6 Artifacts

SUMMARY
EEG artifacts are recorded signals that are non-cerebral in origin. They may be divided into one of two categories depending on their origin: physiological artifacts or non-physiological artifacts.

6.1 Physiological artifacts arise from a variety of body activities that are either due to (1) movements: movements of the head, body, or scalp (e.g., pulsations of the scalp arteries, scalp muscle movement), (2) bioelectrical potentials: from moving electrical potentials within the body (such as those produced by eye, tongue and pharyngeal muscle movement), or electrical potentials generated by the scalp muscles, heart or sweat glands, or (3) skin resistance changes: due to sweat gland activity, perspiration and vasomotor activity.

6.2 and 6.3 Non-physiological artifacts arise from two main sources: (1) external electrical interference from other power sources such as power lines or electrical equipment, and (2) internal electrical malfunctioning of the recording system, arising from recording electrodes, electrode positioning, cables, amplifiers, pen motors or the paper drive.

6.1 ARTIFACTS FROM THE PATIENT
One of the most common pitfalls of EEG interpretation is to mistakenly identify non-cerebral potentials as originating from the brain. Although artifacts can often be recognized by their characteristic shape and distribution, in many cases artifacts can only be identified by the technologist during the recording. It is therefore essential that the technologist be skilled in the identification and elimination of artifacts. The patient and record must be closely observed throughout the recording and notations made whenever artifacts occur.

In many instances, artifacts can be immediately recognized by applying the following two rules of spatial analysis:
(1) Medium to high amplitude potentials that occur at only one electrode usually do not arise from the brain. Cortically generated potentials exhibit a physiological distribution over the scalp characterized by a potential maximum that gradually drops off in voltage with increasing distance across the scalp. Therefore, a prominent waveform that can only be recorded from one electrode is artifact until proven otherwise.
(2) Repetitive, irregular or rhythmical waveforms that appear simultaneously in unrelated head regions are usually not cerebral in origin. Evolving electrographic seizures or abrupt background abnormalities typically spread to involve adjacent electrodes. They do not jump to opposite ends of the head or to non-homologous (non-mirror image) areas of the opposite hemisphere.

6.1.1 Blinking and other eye movements. These movements cause potential changes that are picked up mainly by frontal electrodes, although they may extend into central and temporal electrodes. A simple but useful way of understanding eye movement artifact is to picture the front of the eye as a positive charge that either moves towards or away from the recording electrodes. The electrodes that record the largest potential change with vertical eye movements are Fpl and Fp2 because they are placed directly above the eye. The electrodes that record the largest potential change with horizontal (lateral) eye movements are F7 and F8 because they are approximately lateral to the eyes. In a typical longitudinal bipolar montage an upward vertical eye movement (e.g., eye closure, eye blink) will produce a downward deflection in Fpl-F3 or Fp1-F7 because the positively charged cornea is moving towards Fpl making it increasingly more positive (Figs. 6.1 and 6.3). If the eyes move to the left, in a lateral direction, then F7 will record the greatest increase in positivity and F8 will record the greatest negativity (in this case the negativity recorded by F8 is caused by a loss of positivity as the cornea moves away from it). Therefore the pen will deflect up in Fpl-F7 and down in F7-T3. The opposite will occur in Fp2-F8 and F8-T4. Notice that lateral eye movements make the aforementioned pairs of channels point in opposite directions (Fig. 6.1, example 5).

Rapid eye movements may cause jagged artifacts (Fig. 12.2). Muscle artifact may appear along with eye movements. Lateral eye movements may be preceded by a single sharp muscle potential sometimes referred to as a lateral rectus spike. Rarely, a lateral rectus spike in combination with the eye movement artifact may mimic abnormal epileptiform spike and wave activity.

Eye movement artifacts have long been believed to be due to movement of the eyeball which carries a steady electrical charge, the cornea being about 100 mV positive with respect to the retina. However, it seems that movement of this corneoretinal dipole is not necessary to produce blink artifacts: movements of the lids across the eyeball can produce a similar artifact. Moreover, some low amplitude eye movement artifacts can be recorded even after removal of the eye including cornea and retina, suggesting that movement of residual membranes deep in the orbit can cause artifacts.

Eye movement artifacts in the EEG can usually be identified by their frontal distribution, their symmetry and their characteristic shape. The amplitude of vertical eye movements in longitudinal bipolar montages either remains the same or (more often) decreases in successive channels moving from anterior to posterior: the amplitude of vertical eye movements never increases in a more posteriorly located channel. The frontal origin of eye movement artifacts may remain unclear in referential montages; particularly those using ear electrodes that may be contaminated by eye movements. Repetitive eye movements may mimic cerebral rhythms; slowly repetitive eye movements may closely resemble bilaterally synchronous frontal slow waves, and repetitive eye movements associated with lid flutter during eye closure may cause frontal rhythms of about 10 Hz. As a general rule, however, it is best to assume that activity in the alpha frequency range localized to the frontopolar head regions is eye movement artifact until proven otherwise.
Asymmetric eye movements usually occur under one of the following circumstances: (1) decreased movement of the eye or eyelid of one eye, (2) absence of an eye or destruction of the retina of one eye, (3) asymmetric electrode placement, or (4) a frontal skull defect. In the case of a missing part or breach of the frontal bone, the eye movement artifact is lower in amplitude ipsilateral to the skull defect. This is thought to occur by virtue of a shunting of the eye potential through the skull.

Eye movement artifacts can be identified during the recording by observing the patient and correlating eye blinks and movements with pen deflections. Even eye movements during eye closure can usually be seen through the eyelids. These movements can be further identified by their disappearance when the patient complies with the instruction to keep his eyes closed and still. If unable to do this, the patient may be told to place his fingertips on his eyes, or the technician may hold the eyelids and at the same time monitor eye movements felt through the eyelids. Taping cotton balls over the eyes may stop some eye movements but obscures observation of eye movements and interferes with recording the effect of other eye opening and closing on the EEG. If eye movements cannot be stopped and cannot be distinguished from frontal slow waves in the EEG, they may be monitored by electrodes placed near the eyes and linked so that eye movements can be distinguished from cerebral activity. Recordings from these linkages should be displayed simultaneously with, and next to, the recordings of frontal slow waves. Comparison of these recordings usually allows clear distinction between eye movement artifact and cerebral slow waves.

6.1.2 Muscle artifact. Muscle activity causes very short duration potentials that usually occur in clusters or periodic runs. If they recur as discrete potentials with the same shape and in the same distribution (Fig. 6.2), they may resemble cerebral spike discharges except that most cerebral spikes are of much longer duration than muscle action potentials. If they recur in rapid bursts of discharges (Fig. 6.2), they can produce several different types of potentials that can merge and obscure the recording of cerebral activity. Muscle artifacts from scalp and face muscles occur mainly in the frontal and temporal regions but may be recorded by electrodes nearly anywhere on the head. Reducing the settings of the high frequency filter will reduce the amplitude of these fast potentials, but will also change their form (3.5.2) so that single muscle potentials may look more like spikes, and repetitive potentials may look like cerebral fast waves (Fig. 6.2).

Muscle artifact, even if not related to recognizable movement by the patient, is usually easily identified by its shape and repetition. It can be reduced and often eliminated by asking the patient to relax, drop the jaw or open the mouth slightly, or change position. Artifact from a single electrode can sometimes be stopped by gently pushing on that electrode, by stroking or massaging the skin near the electrode, or by reapplying the electrode. Reducing high frequency filter settings is only of limited value because of the aforementioned distortion.

A few specific conditions cause special electrographic patterns. Repetitive movements such as chewing, blinking or tremor may give rise to a combination of fast muscle and slow movement artifacts which may resemble cerebral discharges, especially if the combinations repeat with similar shape. Such rhythmical combinations may occur in tremor of Parkinson's
**6.1.3 Movement artifact.** Movements of the head and body or of the electrode wires can cause artifacts even if all electrodes make good mechanical and electrical contact. Movement artifacts are rhythmic in tremor, chewing and sucking (Fig. 6.2), breathing, or repetitive head movements, caused by the force of the blood rushing into the head (also referred to as cardioballistographic artifact).

Movement artifacts are usually easily recognized during the recording by their association with visible movements and should be identified by indicating the moment and kind of movement on the chart. Many movement artifacts can be abolished by asking the subject to stop moving. In persons who do not comply, for instance in restless or confused patients, infants and children, patients having seizures, tremors or other movement disorders, the movements must be reduced as far as possible.

The main difficulty for the electroencephalographer occurs when the technologist has failed to document in writing on the record the occurrence of movements producing artifacts. Unfortunately, asking the technologist to try to recall if specific waveforms were associated with body movements is almost always a useless exercise. In addition to carefully observing the patient, the recording, and making frequent notations about movements, movements may be recorded and sometimes identified with special monitors (e.g., accelerometers). In addition, the ECG channel sometimes serves as an effective monitor for detecting gross body tremors and other movements.

**6.1.4 Electrocardiogram.** Potential changes generated by the heart are picked up in the EEG mainly in recordings with wide interelectrode distances, especially in linkages across the head and to the left ear, particularly in subjects who are overweight. The artifact may appear in all channels using a common reference, or only in one or a few channels. Small artifacts reflect mainly the R wave of the electrocardiogram (Fig. 6.2). Larger artifacts may reflect additional components of the electrocardiogram. Very large artifacts are often produced by interference from a cardiac pacemaker (Fig. 6.3). The R wave usually appears maximally over the left posterior head regions as a positive sharply contoured waveform and, with lower amplitude, over the right anterior head region as a negative waveform. This is because the main cardiac vector producing the R
wave is positive and directed diagonally from right to left and from anterior to posterior. Thus, in a longitudinal bipolar montage the ECG artifact, if present, appears as an upward deflection in T3-T5 and a downward deflection in T5-O1 (i.e.,

Fig. 6.3. Non-biological artifacts. 1: 60 Hz interference before and after turning on the 60 Hz filter (60-). 2: Artifacts induced by a nurse walking near the patient. 3: Cardiac pacemaker artifacts. 4: 'Electrode popping' artifacts (arrows) from the left posterior temporal electrode making poor contact. 5a and 5b: 'Paper stop' artifacts (arrows) due to intermittent failure of paper drive.

positivity at T5). If the head is turned, then the electrodes situated on the left and posterior with regard to the torso will still record the maximum positivity. The ECG artifact often changes amplitude and distribution as the patient breathes because breathing changes the position of the heart with respect to the head. Premature ventricular contractions are usually maximal over the posterior head regions but are greater in amplitude and duration than the normally conducted heart beat. Their intermittent occurrence in the absence of an ECG monitor may give the impression of abnormal posterior sharp waves or rhythmic delta activity. In contrast to most other artifacts, the heart beat artifact cannot usually be eliminated by corrective actions during the recording. It is rarely the only manifestation of a bad electrode contact and can therefore not usually be abolished by improving the contact or replacing the electrode. Referential recordings combining both ears as a reference tend to show less heart beat artifact than referential recordings to one ear. In approximately 80% of individuals a non-cephalic reference montage using a balanced neck to chest electrode pair as the reference will produce a recording free of ECG artifact. This consists of one electrode on the neck and one on the sternum, connected through a variable resistor that may be adjusted to null the ECG components affecting both these electrodes. If there is any doubt whether sharp waves are due to the heart beat artifact or to cerebral activity, the technician should record the heart beat in one channel and compare it with the timing of the suspected sharp waves.

If the heart beat has not been monitored during the recording and the EEG reader has difficulty in distinguishing heart beat artifact from cerebral activity, it is useful to measure the interval between clear heartbeat artifacts and apply this measure to subsequent suspicious events to determine whether they have equal intervals and therefore are likely due to heart beat, or fall into the interval between events and are less likely of cardiac origin. However, this method may fail in extrasystoles and other cardiac arrhythmias, especially those altering the shape of the heartbeat artifact.

6.1.5 Pulse wave artifact. Periodic waves of smooth or triangular shape may be picked up by an electrode on or near a scalp artery as the result of pulse waves producing slight changes of the electrical contact between electrode and scalp. This is more likely to happen with electrodes in the frontal and temporal areas than with electrodes in the posterior head regions.

This artifact is recognized by its usually regular recurrence. If the heartbeat artifact is picked up in the same recording, it precedes the pulse wave artifact by a constant interval (Fig. 24.2). If necessary, the pulse wave artifact may be identified by simultaneous recording of the heartbeat. If it is eliminated by reapplication of the electrode at some distance from the pulsating artery, the new electrode position should be indicated on the chart.

6.1.6 Skin potential. There are 2 important artifacts that arise from skin changes. Perspiration artifact consists of slow waveforms that are usually greater than 2 s in duration. Pen-
expiration alone causes slow shifts of the electrical baseline by changing the impedance or contact between the electrode and the skin. In addition, sweat gland activity produces slowly changing electrical potentials that are recorded by the electrodes. Less often rhythmic potentials are produced, particularly if stainless steel or unchlorided silver electrodes have been used. Perspiration artifact almost always appears in more than one channel, but may be lateralized or asymmetric. Therefore, very slow localized waveforms (greater than 2 s in duration) should never be considered unequivocal evidence of an underlying cerebral dysfunction unless accompanied by other changes such as slowing in the theta frequency range, or amplitude changes in the alpha and beta range. The simultaneous occurrence of perspiration artifact and generalized background slowing should always raise the question of hypoglycemia. Perspiration artifact can be reduced by cooling the patient and drying the scalp with a fan or alcohol.

The second less common artifact produced by the skin is the sympathetic skin response (SSR) also known as the galvanic skin response, or psychogalvanic skin response. The SSR consists of slow waves, each with a duration of 0.5–1 s (1–2 Hz), that last 1.5–2 s with 1–3 prominent phases (Fig. 6.4). The first phase may be negative or positive in polarity. The SSR represents an autonomic response produced by sweat gland and skin potentials mediated by unmyelinated cholinergic sympathetic fibers in response to a sensory stimulus or psychic event. It is more likely to be recorded as the environmental temperature increases. The SSR may be difficult to identify correctly, particularly if it occurs in only one or two channels. Like other isolated delta wave artifacts its presence can be suspected if it is combined with normal background activity. It usually appears in the frontocentral channels in longitudinal bipolar montages and produces a characteristic triple phase reversal in transverse bipolar montages. SSR can

Fig. 6.5. Palatal myoclonus. Each involuntary movement of the pharynx and palate are marked by the fast paired deflections. The 10–20 electrode derivations that typically show this artifact best are those referenced to A1 and A2. This is clearly illustrated by the prominence of the artifact in the referential montage compared to the bipolar montage. Courtesy Dr. B.F. Westmoreland, Mayo Clinic.

be confirmed by simultaneous monitoring using one electrode placed on the palm (an area with abundant sweat glands) and one placed on the dorsum of the same hand. The skin should not be abraded during electrode application because damage to the skin can attenuate the response. A lower gain and longer time constant are used than in routine EEG recording.

6.1.7 Movements of the tongue and other oropharyngeal structures. These movements may produce intermittent or repetitive slow waves in a wide distribution, often with an apparent maximum in longitudinal bipolar montages in the middle of the head. Tongue movement causes a 'glossokinetic' artifact because the tip of the tongue has a negative electrical charge with respect to the root. Tongue movement explains part of the artifacts generated by speaking, swallowing, chewing, sucking, sobbing, coughing and hiccupping; movements of other structures probably contribute to these artifacts (Fig. 6.2) and account for those seen with sobbing. Artifacts from temporal, facial and scalp muscles may be mixed with the movement artifact. Palatal myoclonus causes rhythmical mus-
cle artifacts at rates of about 60–120/min which are often only seen in referential montages to an ear electrode and persist in sleep (Fig. 6.5). A prominent evoked midline response from palatal myoclonus may occasionally appear as rhythmic sharp waves that are maximal at Cz or Pz that should not be mistaken for abnormal epileptiform activity.

Many of these artifacts may be identified during the recording if they are associated with visible movements and if they disappear when these movements stop. However, the identification of a glossokinetic artifact may be difficult if, for example, the mouth remains closed during tongue movements, or if it occurs with an asymmetric distribution (Fig. 6.6). Therefore, it is recommended that patients be routinely asked during the recording to repeat words that elicit tongue movements, such as 'lilt' or 'Tom Thumb' (Fig. 6.6).

6.1.8 Dental restorations with dissimilar metals. Dental fillings with dissimilar metals may produce spike-like artifacts whenever the metal pieces are moved against each other, for instance in chewing, swallowing or speaking.

6.2 INTERFERENCE

The most common artifact due to electrical interference comes from power lines and equipment. It has a frequency of 60 Hz in North America and of 50 Hz in many other countries. A slight amount of this interference is unavoidable wherever alternating current is used. While this background interference may be picked up by faulty electrodes and may appear in one or a few channels, inordinately strong interference can cause artifacts even with good recording electrodes and equipment; these artifacts are then likely to appear in all channels of all recordings made in the same recording room (Fig. 6.3). The artifacts may be introduced either electro statically by un shielded power cables and regardless of current flow, or electromagnetically by strong currents flowing through cables and equipment such as transformers and electromotors. Electrostatic interference can be reduced by shielding the offending power cables and by using a shielded room for the recording; electromagnetic interference can be reduced by proper wiring of the power cables. Other types of interference include signals from nearby television stations, radio paging, telephone ringing, cardiac pacemakers (Fig. 6.3), or any movement of a charged body near the recording electrodes; electrostatic artifacts may be produced by a person walking through the recording room (Fig. 6.3) or by drops falling in an intravenous drip. However, modern EEG instruments have such high discrimination and input impedance that they reject all but the most powerful sources of interference from the environment. In setting up a laboratory, it is therefore not necessary to shield the recording room unless a trial recording from a patient or a 10,000 Ω resistor, placed at the prospective recording site, shows strong interference.

When recordings are made in an environment with much interference such as an intensive care unit or an operating room, the patient's head and the connections to the EEG instrument should be kept as far from power cables as possible. All electrode wires should be as short as possible and bound together in a single bundled cable. Electrode wires act as antennas for 60 Hz interference, especially when the individual wires are long or form loops. Any swaying of electrode wires and movement of tubing or of other charged objects should be minimized. Equipment other than the EEG instrument should be unplugged if feasible; even the respirator may be stopped for short periods to obtain artifact-free recordings or to determine the cause of interference.

6.3 ARTIFACTS ARISING FROM RECORDING ELECTRODES AND EQUIPMENT

6.3.1 Artifacts arising from electrodes, electrode terminal board, input cable and selector switches. Most artifacts in this
category are distinguished from cerebral activity in that they differ radically from previously recorded activity, do not blend with other simultaneously recorded activity but seem to be superimposed on it, and appear only in channels connected to one electrode. However, not all of these artifacts are easily recognized. Although some of them have characteristic shapes, others lack such features and may resemble cerebral activity. A common artifact is ‘electrode popping’ which is due to a sudden change of electrode contact causing pen deflections which rise or fall abruptly and may mimic spike discharges (Fig. 6.3). Other electrode artifacts rise and fall more slowly and may resemble cerebral slow waves.

Identification and correction of artifacts in the distribution of one electrode requires checking electrical and mechanical continuity. Because the artifact is often due to faulty contact between the electrode and the scalp, the first step is to look at that junction: the electrode may be partly or completely detached, the lead wire may be broken, or the conductive paste or jelly may have dried up. As a next step, electrical impedance should be measured (2.2.3); if it is high, the electrode should be refilled with conductive jelly or paste, reapplied, or replaced if it is defective. If the artifact persists, the receptor jack or the wiring of the input terminal board may be at fault; this can be investigated by changing the connections between electrodes and receptacles of the faulty channel so that the electrodes and the receptacles of that channel are presented in different channels: the electrodes of the faulty channel are connected to receptacles giving good recordings when connected to other electrodes, and electrodes not giving artifacts when connected to other receptacles are connected to receptacles of the faulty channel. If the artifact changes channels corresponding with the electrodes from the faulty channel, one of these electrodes is at fault and can be identified by connecting the two electrodes to different channels and observing in which channel the artifact then appears. However, if the artifact remains at one receptacle, the input board or subsequent components of the recording channel may be at fault. In practice, the technician at this point or earlier will examine a piece of recording made while the inputs are closed. If the artifact persists under this condition, it arises from the recording instrument and should be investigated accordingly (6.3.2).

6.3.2 Artifacts arising from the recording instrument. Like artifacts from the electrodes, artifacts from the instrument may often be recognized by the sudden appearance of waveforms very different from cerebral activity. The source of these artifacts can often be traced to one functional component of the instrument. Trouble shooting is facilitated by two features of modern EEG instruments. (a) Many components have indicator lights and electrical contact points with prescribed voltage readings which can be checked easily. (b) Components of individual channels are made of modules which can be exchanged. Artifacts due to faults of components that are common to all channels often cause lack of power or 60 Hz interference. Power failure may be caused by a faulty outlet or a blown fuse in the EEG instrument. If a replacement fuse also blows, the power supply may be at fault. Sixty hertz interference in all channels may be due to (a) a powerful source of interference in the recording room (6.2), (b) a faulty or absent connection of the subject with the ground of the EEG instrument (3.4.1), (c) defects in the power supply or other parts of the instrument.

Artifacts caused by components of individual channels appear only at the output of the defective channels and persist independently of the input selection. The causes of these problems can be traced by exchanging modular components of one channel with the corresponding components of another channel. For instance if 60 Hz artifact in one channel of an analog EEG instrument suggests a problem in its amplifier, this can be investigated by exchanging the amplifier for an amplifier of another channel not showing that artifact.

REFERENCES


