ARTIFACT IDENTIFICATION & TROUBLESHOOTING

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ARTIFACTS

GENERAL PRINCIPLES FOR ARTIFACT IDENTIFICATION

DURATION

Many artifactual spikes have a very short duration and appear “spikier” than epileptiform spikes. Spikes lasting less than 20 ms are generally considered artifact.

Fig. 1 Short Duration Spike

The artifactual spike at T4 has a very fast duration

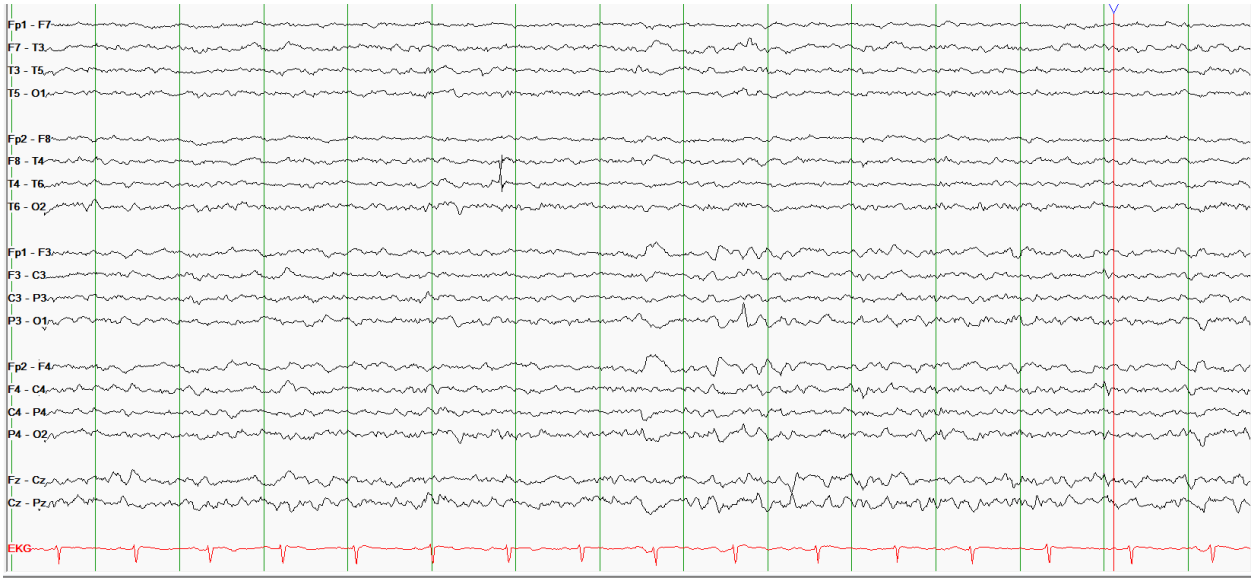


Fig. 2 Short Duration Repetitive Artifactual Spikes

Repetitive short duration artifactual spikes are seen at Fp1.

EVOLUTION

Artifacts that appear rhythmic rarely show progressive evolution in frequency, amplitude, and/ or topographic distribution. An exception to this might be chest percussion artifact, which can seem to evolve. (Keep in mind, however, that seizures in the critically ill may evolve slowly or subtly and may need to be viewed with a condensed time base to see the evolution such as 20 to 30 seconds per page).

Fig. 3 Non-Evolving Rhythmic Artifact

Rhythmic artifact due to head movement.

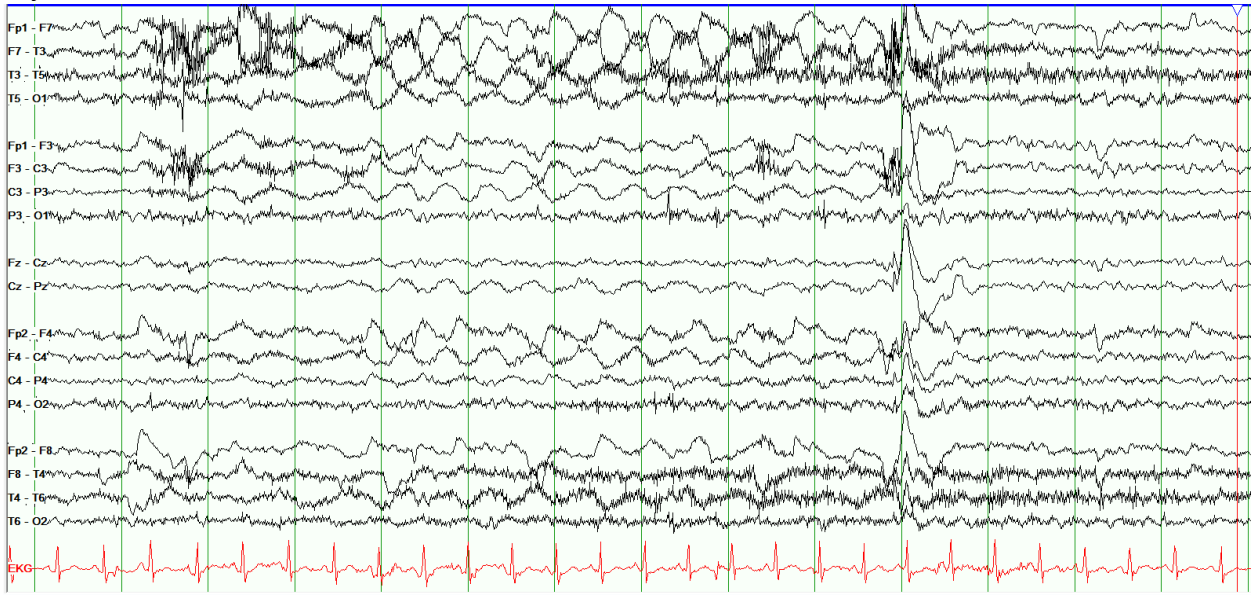
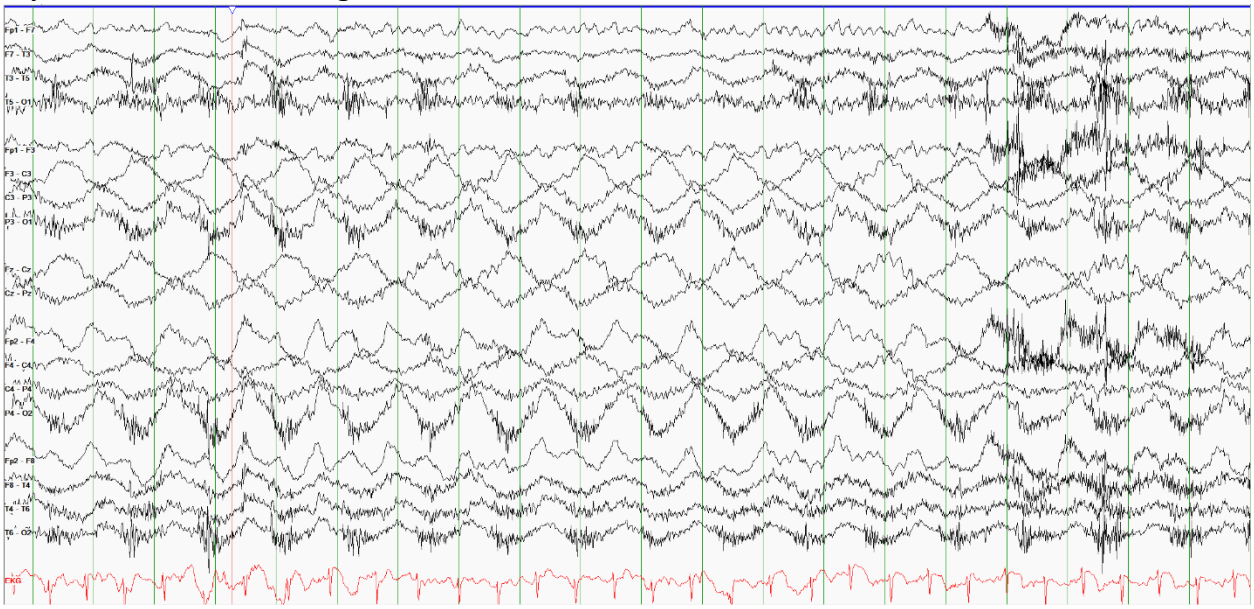


Fig. 4 Non-Evolving Rhythmic Artifact

Rhythmic artifact due to rocking.



FIELD

Many artifacts don't have a logical topographic distribution or consistent polarity, while epileptiform activity tends to have a point of maximum negativity with gradual dissipation with increasing distance from that point (or maximum positivity in neonates). An exception to this is locally distributed artifact due to electrodes being in contact with the patient's bed, usually in the posterior region or one side of the head if the patient's head is turned.

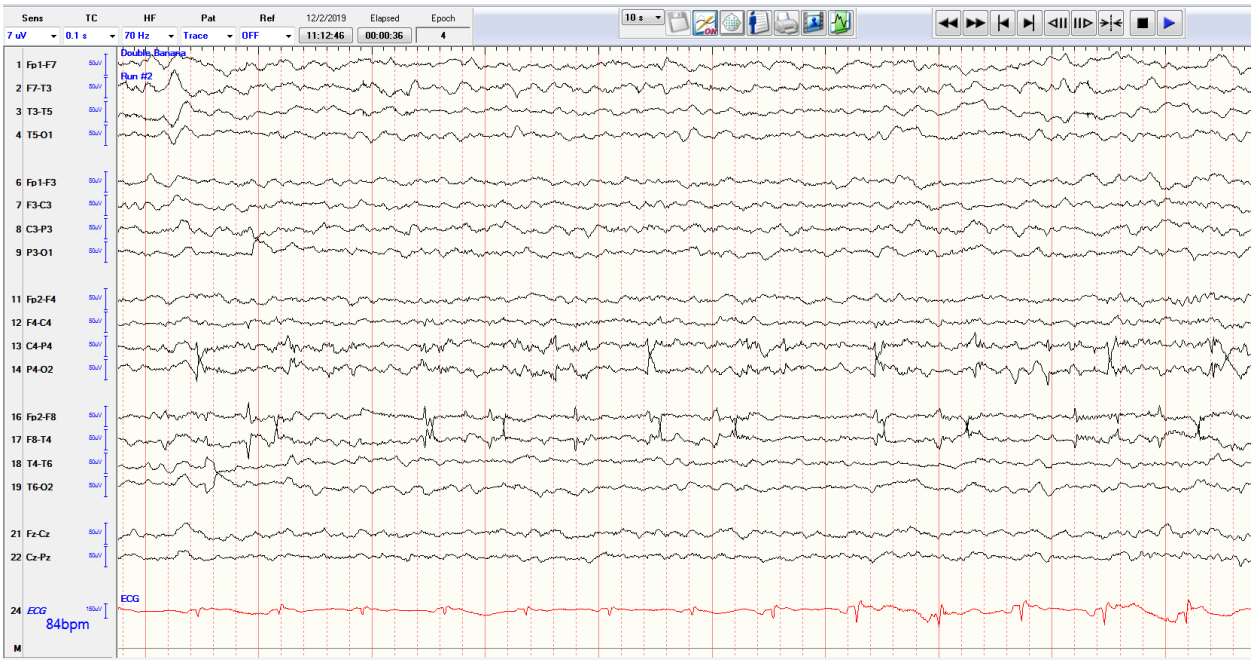
Discharges that are isolated to a single electrode are usually artifactual; although, rarely, epileptiform discharges are detected in only one scalp electrode.

Fig. 5 Artifactual Spike Isolated to One Channel

Artifactual spike isolated to F8. The spike was caused by the patient scratching his head.

Fig. 6 Inconsistent Polarity and Distribution

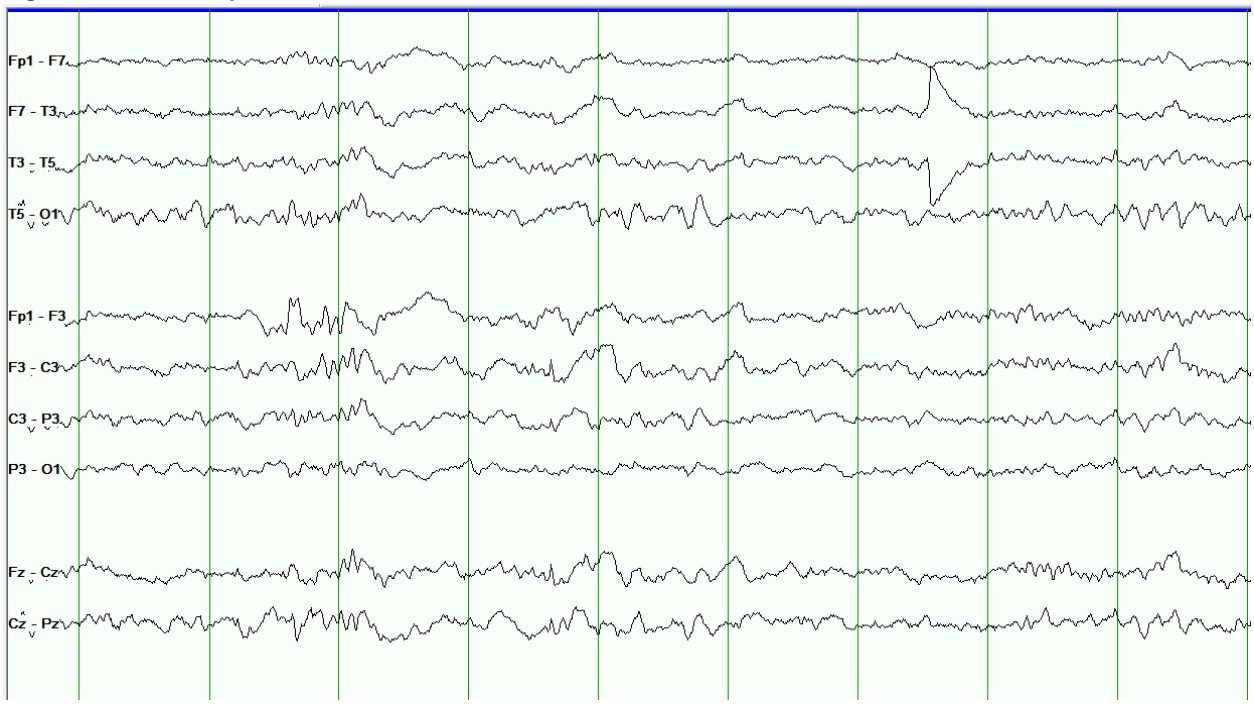
Electrode artifact is seen in multiple electrodes (P3, P4, F8, T6). The repetitive spike-like electrode artifacts at F8 and P4 have an inconsistent polarity.



MORPHOLOGY

Many artifacts are easy to identify by their morphology. Electrode artifact resembling spikes tends to have steep ascending slopes.

Fig. 7 Electrode Pop at T3

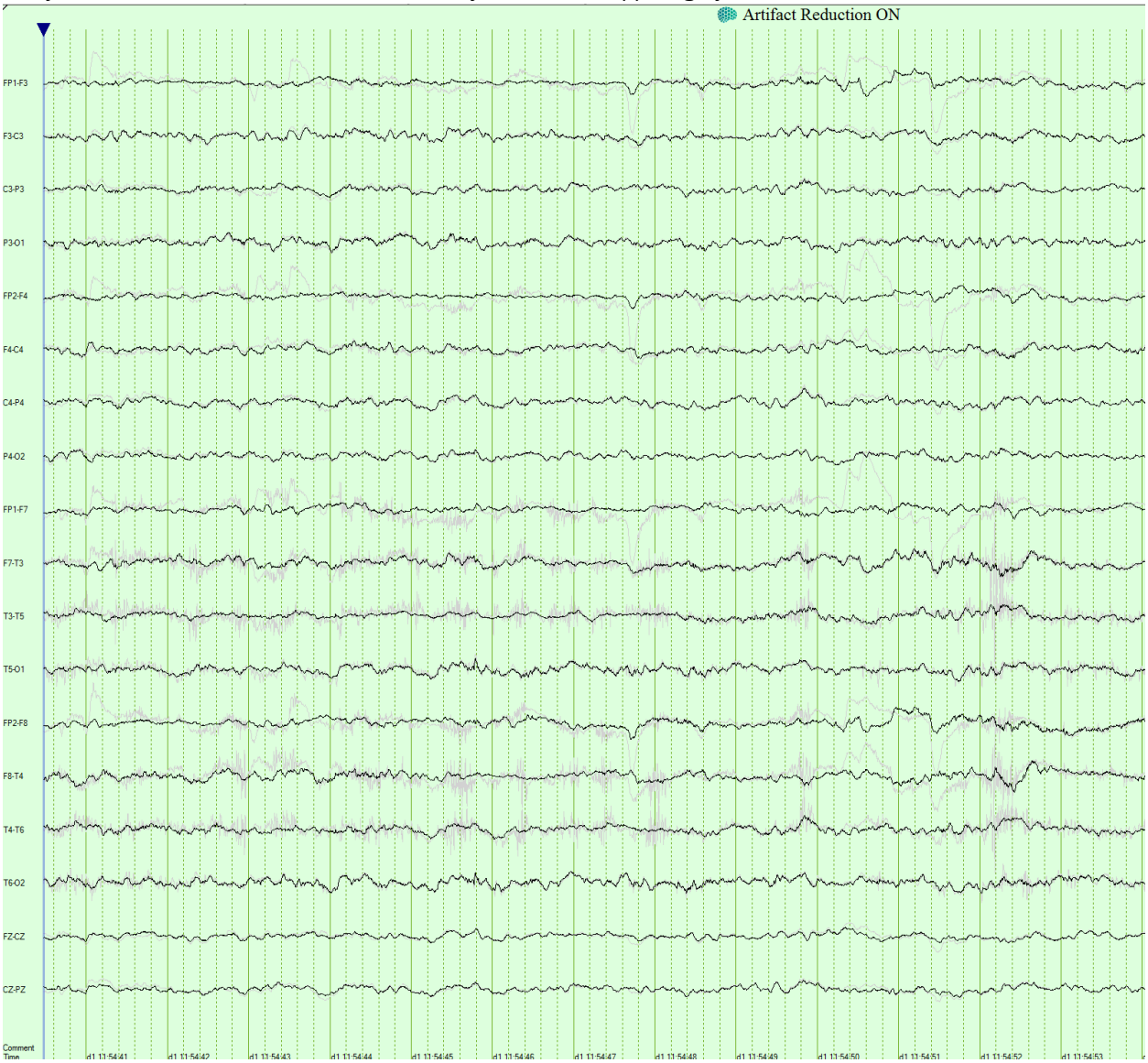


ARTIFACT REDUCTION SOFTWARE

Persyst has an artifact reduction feature that selectively minimizes the appearance of muscle, eye movement, and electrode artifact without affecting the appearance of cerebral activity. Artifact appears light gray and fades into the background making cerebral signals easier to see. This software is helpful for reviewing long term studies.

Fig. 8 EEG with Persyst Artifact Reduction

Persyst artifact reduction. Muscle artifact and eye movement appear gray.



NON-PHYSIOLOGICAL ARTIFACTS

60-HZ ARTIFACT

60-Hz artifact is electrical artifact most often caused by high or imbalanced electrode impedances. Even with low and balanced impedances, it may be present when there are multiple devices in the recording

environment. The notch filter will eliminate 60-Hz artifact but should be used as a last resort during recording because the appearance of 60-Hz artifact is one of the first signs of an electrode issue that requires troubleshooting.

TROUBLESHOOTING 60-HZ ARTIFACT

- The best way to avoid 60-Hz artifact is to have low (<5k Ohms) and balanced electrode impedances.
- If 60 Hz is seen in one channel, that electrode should be rescrubbed to lower impedance.
- If 60 Hz is seen in all channels, the reference and ground should be rescrubbed.
- If the headbox cable is in contact with the power cords of other equipment in the room, lift the headbox cable off of the other cords. It might also be necessary to use a different outlet.
- Gather electrode wires closely together.

Fig. 9 60-Hz Artifact

Diffuse 60-Hz artifact most prominent at P3 and O1 due to higher impedance in these electrodes.

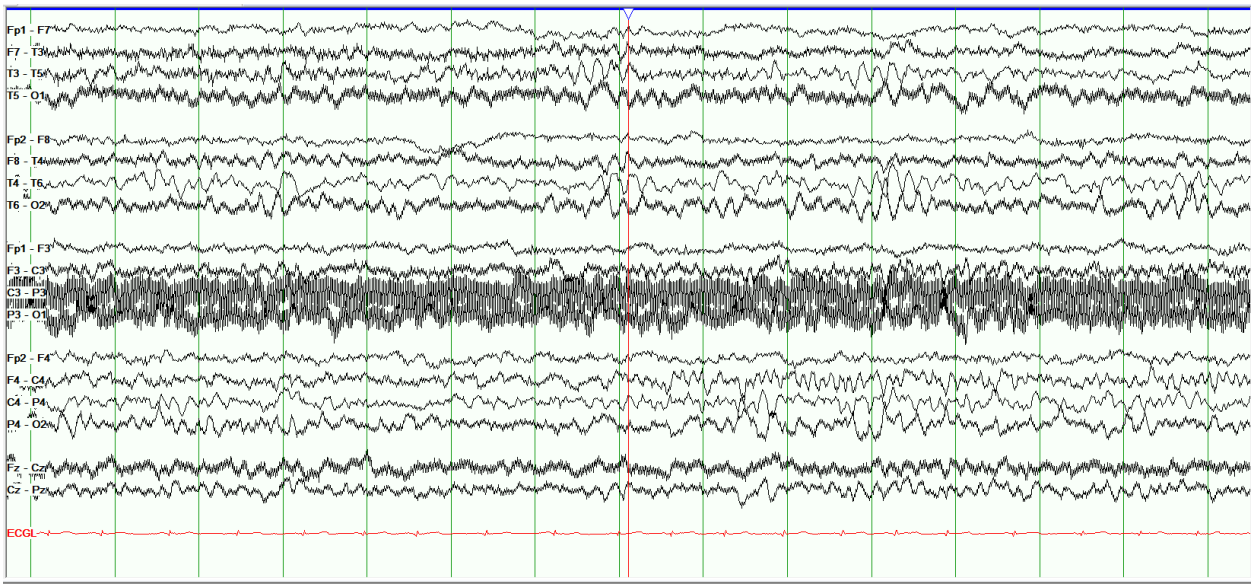
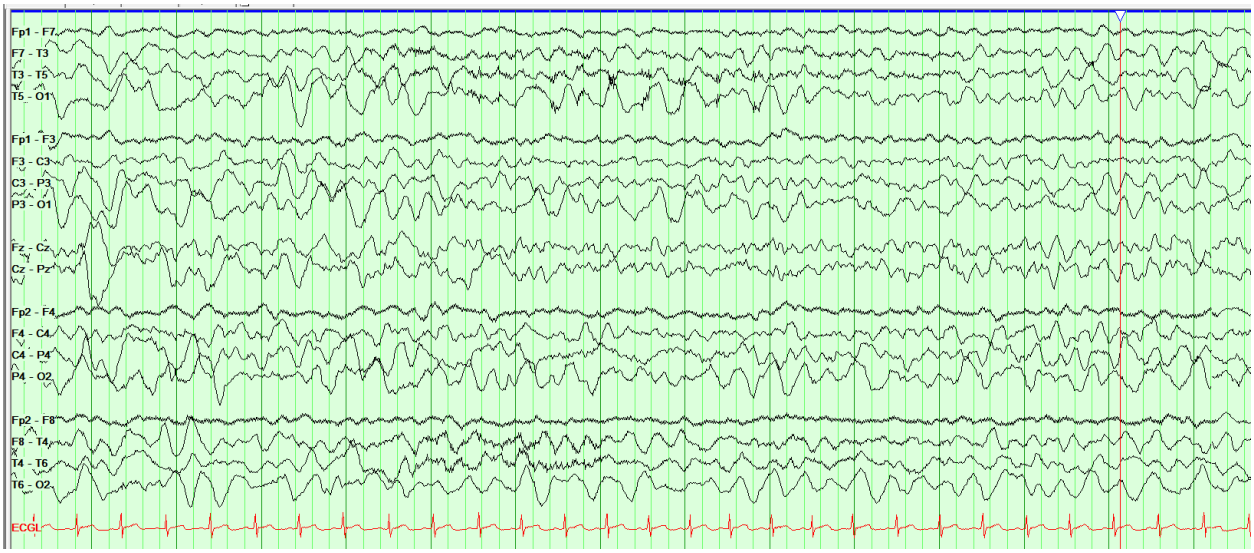


Fig. 10 60-Hz Artifact

60-Hz artifact restricted to the frontopolar electrodes.



CHEST PERCUSSION / CHEST COMPRESSIONS

Chest percussion is a rhythmic striking of the chest to help drain mucus from the lungs. It may be done mechanically or manually by a respiratory therapist. It produces a rhythmic artifact and may appear to evolve.

Chest compressions during CPR also produce rhythmic artifact.

ELECTRICAL ARTIFACT FROM EQUIPMENT

Electrical artifact from surrounding equipment often has a sinusoidal appearance.

TROUBLESHOOTING ELECTRICAL ARTIFACT

- See 60-Hz artifact section for troubleshooting steps.
- Ask the nurse if any equipment can be temporarily unplugged for the duration of the recording and unplug the bed if possible. Technologists should not unplug any equipment without the assistance of the patient's nurse.
- Try using a different outlet for the EEG machine.

Fig. 11 Electrical Artifact

Sinusoidal artifact from surrounding equipment isolated to Cz due to high impedance in that electrode.

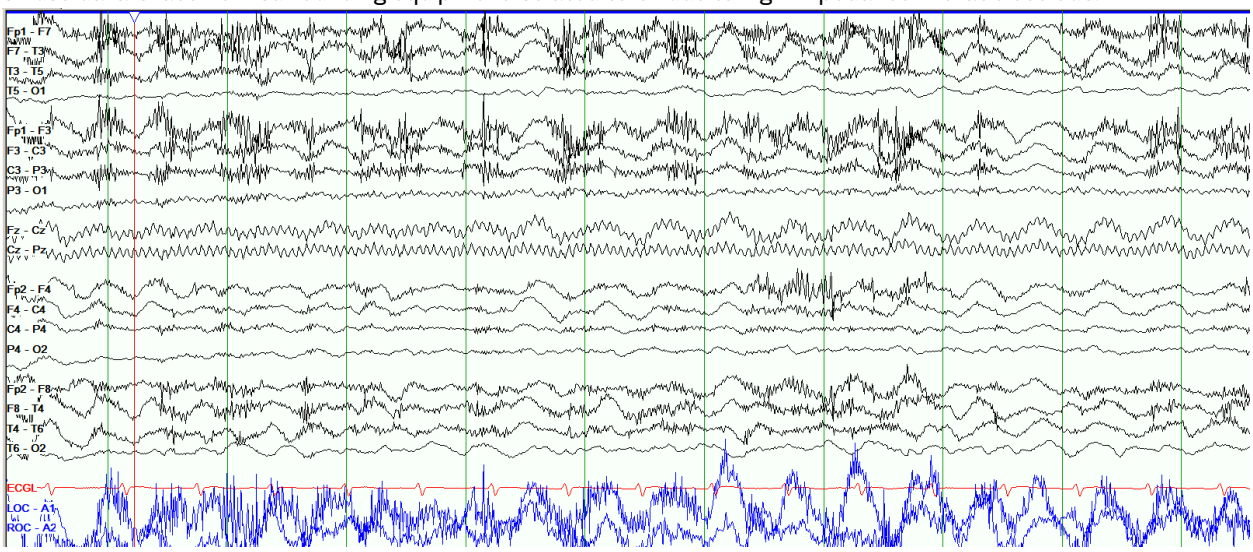


Fig. 12 Electrical Artifact

Artifact appears in multiple channels due to equipment near the patient.

ELECTRODE POP

Electrode pops are seen when an electrode is defective or has lost contact with the scalp or when there is insufficient conductive paste. They have a characteristic morphology with steep ascending slopes and are restricted to a single electrode.

TROUBLESHOOTING ELECTRODE POPS

- Reapply the electrode.
- If electrodes are attached with collodion, try injecting conductive gel into the cup with a plastic syringe.
- If reapplication or additional conductive paste or gel fail, try a new electrode.

Fig. 13 Electrode Pop

Electrode pop at Cz.

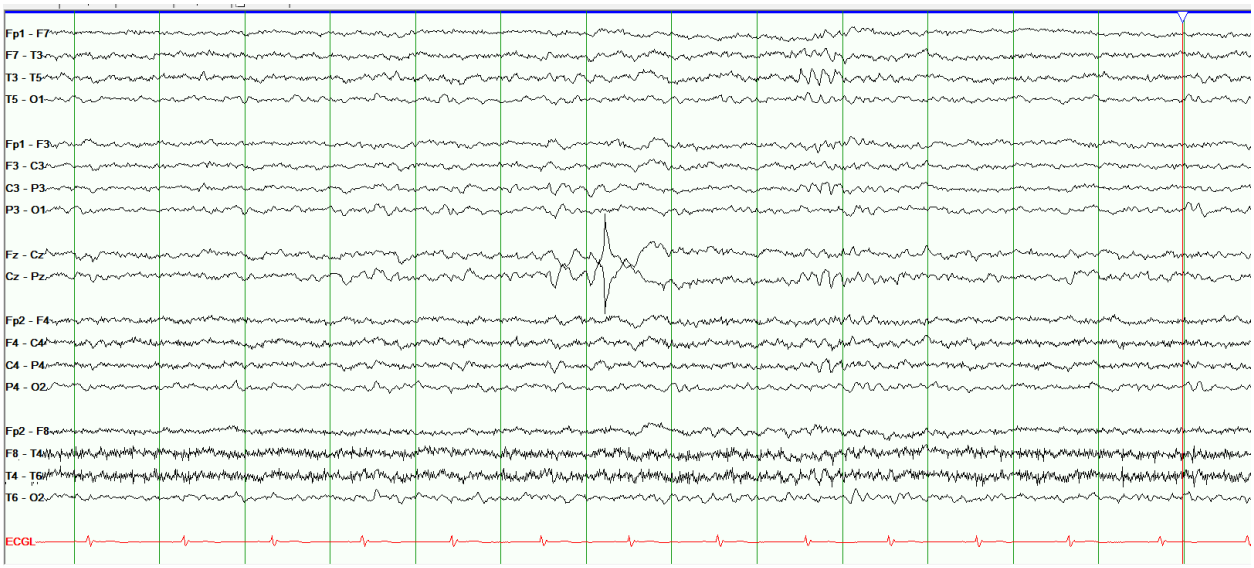


Fig. 14 Electrode Pop

Electrode pops at C4, P4, and T4.

ELECTROSTATIC ARTIFACT

Electrostatic artifact is caused by movement near the patient, headbox, or wires.

Fig. 15 Electrostatic Artifact

Electrostatic artifact. The patient was playing with the zipper of the bag containing the headbox.

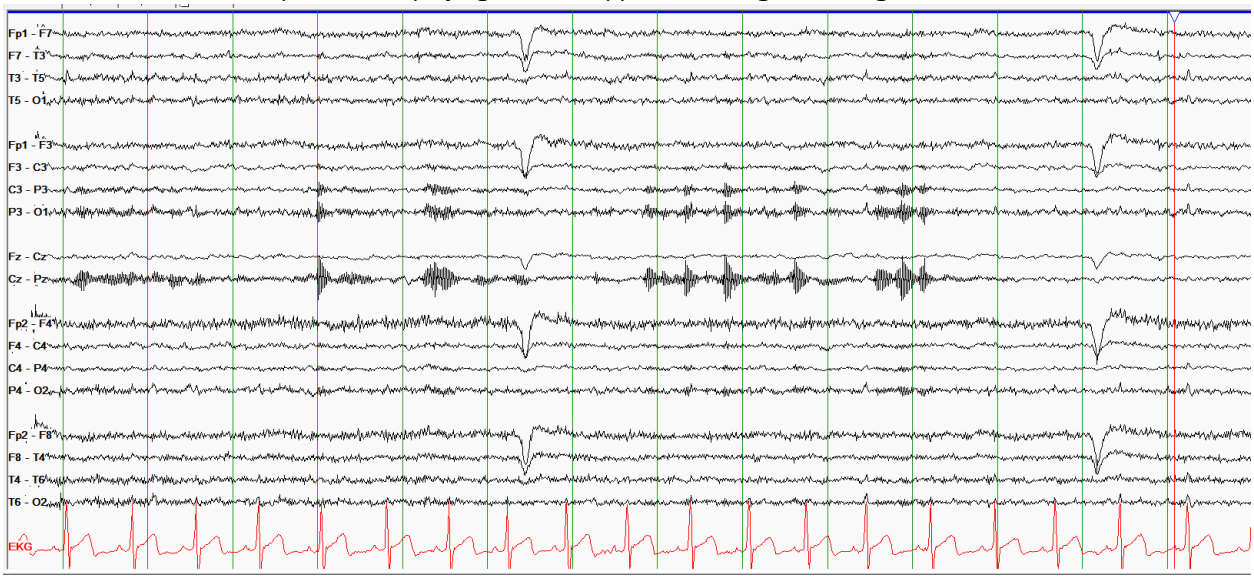
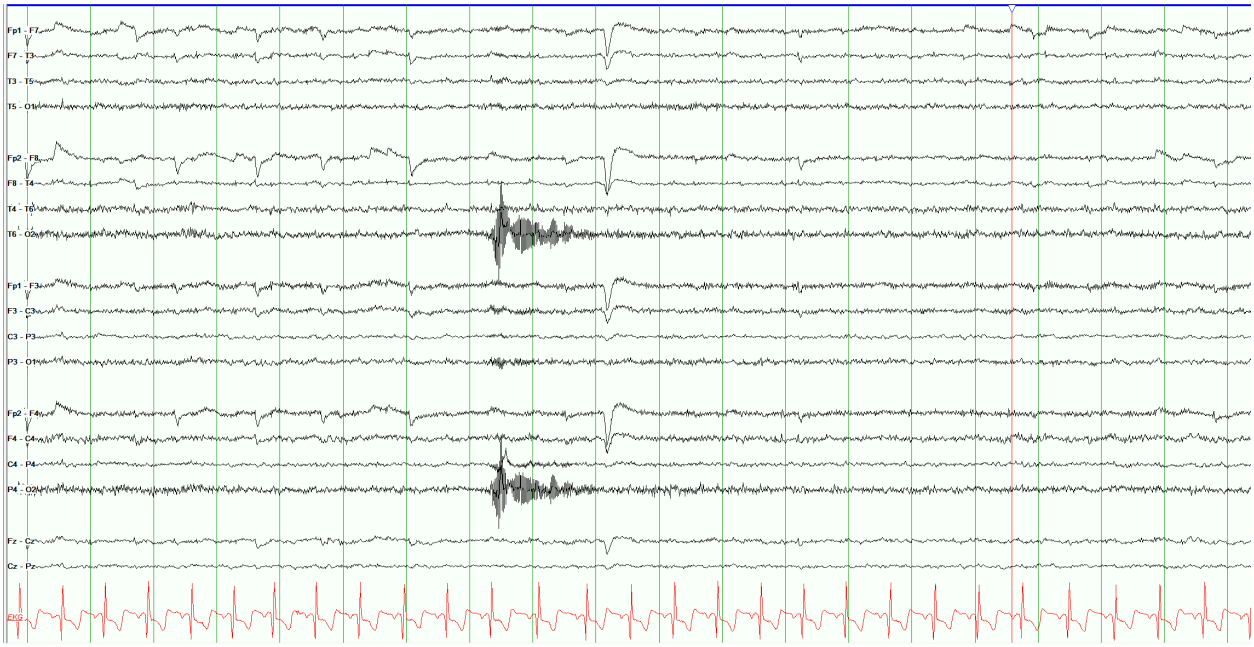


Fig. 16 Electrostatic Artifact

Electrostatic artifact is seen in O2 when the patient's father crosses his leg near the patient's head.



MOVEMENT ARTIFACT

Movement artifact varies in appearance depending on how the patient is moving. It is easy to identify with review of the video. When movement artifact is rhythmic, it can resemble seizures or other abnormal patterns such as intermittent rhythmic delta activity. Inconsistent polarity, implausible field, and lack of evolution are characteristics that might help to identify movement artifact in the absence of video. Movements should be documented by the technologist during recording when possible.

Fig. 17 Rhythmic Movement Artifact

Head movement artifact.

Fig. 18 Movement Artifact

Head movement artifact that resembles spike-and-wave activity is produced by the patient banging his head against the wall.

PATTING

Patting is a common artifact in recordings of infants. It may resemble spikes, spike-and-wave discharges, or rhythmic activity.

Fig. 19 Patting Artifact

Patting artifact is present in the 4th-8th seconds.

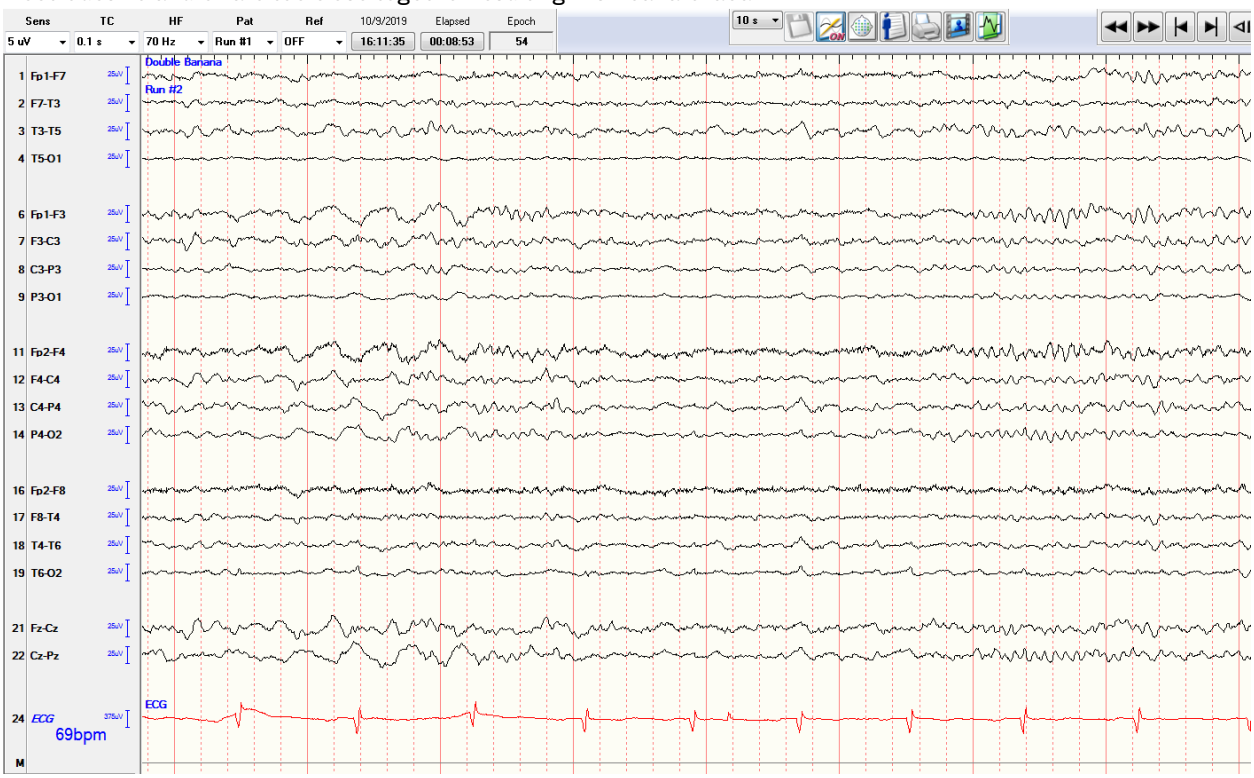
SMEAR / SALT BRIDGE

Smear (a.k.a. salt bridge) artifact occurs when electrodes are too close together or there is conductive paste between them. It results in a flat line that resembles suppression but is restricted to one channel. Smear can happen due to head movement during recording or setup, inaccurate measurement and placement, or excessive paste.

Technologists should always use at least two bipolar montages during recording. Smear artifact due to head movement during recording is often identified when the montage is changed to a transverse or circumferential (hatband) montage.

Fig. 20 Smear in a Single Channel

Electrodes T5 and O1 are too close together resulting in smear artifact.



TROUBLESHOOTING SMEAR ARTIFACT

- Check the distance between the electrodes and wipe the area between them with alcohol

STIMULATOR-INDUCED ARTIFACT

The appearance of stimulus-induced artifact varies with the type of stimulus device.

Deep brain stimulation (DBS) can resemble diffuse 60-Hz artifact. The device may need to be momentarily paused by the physician to obtain an interpretable EEG recording.[i]

Responsive neurostimulation (RNS) may produce high amplitude artifact with a spike-like appearance over the location of the RNS generator.[ii]

VENTILATOR ARTIFACT

Fluid in ventilator tubing can create bursts of rhythmic activity that resemble periodic discharges or burst-suppression or burst-attenuation. To confirm the artifact, the technologist should ask the nurse or respiratory therapist to clear fluids from the ventilator tube. If this is not possible, each respiration should be documented to show the constant relationship between the artifact and the respiratory cycle.

PHYSIOLOGICAL ARTIFACTS

CARDIOBALLISTOGRAPHIC/ BALLISTOCARDIOGRAPHIC

Ballistocardiographic artifact is caused by slight head movements with each heartbeat and appears rhythmic. It is most apparent when background EEG activity is suppressed or low voltage. It lags the QRS complex but has a constant relationship with it, repeating at the same frequency. It can be identified by the absence of evolution. If the artifact is primarily in the posterior electrodes, repositioning the head may help to minimize or eliminate it.

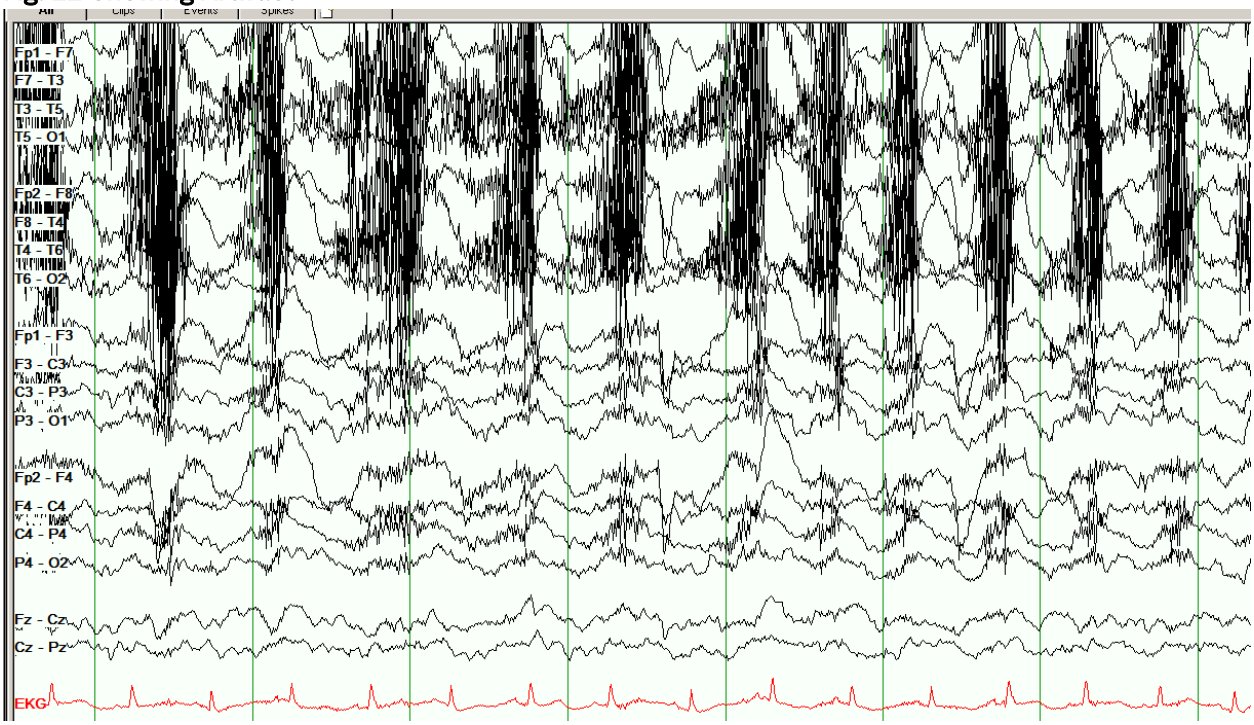
Fig. 21 Ballistocardiographic Artifact

Ballistocardiographic artifact appearing as widespread continuous rhythmic slow waves.

CHEWING AND BRUXISM

Chewing artifact and bruxism produce bursts of EMG activity (muscle) that can be widespread or most prominent in the temporal area. Patients should be instructed not to chew gum or candy during routine or LTM EEG recording so that large portions of the recording aren't obscured by chewing artifact.

Fig. 22 Chewing Artifact



EKG ARTIFACT

EKG artifact is most problematic when recording in A1 A2 referential montages and when recording at increased sensitivity for electrocerebral inactivity. It appears as widespread, low amplitude spikes or sharp waves. It can be eliminated or minimized by selecting a different referential montage such as Cz or average reference. A linked ears referential montage is also an effective alternative because EKG artifact has opposite polarity at A1 and A2 and is often cancelled out when they are averaged. EKG artifact in a patient with cardiac arrythmia is often not as readily identified. All EEG recordings should include an EKG electrode to rule out interictal discharges.

TROUBLESHOOTING ISOLATED EKG ARTIFACT

- Poor contact at one electrode which is linked in a derivation to an electrode with low impedance can reduce the effectiveness of the differential amplifier to reject the EKG signal in that channel. If EKG artifact is restricted to one channel, reapply electrodes in the channel with the artifact.

ELECTRORETINGRAM

Electroretinogram artifact is seen during photic stimulation and is more commonly seen when background activity is suppressed. The artifact is produced by the retina's response to the light stimulus. The technologist can "prove" the artifact by covering one eye at a time during photic stimulation to show that the artifact goes away on the side with the covered eye.[iii] The artifact also disappears at photic frequencies greater than 30 Hz.

EYE MOVEMENT ARTIFACT

The cornea of the eye has a net positive charge while the retina has a net negative charge forming a dipole. Vertical eye movement is detected primarily at Fp1 and Fp2, while lateral eye movement is maximal at F7 and F8, but eye movement can extend farther in its distribution among scalp electrodes. The easiest way to identify eye movement artifact is to add eye monitors.

BLINKS, EYE OPENING, AND EYE CLOSURE

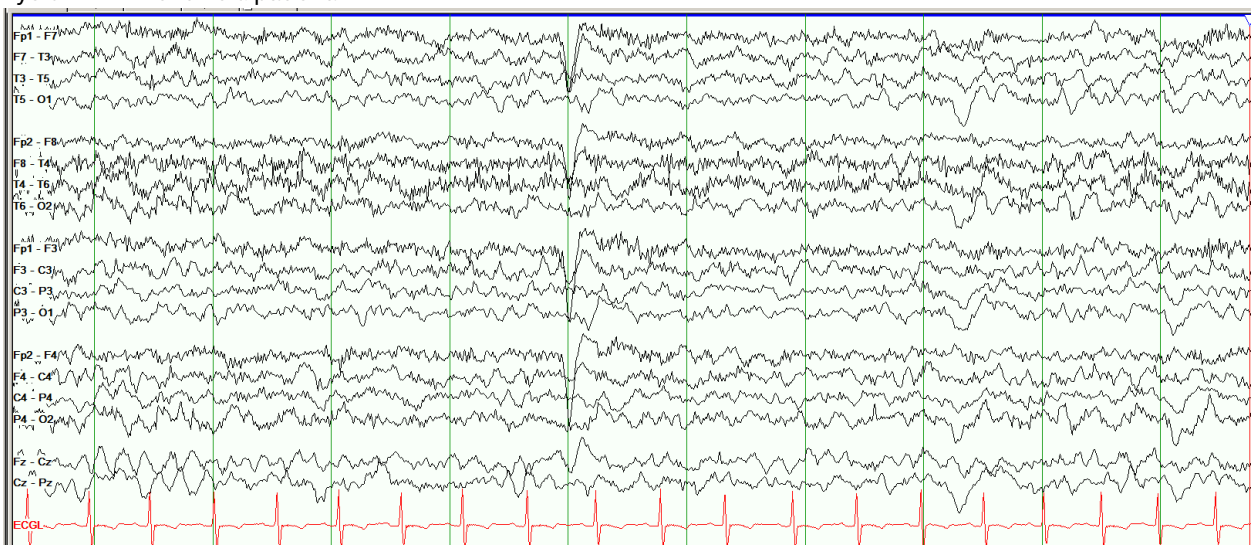
When the eyelids close, the eyeballs naturally roll upwards. This is known as Bell's phenomenon. The upward movement of the cornea results in a positive deflection at frontopolar electrodes. With eye opening, they roll back down moving positivity away from the frontopolar electrodes, resulting in a negative deflection in channels with Fp1 and Fp2. Eye blinks have a characteristic appearance.

Fig. 23 Eye Opening and Blinks

Eye opening and eye blinks. The eyes open in the 10th second. Eye blinks are seen around the 13th and 16th seconds.

Fig. 24 Eye Blink Artifact

Eye blink 21-month-old patient.



LATERAL EYE MOVEMENT

With conjugate lateral eye movement, the movement of the corneas results in a positive deflection at F7 or F8, depending on the direction in which the eyes move. As the corneas move toward F7, they simultaneously move away from F8, and vice versa, resulting in opposite polarity in these electrodes. When the eyes look left, the positive deflection is seen at F7. When the eyes look right, the positive deflection is seen at F8. Rapid lateral eye movements are often seen in association with a lateral rectus spike and are common in REM sleep. Slow lateral eye movements are common in drowsiness and have a longer duration than lateral eye movements during wakefulness and REM sleep.

Fig. 25 Lateral Eye Movement With Lateral Rectus

Frequent lateral eye movements preceded by lateral rectus spikes during REM sleep.

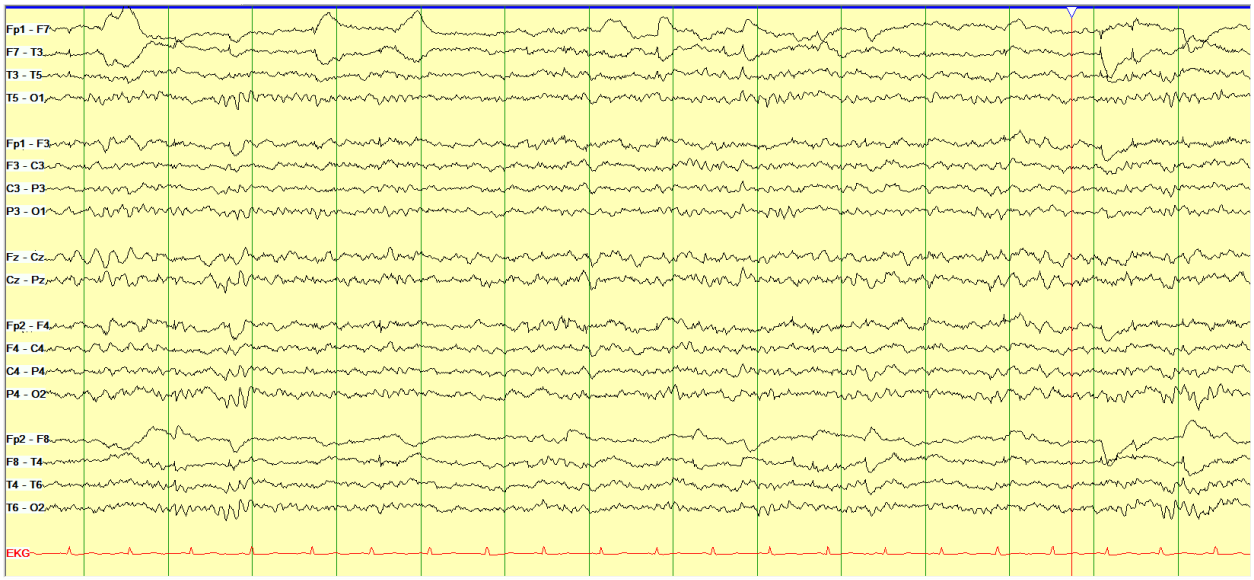


Fig. 26 Lateral Eye Movement

Lateral eye movement is seen in the 5th second. Note the opposite polarity at F7 and F8.

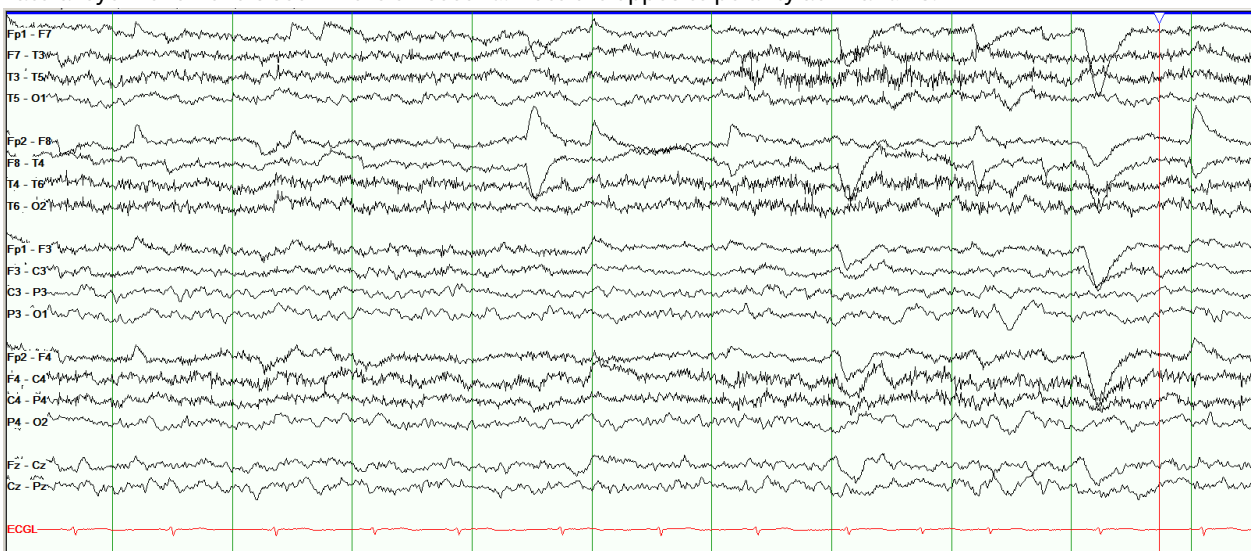


Fig. 27 Slow Lateral Eye Movements

A single slow lateral eye movement during the transition from drowsiness to stage II sleep in a 12-year-old patient.

Fig. 28 Eyelid Flutter

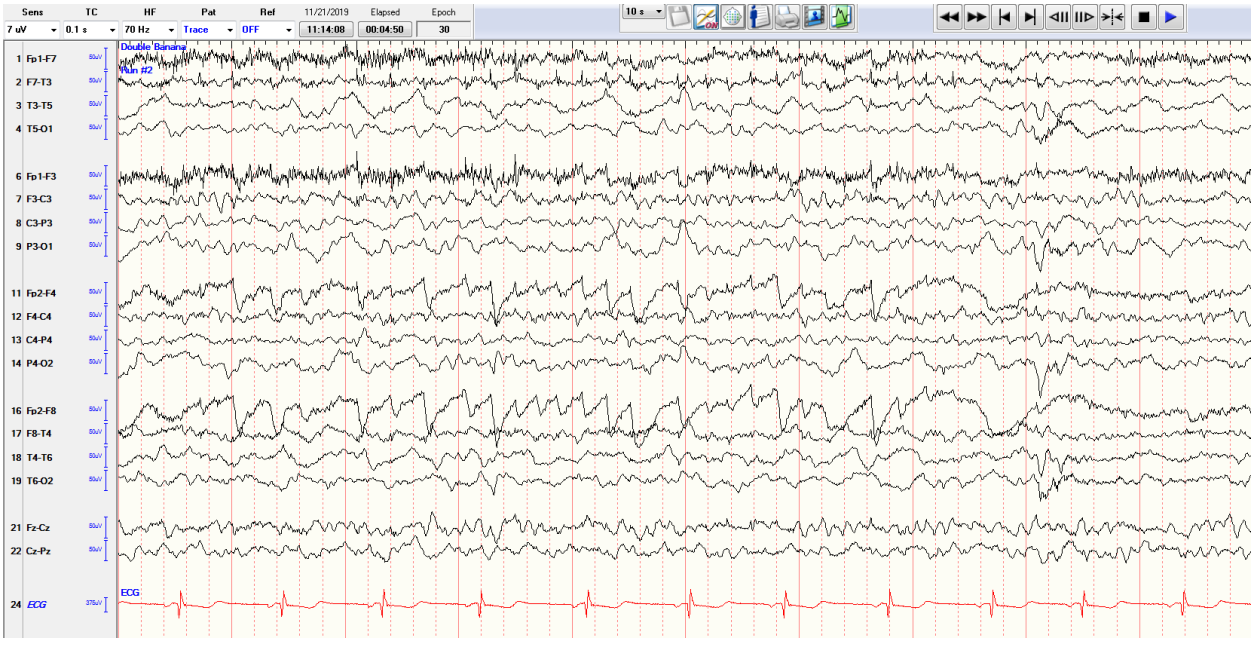
Eyelid flutter during 3-Hz photic stimulation.

ASYMMETRIC EYE MOVEMENT

Unilateral eye movement artifact might be seen if the patient has a diseased eyeball or prosthetic eye or if eye movement is only in one eye. It appears as unilateral or asymmetric activity in frontal channels. When eye movement is asymmetric, the technologist should ensure that leads are plugged into the correct pin positions in the headbox. Zooming the camera in on the patient's face might also be helpful so that eye movements can clearly be seen.

Fig. 29 Unilateral Nystagmus

Asymmetric eye movement. The patient has a history of visual impairment in the left eye. Twitching of the left eye and nystagmus of the right eye were observed during the EEG recording.



EYE MONITOR PLACEMENT

One must understand “in phase” and “out of phase” to interpret activity in the eye channels. When waveforms in two channels are in phase with each other, the deflections are in the same direction, and the waveforms have the same polarity. When waveforms in two channels are out of phase, the deflections are in opposite directions and have opposite polarity. Whether eye movements are in phase or out of phase in the eye channels will depend on the placement of eye monitors.

Fig. 30
In-phase and out-of-phase eye movements

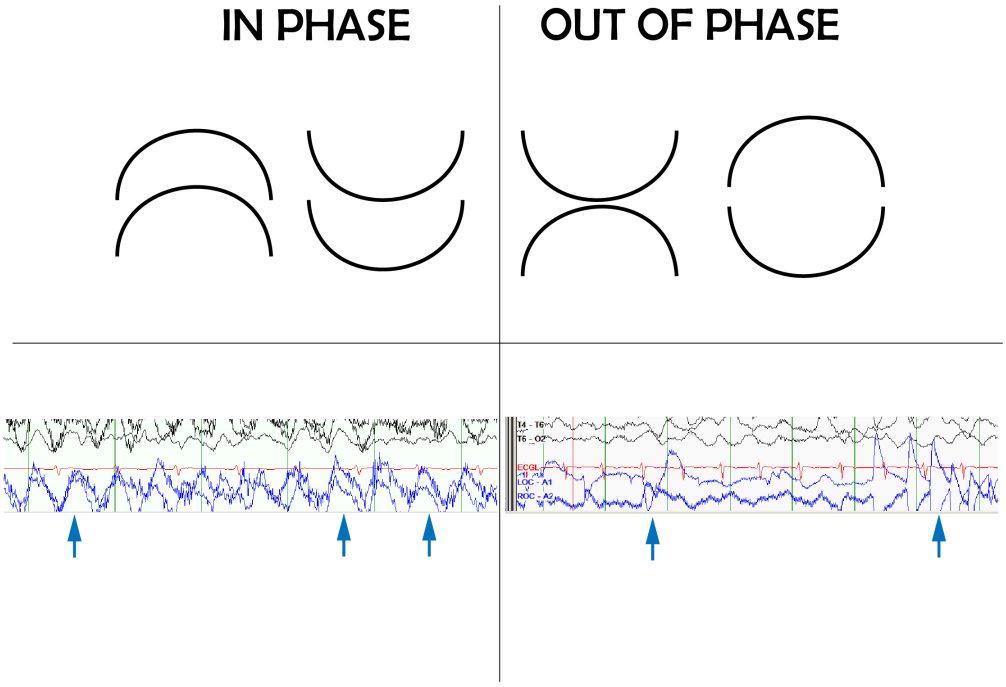
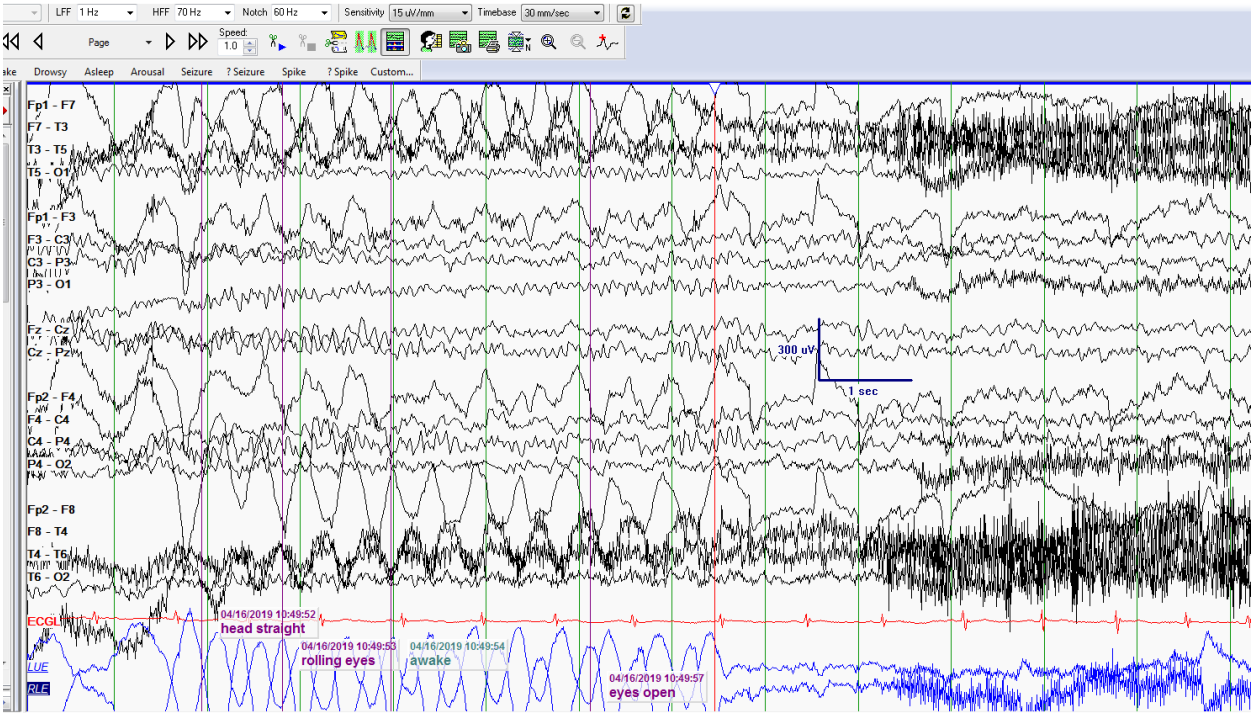


Fig. 31 Out of Phase Eye Movements With Left Upper Right Lower Placement

Eye movement artifact due to eye rolling. Note that the eye channels are out of phase with each other with a left upper right lower placement.



There are four options for eye monitor placement. It is important to document placement of eye leads if the placement deviates from the lab's standard protocol or if there is no standard protocol and placement varies by technologist. These are the four placements:

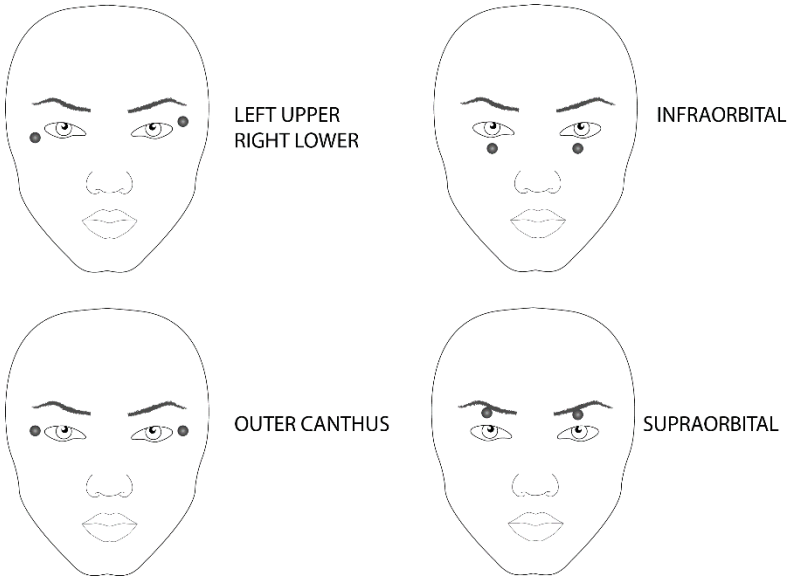
- Infraorbital - both electrodes are placed below the center of the eye
- Supraorbital- both electrodes are placed above the center of the eye
- Outer canthus- both electrodes are placed just lateral to the outer canthus of each eye
- Left upper canthus and right lower canthus- one electrode is placed slightly above the left outer canthus. The other electrode is placed slightly below the right outer canthus.

The fourth option with one electrode above the eye and one below is advantageous because it is the only method in which eye channels will be out of phase with each other for vertical eye movement. With this placement, vertical eye movement is out of phase in the eye channels while cerebral activity is in phase in the eye channels.

Perhaps the least useful of these options is outer canthus placement as much of the same activity is detected in F7 and F8. The same is true of supraorbital since much of the same activity is detected in Fp1 and Fp2.

With infraorbital placement, vertical eye movements will be in phase in the eye channels but out of phase with eye movement detected in the frontal electrodes. Infraorbital placement is perhaps more useful for detecting glossokinetic artifact than eye movement (see glossokinetic artifact).

Fig. 32 Eye Monitor Placements

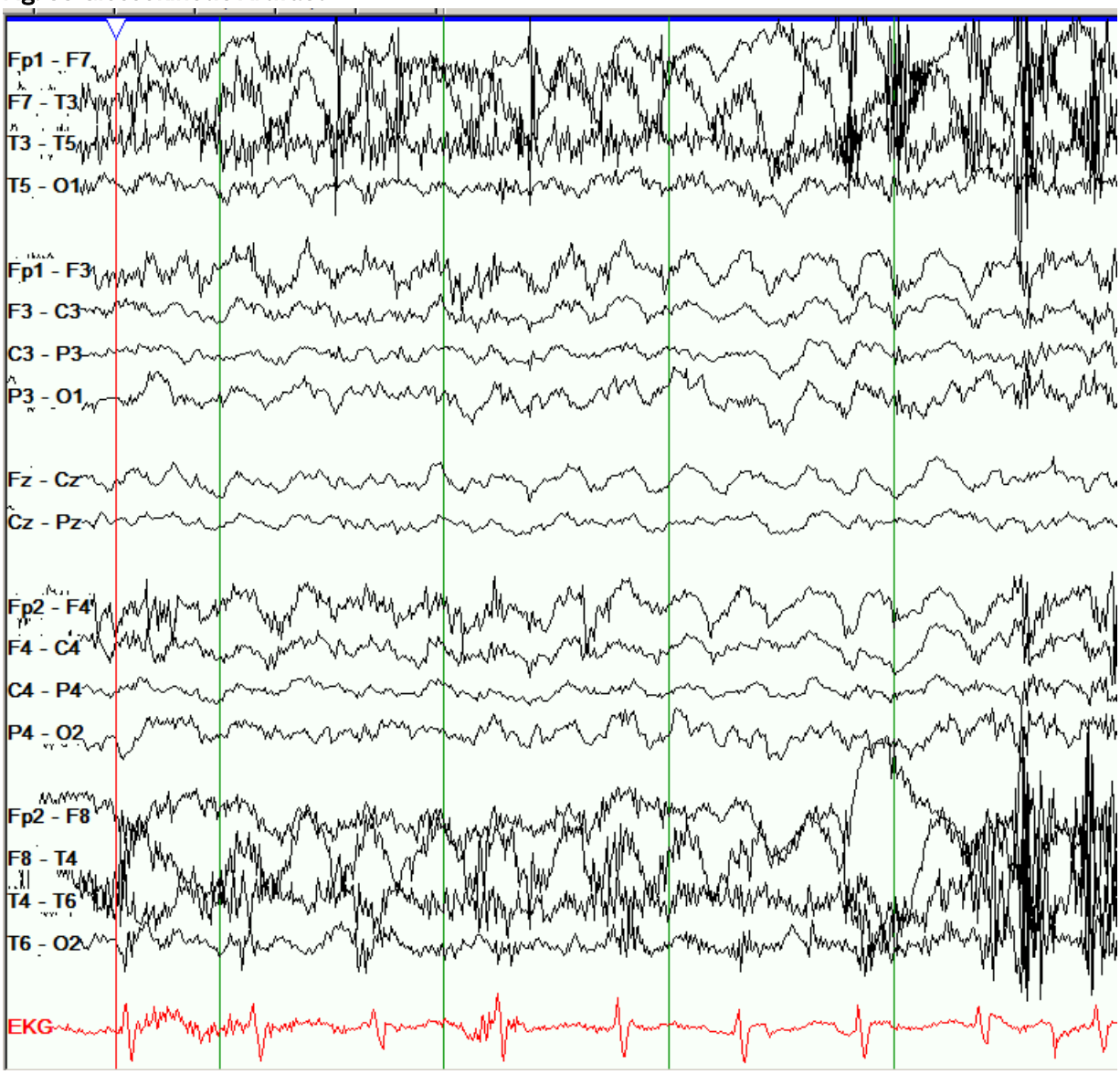


GLOSSOKINETIC ARTIFACT

Similar to the eyes, the tongue has a dipole. This is due to the negative charge at the tip relative to the base. Tongue movement produces rhythmic delta waves on the EEG and is especially apparent in frontal electrodes but can have a wide distribution. It can be distinguished from cerebral activity by placing leads near the mouth or under the eyes (infraorbital monitors). Delta activity produced by tongue movement will have a higher amplitude in these channels than in the frontal electrodes. The technologist can also ask the patient to say a phrase such as “la la la” or “Tom Thumb” to reproduce the artifact on the EEG.

If eye monitors are being used with one above the outer canthus and one below, the tongue movement artifact will be in-phase but will have a lower amplitude at the upper canthus electrode.

Fig. 33 Glossokinetic Artifact



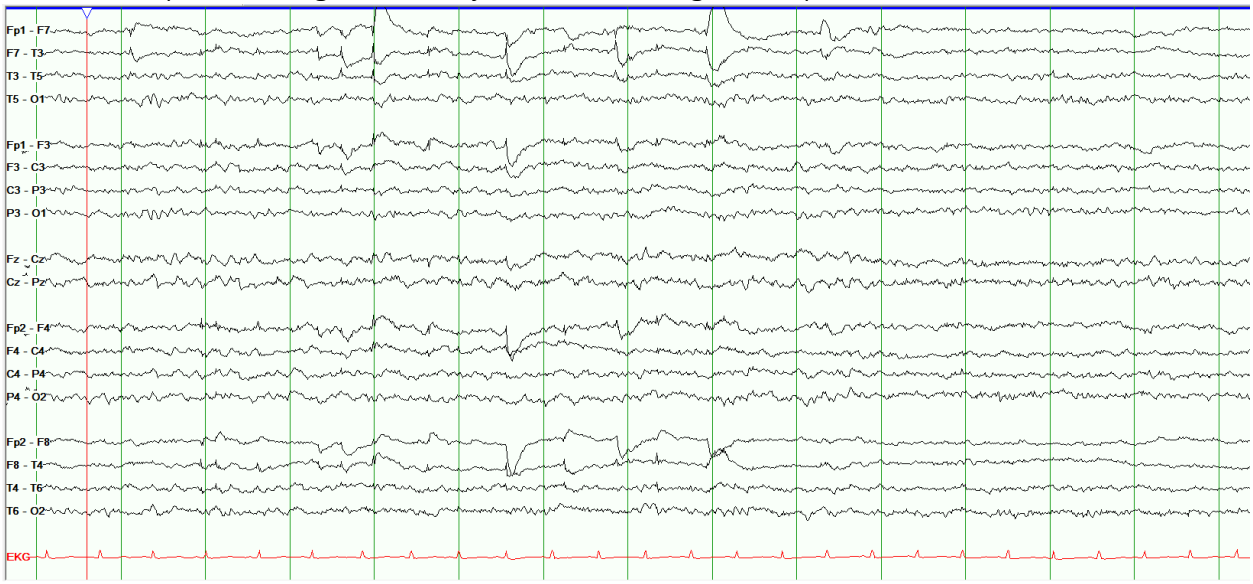
LATERAL RECTUS SPIKE

Lateral rectus spikes appear as short-duration spikes in the frontopolar, frontal, and anterior temporal electrodes. Their duration is much shorter than epileptiform spikes making them easy to identify. They occur with lateral eye movements and are prominent in REM sleep.

Fig. 34 Lateral Rectus Spikes

Fig. 35 Lateral Rectus in REM

Lateral rectus spikes occurring with lateral eye movements during REM sleep.



MYOGENIC ARTIFACT (MUSCLE)

Muscle artifact is most frequently seen in the frontal and temporal areas and is present during wakefulness but diminishes in drowsiness and sleep. It is more pronounced in patients who are tense or agitated. Prominent muscle artifact can obscure interictal discharges.

TROUBLESHOOTING MUSCLE ARTIFACT

Asking the patient to open the mouth slightly to relax the jaw is often helpful to reduce temporal muscle artifact. If this fails, other efforts should be made to relax the patient such as replacing the towel roll with a pillow, dimming the lights, or adjusting the room temperature. The high frequency filter (HFF) can be

lowered if muscle artifact persists despite efforts to relax the patient; however, lowering the HFF can make muscle artifact falsely resemble cerebral activity, especially beta or epileptiform spikes. The HFF should never be lowered below 35 Hz during acquisition.

MUSCLE SPIKES

Muscle spikes can be recognized by their limited field usually restricted to one electrode and their short duration; they are “spikier” than epileptiform spikes.

Fig. 36 Isolated Muscle Spike

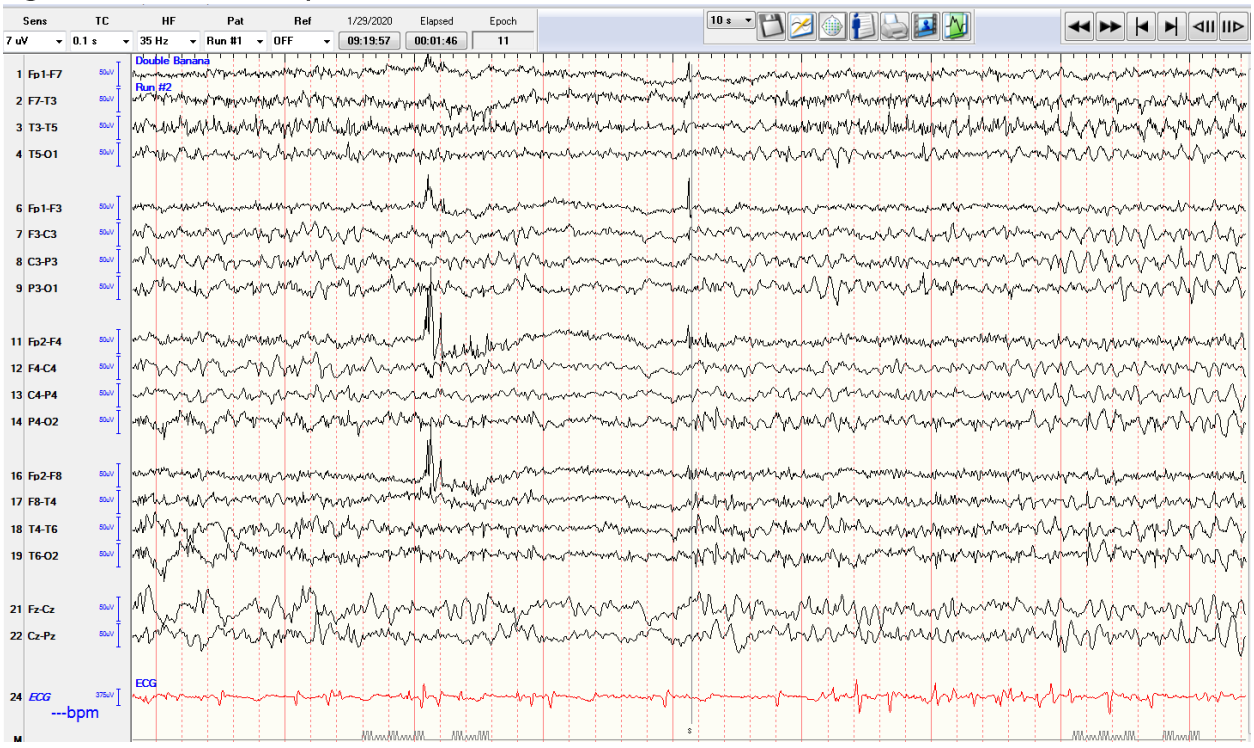
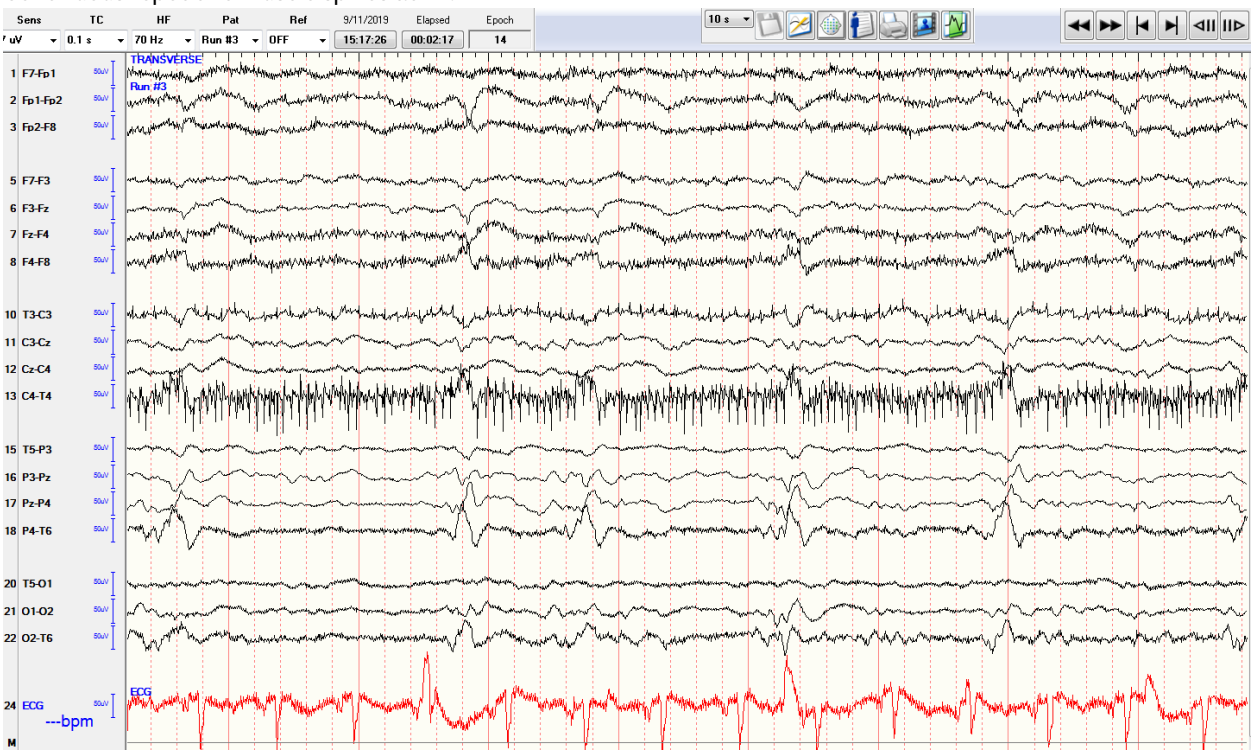


Fig. 37 Continuous Muscle Spikes

Continuous repetitive muscle spikes at T4.

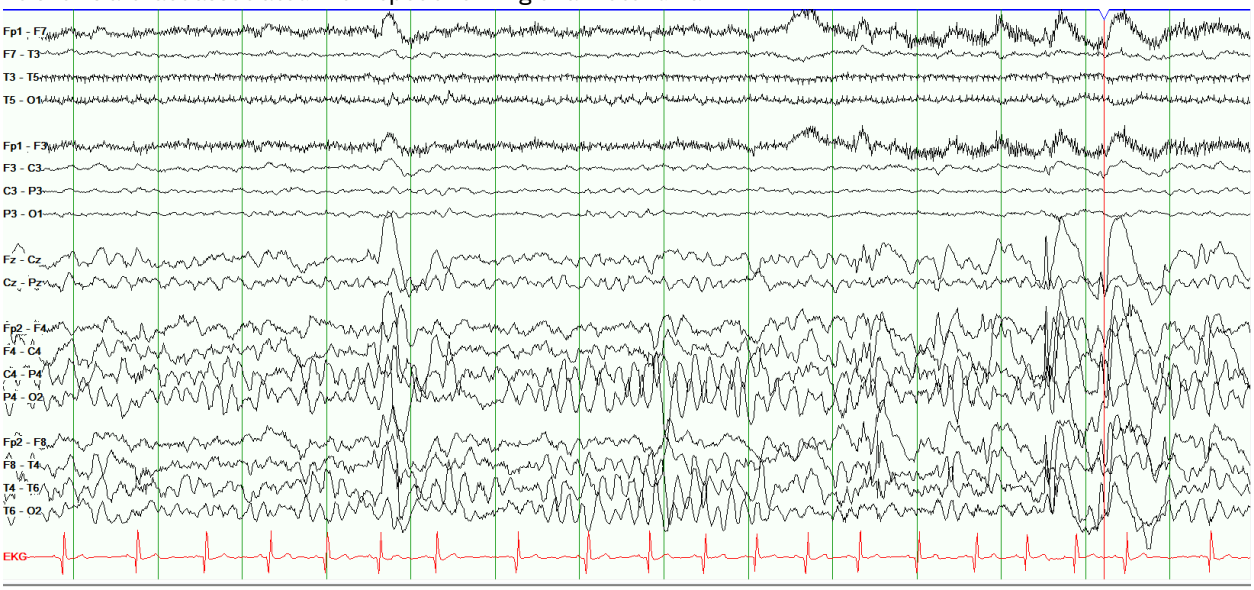


CONTINUOUS FIRING OF A MOTOR UNIT

Repetitive firing of a motor unit produces a continuous train of short duration spikes in one electrode.

Fig. 38 Repetitive Firing of a Motor Unit

T5 shows artifact associated with repetitive firing of a motor unit.



ISOLATED MUSCLE ARTIFACT

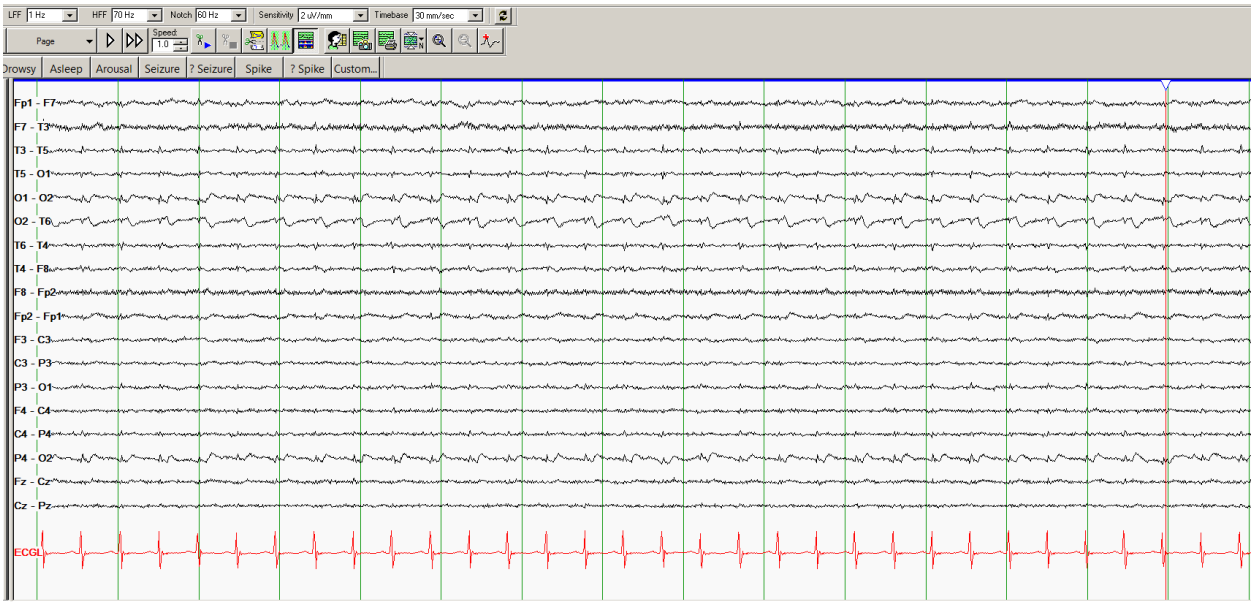
When muscle artifact is restricted to one electrode, the technologist can try to eliminate it by gently massaging the skin near the electrode.

PULSE ARTIFACT

Pulse artifact occurs when an electrode is overlying a small scalp artery. It appears as regular, rhythmic deflections in one channel. It is most prominent in low voltage recordings among a suppressed background but can also be seen against a normal background. It tends to occur more in posterior electrodes where there is more pressure on the electrodes from contact with the bed. It does not line up with the QRS complex but has a constant relationship with it. Slightly relocating the electrode or changing the head position may reduce or eliminate the artifact. If pulse artifact is present in the ground or reference electrode, it may appear diffuse or widespread. Pulse may be more difficult to identify when the patient has an irregular heart rate.

Fig. 39 Pulse Artifact

Pulse artifact is seen at O2 against a diffusely suppressed background. Sensitivity 2 uV/mm.



SNORING

The vibration of tissues that occurs with snoring produces an artifact of intermittent or periodic bursts of high frequency activity.

SOBBING

Sobbing is a catching of the breath that occurs with crying. Sobbing often continues in infants after a period of actively crying and can persist into stage II sleep. It produces a short-duration artifact with varied morphology, similar to hiccups.

SUCKING ARTIFACT

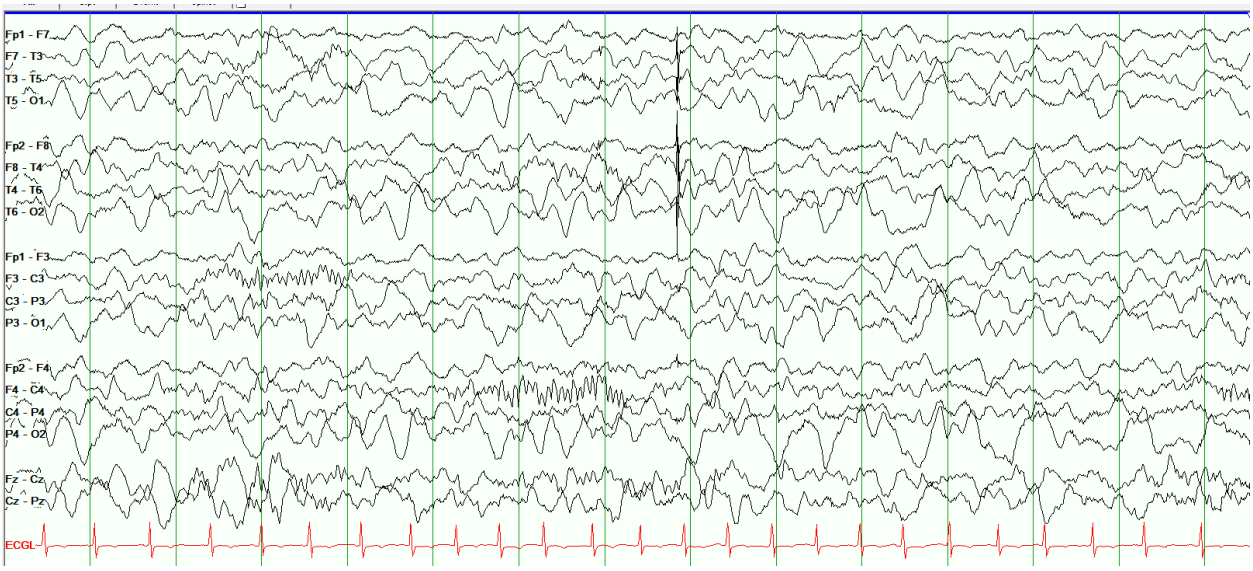
Sucking produces a high amplitude artifact of short duration maximal in the temporal area. Sucking is common when infants are nursing, feeding with a bottle, or sucking a pacifier; these keep the infant calm,

so the technologist documents the artifact rather than trying to eliminate it. Sucking can continue into stage II sleep in infants.

Fig. 40 Sucking Artifact

Fig. 41 Sucking Artifact

Sucking artifact in a 7-month-old sleeping infant.



SWEAT ARTIFACT

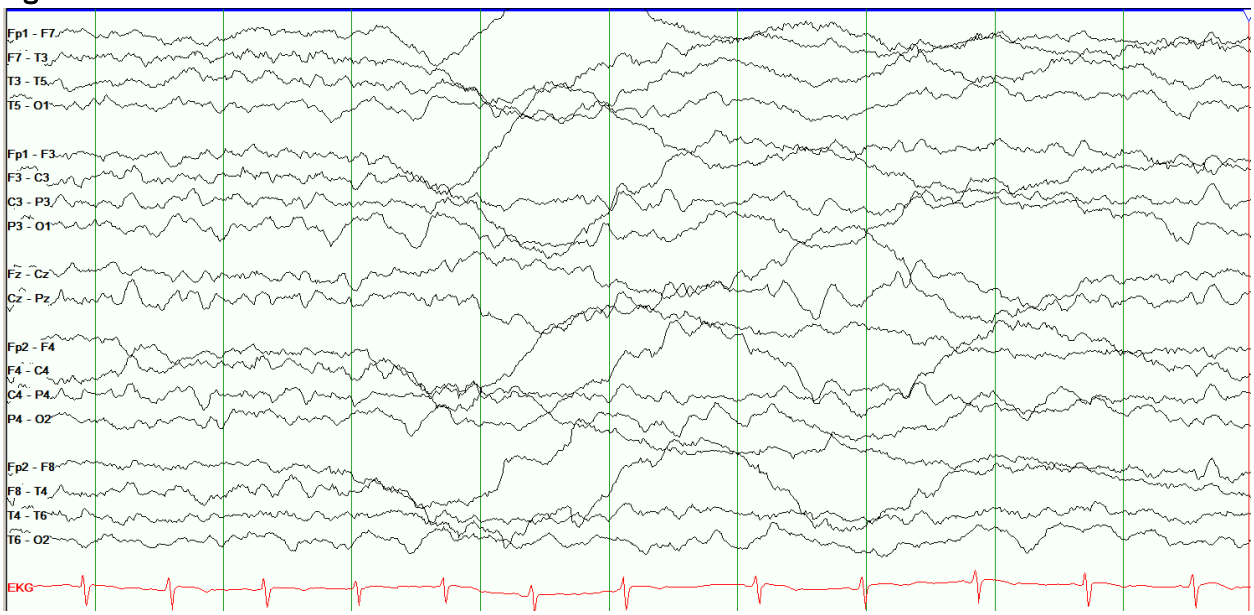
Perspiration changes contact between electrodes and the scalp and creates electrolyte bridges between electrodes.[iv] The result is artifactual long-duration slow waves and channels that “wander” into each other. This artifact is also referred to as sweat sway.

TROUBLESHOOTING SWEAT ARTIFACT

- Try cooling the patient by fanning, lowering the room temperature, etc.

- Unwrap the head if possible.
- Try wiping the scalp with alcohol in the area where sweat is present.
- If efforts to cool the patient fail, the LFF can be raised to 3 Hz to attenuate the slow waves caused by perspiration. Filter changes should be clearly documented.

Fig. 42 Sweat Artifact



SYMPATHETIC SKIN RESPONSE

Sympathetic skin response is an autonomic response produced by the sweat glands that can produce a slow wave EEG artifact. The artifact is usually in the frontocentral region and appears as a 0.5- to 1-second slow wave with 1-3 prominent phases lasting 1.5-2 seconds. It can be identified by its characteristic triple phase reversal in a transverse montage.[v]

[ii] Aniles, E. (2017). Deep brain stimulator artifact on EEG recording. *The Neurodiagnostic Journal, 57*, 165-167. DOI 10.1080/21646821.2017.1311747

[ii] Bruzzone Giraldez, M.J., Issa, N., Tao, J., Rose, S., Warnke, P., & Wu. S. (2017). The responsive neurostimulation (RNS) artifact on scalp EEG recording. *Neurology, 88*(16), 2.223.

[iii] White, D.M., & Van Cott, A.C. (2010). EEG artifacts in the intensive care unit setting. *The American Journal of Electroneurodiagnostic Technology, 50*, 8-25.

[iv] Libenson *Practical Approach to Electroencephalography*

[v] Mathias, S.V., Bensalem-Owen, M. (2019). Artifacts that can be misinterpreted as interictal discharges. *Journal of Clinical Neurophysiology, 36,* 264-274.