electrical potentials created by IV macrodrip sources during droplets that conduct potentials *via* electrostatic forces from adjacent electrical wiring to the recorded EEG. This may give the false appearance of an epileptiform-appearing spike, polyspike, sharp transient, or paroxysmal burst, evident in a few or in multiple channels. The synchrony of the EEG potentials with another source, such as IV drip, validates the extracerebral source. Static electricity may be generated by clothing, linen, or the patient who may introduce artifact by electrical input introduced into nearby wiring or recording electrodes. This may subsequently create "pseudo-spikes" with complex morphologies and noncerebral distributions and fields. The representation of a regular, rapid, rhythmic burst as artifact is usually betrayed by the very brief duration and regularity. In addition, the electrode cable can act as a capacitor because of the multiple insulated wires that are contained within a single cable. Subsequent movement of the cable is able to generate waveforms that simulate interictal epileptiform discharges (IEDs) (Fig. 10). Closer inspection of these potentials will usually reveal a noncerebral field or waveform polarity.

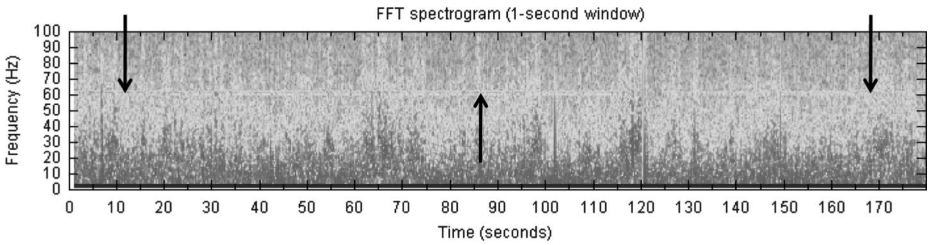

FIG. 7. Frequency versus time spectrographic display of 60-Hz artifact illustrating the discrete representation of this frequency (black arrows) using the fast Fourier transform (FFT). Note the broad range of frequencies that exist, with some reaching 100 Hz.

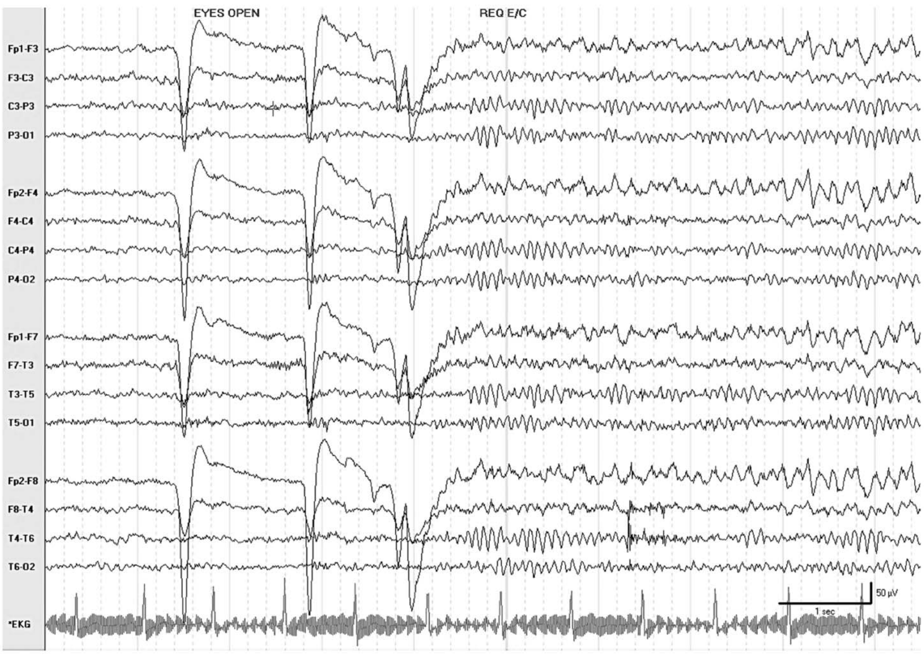

FIG. 8. Sixty-hertz artifact in the EKG where a double ground was identified and eliminated during an EEG on a patient in the emergency department after a possible seizure.

Intrinsic

Internal interference because of biologically active magnetic fields induced by cardiac (i.e., pacemakers or assist devices) or neurologic (i.e., neurostimulators) devices may contribute to a variety of artifacts that challenge the reader. For correct identification, regularity is the key, and regularity is the key to their recognition, independent of morphology. Cardiac pacemakers are medical devices that use electrical impulses to regulate heart rhythm and may be an intrinsic nonphysiologic source of electrical artifact on the EEG. Some permanent pacemakers may be combined with an implantable defibrillator and produce high-voltage, repetitive, brief electrical potentials that appear periodically or continuously depending on the mode of stimulus delivered. When pacemaker-generated artifact is present, EKG artifact may be misinterpreted as periodic lateralized epileptiform discharges in the EEG (Fig. 11). Both continuous and on-demand mode pacemakers using either single- or dual-chambered stimulation help resynchronize the left ventricular outflow in patients with heart failure or cardiac arrhythmias (Cleland et al., 2005; Gregoratos et al., 1998) but act as a source of artifact (Fig. 11). Other electrical devices, such as vagus nerve stimulators, deep brain stimulators, and responsive

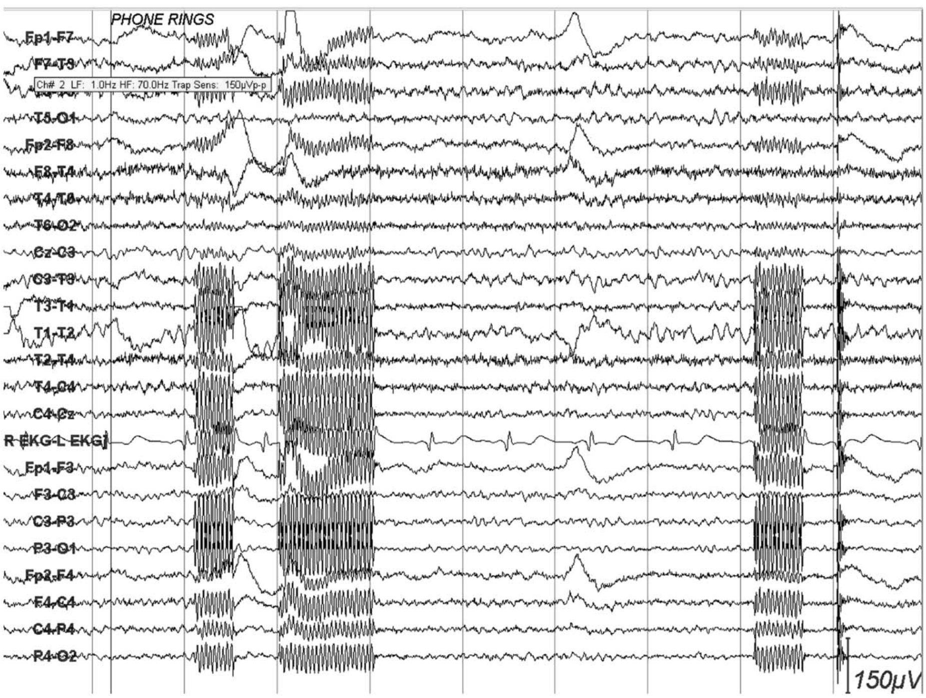

FIG. 9. Telephone ring with a unique artifact pattern that may obscure interpretation of the EEG.

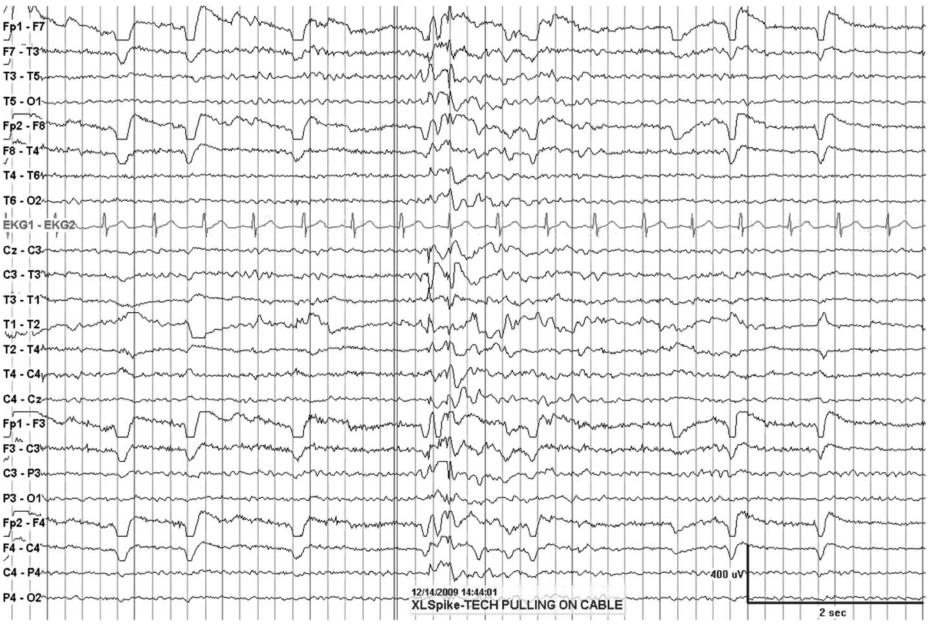

FIG. 10. Cable artifact incurred during transfer of the amplified multiplexed digital signal from the patient *via* cable telemetry to the epilepsy monitoring unit. Note the similarity to a burst of irregular generalized spike-and-wave discharge.

neurostimulators, may create artifact. This may occur when electronic circuitry is surgically implanted and produces undesirable signals that internally affect the EEG. In this way, the unshielded EEG electrodes act as an antenna for extracerebral sources of stimulator-induced electrical fields to produce artifact. This is similar to the extraneous effect created by nearby power lines to generate 60-Hz interference through induction of magnetic fields from nearby electrical current flow causing electrode depolarization and resultant noise (Tatum, 2008).

PHYSIOLOGIC SOURCES

Routine Recording

Identifying the mismatch between potentials that are generated by the brain from activity that does not conform to a realistic head model is the foundation for recognizing artifact. The means to judge the mismatch is based on a believable localization, polarity, and field. The technologist helps monitor, eliminate, or camouflage the extracerebral sources when bioelectric fields introduce artifacts

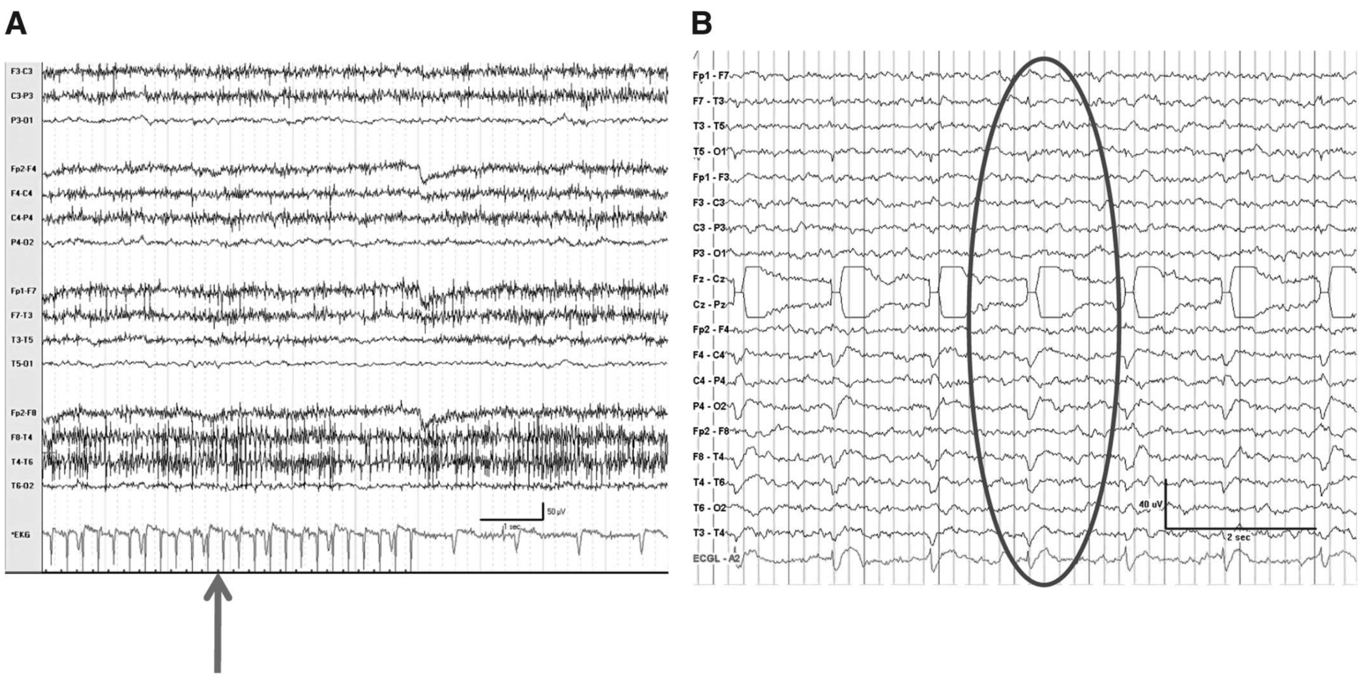

FIG. 11. **A**, Prominent photic stimulation artifact that makes the EKG appear as ventricular tachycardia in the first 6 seconds (red arrow) in a patient with a DDD pacemaker. **B**, Electrocardiogram demonstrating periodic artifact the mimics periodic lateralized epileptiform discharges (blue oval).

FIG. 12. Electrooculogram channels (above the EKG) with left eye linked to A1 and right eye linked to A2 demonstrating out-of-phase reversal seen during vertical eye movements that could be misinterpreted as frontal intermittent rhythmic delta activity.

that limit interpretation during routine EEG recording (Klass, 1995). Physiologic sources of artifacts are often encountered during routine recording and include ocular, orobuccal, cardiac, and myogenic and defects of the cranial bone structures.

Eye movement artifacts are seen in virtually every conscious individual during routine EEG and are crucial to correctly identify different stages of sleep. Vertical eye blink artifact during wakefulness, slow rolling eye movement artifact in drowsiness, and rapid eye movement artifact in rapid eye movement sleep are essential to discern normal levels of arousal. Eye movement artifact on EEG is generated by an inherent corneoretinal resting potential. An electrical dipole normally exists in most biologic tissue, including the eye. The cornea is electropositive relative to the retina and generates a direct current potential difference that can be measured in the horizontal or vertical plane. An electrooculogram is constructed quickly and easily by applying electrodes above and below the eye (Fig. 12). These use

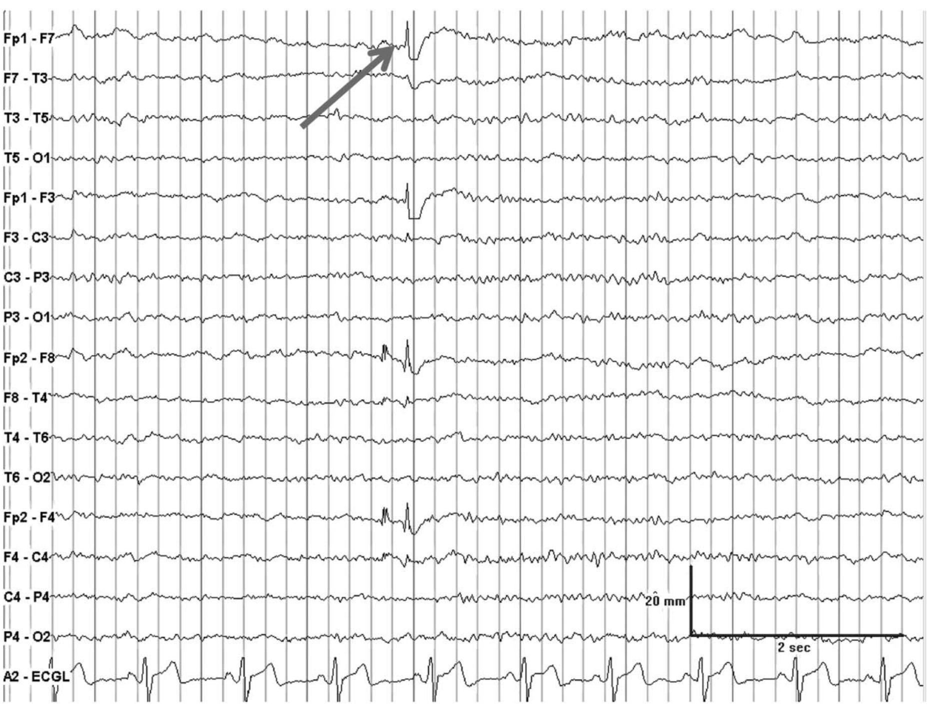

FIG. 13. Frontalis-induced myogenic potentials mimicking abnormal bilateral frontopolar spikes.

FIG. 14. EEG demonstrating diffuse bursts of myogenic artifact from swallowing and coughing and intermittent bitemporal "polyspikes" because of chewing artifact caused by temporalis muscle contraction in the seventh to ninth second of the EEG.

one to four channels that help differentiate cerebral potentials that are *in phase* with extracerebral potentials that are *out of phase* (Bonnet et al., 1992). In-phase deflections characterize cerebral dipoles (or a generator below the electrodes), and out-of-phase deflections occur with eye movement artifact reflecting a generator location that lies between the recording electrodes. Horizontal and skew eye movements are best identified when opposite polarities for phase reversal are noted at the F7/F8 derivation. It is the positive slow-wave phase reversal during conjugate horizontal eye movements that reflects the site closest to the cornea signifying the direction of gaze.

Myogenic (muscle) artifact is another commonly observed artifact on EEG. The temporalis and frontalis are the principal

FIG. 15. Dental artifact mimicking IEDs from an oral source. Note the positive phase reversals in the parasagittal derivations denoting the extracerebral source.

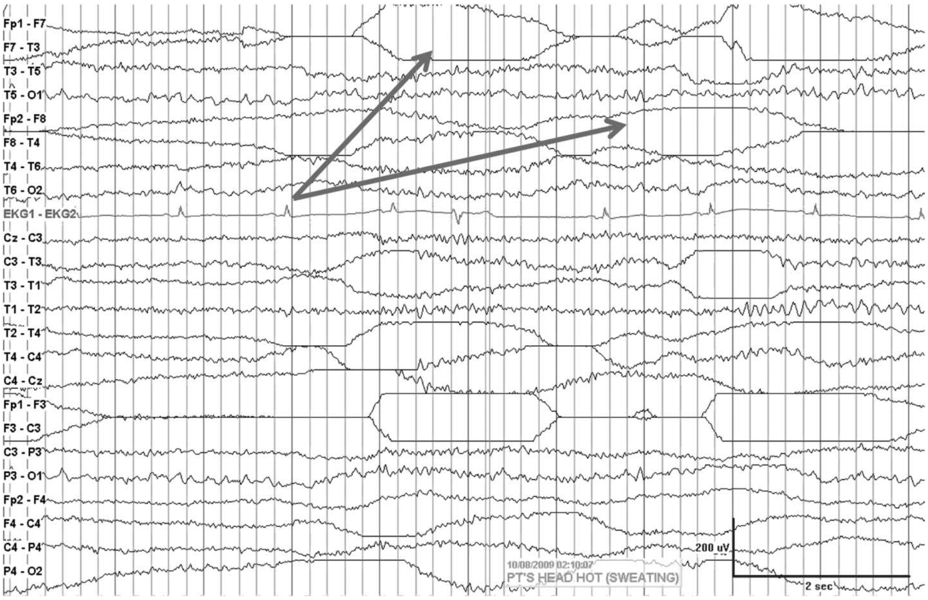

FIG. 16. Sweat artifact preventing interpretation of the EEG.

muscles that produce myogenic artifact on EEG (Fig.13). During recording, by asking a patient to "open your mouth" may help alleviate bitemporal myogenic artifact incurred from contraction of the masseter muscles or with jaw clenching. Lateral rectus "spikes" may appear during eye movements and simulate IEDs (see Fig. 11). These represent motor unit potentials of extracerebral origin recorded from the lateral recti and other muscles of the globe that are proximate to the lateral orbit and are best identified in the F7/F8 derivations. A slow potential because of the higher amplitude direct current may be created by an active dipole during eye movements. The appearance together of the lateral rectus spike and direct current potential mimics a spike-and-wave that may lead to an erroneous interpretation of the EEG. Similar to the lateral rectus spikes seen with rapid eye movements, frontalis muscle contraction during periocular movement may elicit sustained or individual myogenic potentials that mimic IEDs (Klem, 2003). Activation with intermittent photic stimulation, or eye flutter artifact elicited at frequencies of <6 Hz, may mimic generalized spike-and-wave when coupled with myogenic potentials and create a "pseudo−photoparoxysmal response" (Fig. 5A) with muscle spikes time-locked to the flash frequency. Newer techniques of muscle artifact removal may help improve the interpretation of the ictal scalp EEG (De Clercq et al., 2005). However, a pitfall that exists is that it can render a record more rhythmic in appearance.

Cardiac muscle is another important source of EEG artifact. Recording the EKG during an EEG is essential to monitor the

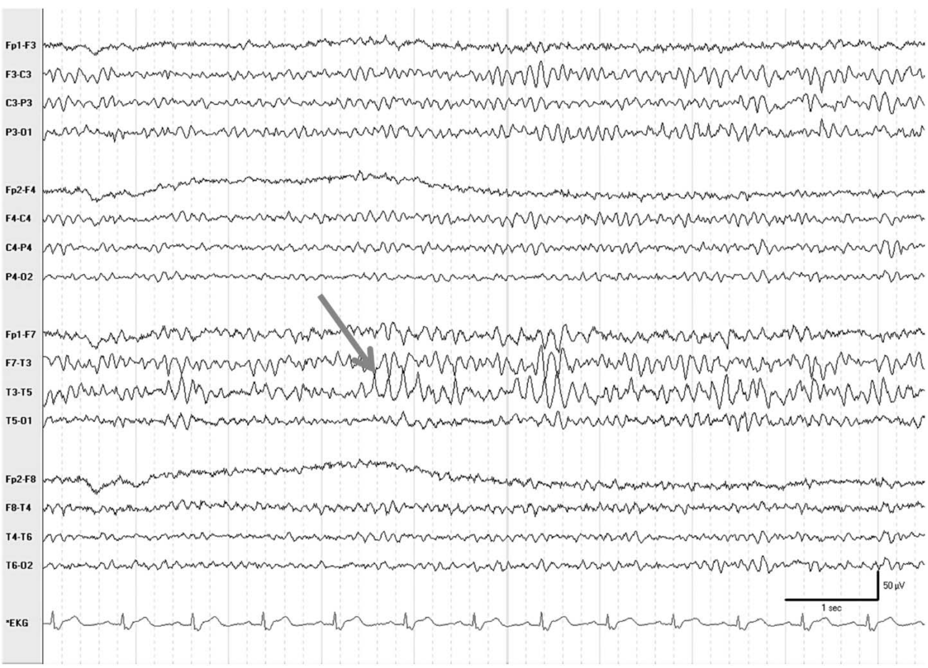

FIG. 17. Left temporal "sharp waves" in a patient after a left temporal lobectomy for epilepsy. Note the higher amplitude waveforms because of breach in the skull.

cardiac−cerebral relationship. Channel I of the EKG is approximated on the chest by electrodes linking the left and the right thoraxes. Bipolar recording identifies the QRS complex as the spread of electrical activity within the ventricular myocardium. Periodic EKG artifact may appear in the EEG that may mimic an IED or a periodic lateralized epileptiform discharge, although the amplitude and regularity make it easy to recognize (Fig. 11). Bipolar montages may reveal "focal" diphasic waveforms in the temporal derivations of the left hemisphere because of the vector created by the electrical conduction of the left ventricle generating the QRS complex. Opposite polarities of the R wave from the EKG may be seen at the left (negative) and the right (positive) ear electrodes. The artifact produced by the EKG should be readily identifiable by the regularity and periodicity synchronizing EEG with the EKG. Referential montages often accentuate EKG artifact, especially with ear references or longer interelectrode distances. Additionally, periodic epileptiform discharges may be more likely suspected when high sensitivities (i.e., electrocerebral inactivity recordings recordings) are used. Patients who are overweight or have short stocky necks may be predisposed to this type of EKG artifact because the QRS complex is amplified. Reduction in EKG artifact may be possible if the technologist is able to alter the position of the head and neck. Alternatively, linking the ears as a reference may cancel the EKG artifact produced by cardiac muscle contraction and the resultant electrical potential that is produced. Additional artifacts produced by the heart include pulse artifact or movement-generated (ballistocardiographic) artifact that arises from the mechanical force of contraction. These usually arise in a single channel with pulse artifact but may give rise to a lateralized or diffuse rhythmic slow wave after the QRS complex that is typically time-locked by 200 milliseconds. Stabilizing the head with towels under the neck often eliminates this problem when head movement is the generator. Similarly, when an electrode is positioned over an artery and produces pulse artifact, it may produce periodic waveforms that are time-locked to the cardiac rhythm. Elimination of the artifact can be obtained by pressing or moving the electrode to an adjacent region on the scalp away from the artery.

Glossokinetic or tongue movements may create significant artifact in the EEG (Fig. 14). Similar to the eye, the tongue is a bioelectric dipole, with the tip of the tongue negative relative to the root. During oropharyngeal motion, a direct current potential is produced that is often diffusely seen with frontal and temporal predominance. Cephalad−caudad motions may be produced by tongue movements involuntarily while speaking or when swallowing and mimic intermittent bursts of abnormal slowing or frontal intermittent rhythmic delta activity on the EEG. However, similar artifact may be reproduced when asked to say "lilt" or "tatata, lalala, gagaga" identifying similar patterns as artifact more conclusively. Validation is possible through application of tongue movement monitors with electrodes placed above and below the mouth over the cheek and chin. Using a bipolar montage, opposite phase reversals are evident with tongue movement in a similar fashion to those recorded during eye movements. Dental artifact may mimic spikes because of electrical properties created by metal amalgam that is used for filling caries (Fig. 15).

Physiologic respiratory artifacts are crucial to observe during EEG. Respiratory artifacts will allow sleep−wake differentiation relative to "spells" in infants and young children with abnormal events during sleep or rapid latency/frequency of sleep transitioning. In adults, sleep-related movements, such as snoring, periodic leg movements, myoclonic jerks, and arousal patterns, may be suggested by the pattern of myogenic or movement artifact that appears on the EEG. Sweat artifact will have very slow (0.25 to 0.50 Hz) and detectable appearances that are readily identifiable obscuring underlying cerebral rhythms (Fig. 16). Rhythmic artifact may also be encountered in the EEG and become lateralized or generalized depending on the source. Amplitudes from movement monitors will be of greater amplitude than those recorded from the scalp. The time-locked synchrony of a movement with the appearance of a waveform on the EEG will become evident, suggesting artifact. If this occurs during sleep, then a definitive investigation may be obtained with overnight polysomnography.

Other sources, such as bone, may introduce artifact with rhythms because of a focal electrophysiologic breach caused by an altered architecture of the skull or by artificial bone that may become overinterpreted as focal IEDs (Fig. 17). The breach effect is best exemplified using bipolar recordings to permit better spatial contrast. EMG artifact at the breach is readily differentiated by the presence of the "abnormality" at a location that overlies a common muscle (i.e., temporalis or frontalis), by higher frequency components (duration of spikes <20 milliseconds) caused by the motor unit potentials, and by the inconsistent appearance that is minimized or eliminated during sleep or with special maneuvers, such as jaw relaxation.

The major and the most important physiologic artifacts in EEG are *cardiac* and *ocular* sources. Polygraphic recording with simultaneous monitoring of several physiologic systems and behavioral variables may help accurately represent the EEG by illustrating artifact. During bipolar recording, extra electrodes may be applied several inches from a suspected source of artifact to help monitor and document motor movements if they are present. Tremor-induced artifact may even raise a differential diagnosis based on frequency and amplitude characteristics that can be more attributable to a specific tremor, such as those of Parkinsonian (usually slower and higher amplitude) origin.

Recording Sites

Some areas in the hospital are electrically complex (hostile environments) and are predisposed to forming artifacts (Ebersole, 2003). The most common source of electrical artifact is because of alternating current from nearby power supplies, devices, or outlets that create 60-Hz interference of EEG interpretation and are the norms in special care units. The magnetic fields created by electrical motors may also result in high-amplitude potentials that are continuous or intermittent. The distribution may be diffuse or focal and restricted to a single channel. Both extrinsic and intrinsic electrical noise can result in artifact that may obscure the EEG and mimic IEDs. External electrical noise produced environmentally by ventilators, feeding/infusion pumps, and IV drip may create capacitance, inductance, and electrostatic artifacts. Internal interference because of biologically active magnetic fields may be introduced by ventricular assist devices, cardiac pacemakers, and neurostimulators that contribute to a variety of artifacts. About recording concepts, *intermittency is the rule, and regularity the clue* to identifying artifact regardless of the morphology. Technologists trained to recognize, identify, and eliminate artifact when it is encountered are critical to optimize a recording. Application of additional extracerebral monitors, repositioning, directing acceptable electrical modification, and documenting medication administration during the recording provide crucial information for an interpretation where clinical correlation is intuitive.

CONCLUSIONS

Many nonphysiologic and physiologic artifacts are encountered in the process of recording EEG (Stern and Engel, 2005). Some artifacts are essential to understand functions of the brain; however, many artifacts are not and limit useful interpretation of the EEG. Identifying and recognizing artifact to "troubleshoot" and eliminate or camouflage sources of artifact requires a coordinated team composed of technologists, nursing, personnel experienced in informatics, and neurophysiologists to ensure optimal EEG recordings. The American Society of Electroneurodiagnostic Technologists, Inc, in conjunction with the Board of Registration for Electroencephalographic and Evoked Potential Technologists has set standards for recording EEG. The American Clinical Neurophysiology Society in conjunction with the American Board of Clinical Neurophysiologists has established guidelines for physician interpretation and reporting. With the unique and complex nature imposed by the many artifacts that exist, even "seasoned" technologists and electroencephalographers will still be challenged to recognize every artifact that may jeopardize correct interpretation of the EEG for clinical correlation.

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