## EANS/UEMS European examination in neurosurgery

Variants of questions with answers (compilation - Vyacheslav S. Botev, Department of Neurosurgery, M.Gorky Donetsk National Medical University)

## NEUROPHYSIOLOGY PART II

## I. ELECTRONICS AND INSTRUMENTATION

### Questions

1. What is the maximum recommended electrode impedance for recording EEG?

A. 500 ohms
B. 1000 ohms
C. 5000 ohms
D. 50000 ohms

2. Increasing the high-frequency filter cutoff will cause the waveform to appear
A. Sharper
B. Smoother
C. Phase shifted to the right
D. Smaller

3. What is the charge moving across a potential energy gradient?
A. Resistance
B. Current
C. Energy
D. Power

4. What types of signals are used in the calibration process for EEG?
A. Square wave inputs
B. Sine wave inputs
C. Cosine wave inputs
D. Triangular wave inputs

5. Which of the following does not increase the EEG impedance?
A. Interface between the scalp and the electrode
B. The wiring from the electrode to the amplifier
C. Display of the acquired EEG waveform on the computer screen
D. Skull thickness

6. Ideally, where should the reference electrode be located in reference to the recording electrode in order to get the most robust waveform?
A. On top of
B. Next to
C. Far from
D. Depends on the electrode type used

7. What percentage of the input amplitude will pass at the cutoff frequency of a filter?
A. 0%
B. 50%
C. 70%
D. 100%

8. When multiple capacitors are placed in a circuit, they exhibit the behavior opposite to that of
A. Inductors
B. Resistors
C. Invertors
D. Operative amplifiers

9. Which of the following statements regarding analog-to-digital conversion is true?
A. Analog EEG measures the data at discrete time points
B. Digital EEG is made up of continuous nondiscrete data
C. The higher the sampling rate, the closer the digital signal resembles the analog signal
D. The less number of bits an analog-to-digital converter (ADC) has, the more the digital sample resembles the analog signal

10. All of the following statements regarding inductors are true except
A. Their currents are generated by the electrical field surrounding a wire that creates currents in other wires
B. They have a reactance similar to resistors
C. They pose an impediment to current generated by another source
D. The reactance is directly proportional to the inductance

11. While performing a sensory nerve conduction study, the neurology resident in the electrodiagnostic laboratory notices a stimulus artifact before the sensory response. All of the following techniques can help reduce the stimulus artifact except
A. Increase the stimulus intensity
B. Increase the distance between the stimulator and recording electrode
C. Place the ground between the stimulator and the recording electrode
D. Rotate the anode of the stimulator

12. All of the following statements about common mode signals are true except
A. Common mode signals are dissimilar potentials at different electrode sites that should be ideally rejected
B. Amplifiers are designed to preferentially block common mode signals and to pass the differential-mode signals
C. Unequal impedances between electrodes can affect common mode signals
D. It is recommended that the common mode signals be rejected at a ratio of 80 dB.

For Questions 13–16:
A 27″ computer screen has a resolution of 1920 (horizontal) by 1080 (vertical) pixels with vertical borders of 250 pixels each. An EEG sampled at 1000 Hz is displayed at 15 seconds per page.

13. How many pixels per inch (PPI) are present on the computer screen?
A. 40
B. 63.1
C. 71.1
D. 81.6

14. How many pixels are available to display 1 second of EEG?
A. 39
B. 95
C. 128
D. 142

15. What is the maximum frequency of the EEG activity that can be displayed based on the specified parameters?
A. 47 Hz
B. 95 Hz
C. 500 Hz
D. 1000 Hz

16. What would be the maximum resolvable frequency if the margins of the screen are eliminated and the number of seconds per page is reduced from 15 seconds to 10 seconds?
A. 47 Hz
B. 96 Hz
C. 192 Hz
D. 500 Hz

For Questions 17–20:
Assume an EEG acquisition system that has a 10-bit analog-to-digital converter (ADC) with a voltage range of –2 mV to +2 mV.

17. In how many discrete voltage bins can the digital signal be placed?
A. 4
B. 10
C. 210
D. 2000

18. The voltage resolution of the sampled data is closest to which value?
A. 0.2 μV
B. 2 μV
C. 0.4 μV
D. 4 μV

19. What will happen to the voltage resolution if the voltage range of the EEG system is reduced to the –1 mV to +1 mV range?
A. It will remain the same because the number of bins has not changed
B. It will decrease by a factor of 2
C. It will increase by a factor of 2
D. It will increase by a factor of 4

20. What will be the approximate voltage resolution if a 12-bit analog-to-digital converter (ADC) is used instead of the 10-bit ADC in the EEG system?
A. 1 μV
B. 2 μV
C. 4 μV
D. 16 μV

## Electronics and Instrumentation Answers

1. C. 5000 ohms.
The recommended electrode impedance is 5000 ohms or less to minimize electroderelated artifact.

2. A. Sharper.
Increasing the high-frequency components will make the waveform appear sharper. In general, a higher cutoff frequency will result in inclusion of higher frequency components that tend to be sharper and smaller in amplitude. Due to the presence of higher amplitude lower frequencies, the overall waveform size may not change much. However, the superimposed faster frequencies may make the waveform sharper (more spiky) along with a phase shift to the left.

3. C. Energy.
Energy is the charge moving across a potential gradient and is measured in joules (J). Power is the rate of transfer of energy and is measured in watts (W) or J/sec. Current refers to the rate of flow of charge in response to an applied electrical potential or voltage and is measured in amperes (A). Resistance is the impediment to the flow of charge and is measured in ohms (Ω).

4. A. Square wave inputs
Calibration maneuvers use square wave inputs and are done to assess the fidelity of the recording system.

5. C. Display of the acquired EEG waveform on the computer screen.
Display of the acquired EEG signal on the computer screen does not add to the EEG impedance. EEG impedance is a measure of the resistance along with the capacitive and inductive reactance. Impedance derives from any material through which the EEG signal passes from its generator to the analog-to-digital converter (ADC).

6. C. Far from.
The reference electrode ideally should be far from the recording electrodes, regardless of the type of electrodes used, to subtract artifacts and noise that may be contaminating both input electrodes (ie, common mode rejection) and to enhance the underlying waveform because the reference electrode will likely be less involved in the particular electric field, contributing to the recording electrode waveform. Placing the reference electrode on top of the recording electrode will result in no signal because the exposure to the same electrical field magnitudes would cancel out. Placing the reference electrode next to the recording electrode will result in a small signal because both electrodes would still be exposed to similar electrical fields, resulting in cancellation of common fields, which is not ideal.

7. C. 70%.
Cutoff frequency or corner frequency is the frequency either above or below which the power output of a circuit, such as an electronic filter, has fallen to a given proportion of the power in the passband, which is the band of frequencies that the filter lets through. Most frequently, this proportion is one-half the passband power, also referred to as the 3 dB point because a fall of 3 dB corresponds approximately to one-half power. Because power is the square of voltage, the resulting voltage value in relation to the passband voltage is

$$v = \sqrt[2]{\frac{1}{2}} = 0.707, \quad \text{or} \quad 70\%$$

8. B. Resistors.
Multiple capacitors in a circuit interact in a manner that is opposite to the behavior of resistors. When capacitors are placed in parallel, there is an additive effect. On the contrary, when capacitors are placed in series, they add in a reciprocal manner.

9. C. The higher the sampling rate, the closer the digital signal resembles the analog signal.

Analog EEG measures continuous (not discrete) data with respect to time and value. Digital EEG, on the other hand, intermittently samples data at discrete moments, and the corresponding amplitudes at that moment are assigned to the nearest discrete values. The degree of fidelity with which the digitally sampled data resembles the original analog data depends on how finely it is sampled, that is, how many discrete steps there are with respect to time (ie, sampling rate) and the amplitude (ie, number of bits in the analog-todigital converter or ADC).

10. A. Their currents are generated by the electrical field surrounding a wire that creates currents in other wires.
The inductive current is generated by the magnetic field, not the electrical field, surrounding a wire that creates currents in other wires. Inductance is similar to resistance in that it poses an impediment to current flow. In terms of inductors, the reactance is to the current generated by another source, which is directly proportional to the inductance, L (given in Henries).

11. A. Increase the stimulus intensity.
Increasing the stimulus intensity will only worsen the stimulus artifact. Multiple techniques are recommended to decrease the stimulus artifact. These include decreasing the stimulator intensity, increasing the distance between the stimulator and recording electrodes, placing the ground between the stimulator and recording electrode, and rotating the anode of the stimulator electrode.

12. A. Common mode signals are dissimilar potentials at different electrode sites that should be ideally resected.

Common mode signals are potentials that are similar at different electrode sites. The ability of an amplifier to block common mode signals and to pass differential-mode signals is called common mode rejection ratio (CMRR) and is usually expressed in decibels (dB). Unequal impedances between electrodes can affect common mode rejection and can cause artifacts. It is recommended that the CMRR should be at least 80 dB (10 000:1) at the highest sensitivity of the amplifier.

13. D. 81.6

The PPI of a display is related to the size of the display in inches and the total number of pixels in the horizontal and vertical directions. Note that the size of a display typically refers to the diagonal measurement across the screen. Therefore, if given the horizontal and vertical number of pixels, the number of pixels along the diagonal can be calculated in two steps: (a) Calculate diagonal resolution in pixels using the Pythagorean theorem:

(a) Calculate diagonal resolution in pixels using the Pythagorean theorem:

$$d_p = \sqrt{w_p^2 + h_p^2}$$

(b) Calculate PPI:

$$PPI = \frac{d_p}{d_i}$$

where

- $d_p$ is diagonal resolution in pixels
- $w_p$ is width resolution in pixels
- $h_p$ is height resolution in pixels
- $d_i$ is diagonal size in inches (this is the number advertised as the size of the display).

For example, for a 27″ screen with a 1920 × 1080 resolution (in which $w_p$ = 1920, $h_p$ = 1080, and $d_i$ = 27), we get 2203 pixels along the diagonal and a PPI of 81.6.

14. B. 95.

The number of pixels displayed in the EEG is a reflection of the total number of horizontal pixels of the display subtracting the number of pixels in the border. To obtain the number of pixels per second of EEG, the number of pixels displayed in the EEG is divided by the number of seconds displayed.

In the stated case,
1920 horizontal pixels – (250 border pixels × 2) = 1420 pixels/EEG page
and
(1420 pixels/EEG page) / (15 sec/EEG page) = 95 pixels/sec

15. A. 47 Hz.

The maximum frequency that can be clearly displayed given the screen resolution and number of seconds of EEG per screen is 47 Hz. In general, the maximum frequency faithfully representable on a pixel display is one-half the number of pixels per second, which is 95 in this case. The maximum resolvable frequency of EEG, in this case, based on the sampling rate of 1000 Hz is 500 Hz (Nyquist frequency). However, this question is specifically referring to the maximum frequency of the EEG activity that can be displayed on the screen with the specified parameters. In this case, there are only 95 pixels available to be displayed per second of EEG. Therefore, this could be considered to be equivalent to a sampling rate of 95 Hz. Based on the Nyquist theorem, the maximum resolvable frequency is one-half of the sampling rate or 47.5 Hz. The maximum frequency displayed could be increased by decreasing the number of seconds displayed per page, thus increasing the number of pixels per second. Note that when a signal contains not just one but many different frequencies added together, the minimum sampling rate needed to avoid aliasing is twice the highest frequency present irrespective of how many other frequency components there are.

16. B. 96 Hz.

In the proposed scenario, the maximum resolvable frequency will be 96 Hz. After making the noted adjustments, there will be

(1920 horizontal pixels/EEG page) / (10 s/EEG page) = 192 pixels/sec,

which would correlate to a sampling rate of 192 Hz. Based on the Nyquist theorem, the maximum resolvable frequency is one-half of the sampling rate, or 96 Hz in this case. Although digital EEG recording systems typically have very good resolution and dynamic range, the ability to display the data depends on the screen resolution of the monitors. The displayed resolvable frequency can be increased by increasing the screen resolution or decreasing the number of seconds displayed, both of which would increase the number of pixels per second. Thus, when evaluating for gamma activity or high-frequency oscillations, the number of seconds displayed on the screen is typically around 1 to 2 seconds.

17. C. 210.

The digital signal can be placed in $2^{10}$ or 1024 bins or digitally assignable increments. The number of discrete voltage bins or divisions is determined by the number of bits an analog-to-digital converter (ADC) has, that is, $2^n$, where n is the number of bits an ADC has.

18. D. 4 µV
The magnitude of the voltage step or resolution is equal to the dynamic range (ie, the range of measurable voltage values) divided by the number of discrete bins (determined by the number of bits the analog-to-digital converter [ADC] has). In this case, the dynamic range is 4 mV (–2 mV to +2 mv), and the number of bins is 1024. Thus, the voltage resolution is roughly 4 µV, which is calculated as follows:

4 mV/1024 bins = 4000 µV/1024 bins = 3.9 µV ~ 4 µV.

19. C. It will increase by a factor of 2.

In the new scenario, the dynamic range has been reduced from the original –2 mV to +2 mV to the new –1 to +1 mV, that is, by a factor of 2 (from 4 µV to 2 µV). This will increase the voltage resolution by a factor of 2. In other words, the voltage resolution will be higher at 2 µV instead of the original 4 µV. This is calculated as follows:

2 mV/1024 bins = 2000 µV/1024 bins = 1.96 µV ~ 2 µV.

20. A. 1 µV.
By increasing the bit depth of the ADC, the voltage resolution will increase by a factor of $2^{\Delta n}$, where Δn is the change in the number of bits. In this case, the new resolution will increase by a factor of $2^2$ (=4). So the new resolution will be 1 µV, which is calculated as follows:

Original $2^{10}$ bit depth: 4 mV/1024 bins = 4000 µV/1024 bins = 3.9 µV ~ 4 µV

New $2^{12}$ bit depth: 4 mV/4096 bins = 4000 µV/4096 bins = 0.97 µV ~ 1 µV.

## II. EMG QUESTIONS

1. While performing single-fiber EMG (SFEMG), which of the following measures should be undertaken?

A. Lower the high-frequency filter to 200 Hz
B. Raise the high-frequency filter to 500 Hz
C. Raise the low-frequency filter to 200 Hz
D. Raise the low-frequency filter to 500 Hz

2. All of the following statements about single-fiber EMG (SFEMG) are true except
A. Normal SFEMG in a weak muscle is not consistent with myasthenia gravis
B. SFEMG is the most sensitive test for neuromuscular junction (NMJ) dysfunction
C. SFEMG is the most specific test for NMJ dysfunction
D. Jitter value changes with aging

3. Which of the following statements regarding single-fiber EMG (SFEMG) is correct?

A. Abnormal SFEMG always means there is an underlying neuromuscular junction (NMJ) disorder
B. Normal SFEMG in a weak muscle makes a NMJ dysfunction less likely
C. SFEMG is a very specific but not very sensitive test for NMJ dysfunction
D. With increasing age, jitter remains the same but blocking increases

4. A blink study was performed in a 58-year-old man with facial symptoms. The results are summarized in the following table. What does this study suggest?

| Side and site of stimulation | Ipsilateral R1 | Ipsilateral R2 | Contralateral R2 |
|---|---|---|---|
| Right V1 | Normal | Normal | Absent |
| Left V1 | Absent | Absent | Normal |

A. Right trigeminal neuropathy
B. Left trigeminal neuropathy
C. Right facial neuropathy
D. Left facial neuropathy

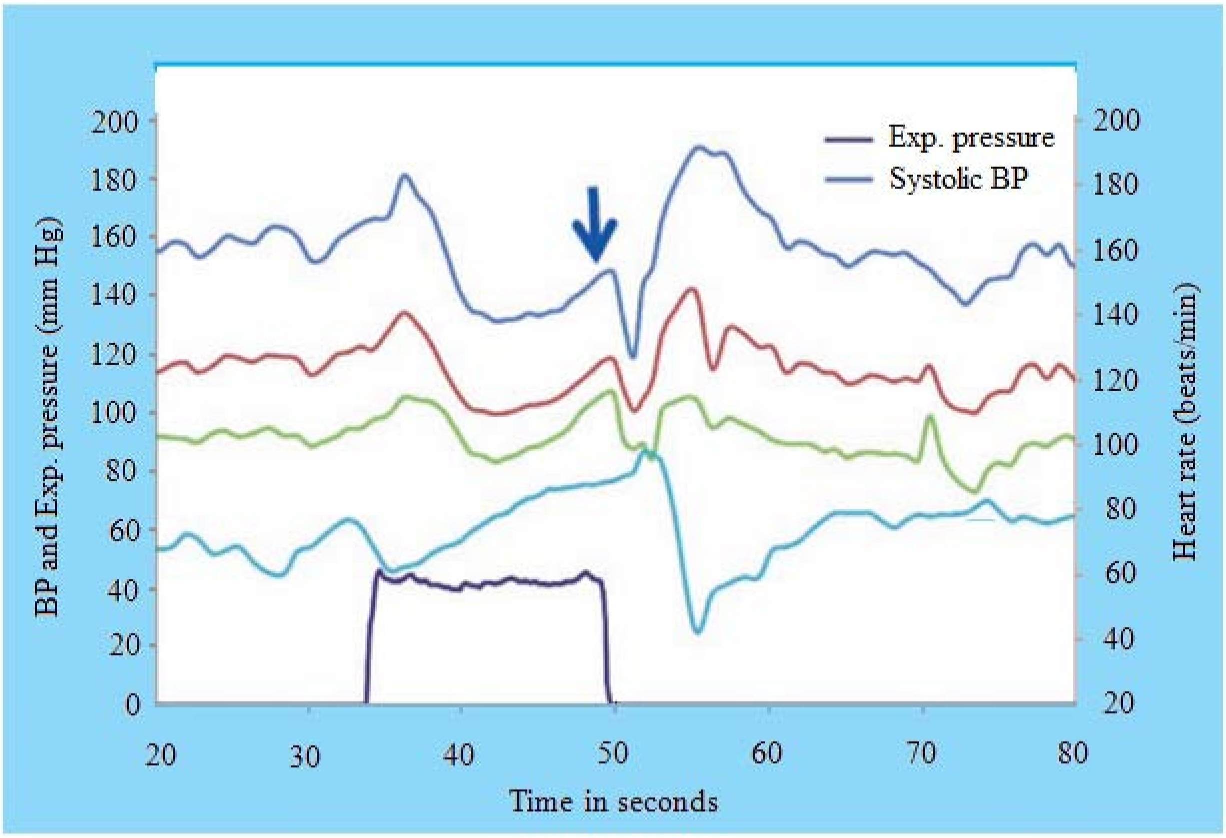
5. While performing a blink reflex study with right trigeminal stimulation, ipsilateral R1, ipsilateral R2, and contralateral R2 responses were absent. A focal lesion in which of the following locations could lead to these findings?

A. Right facial nerve or nucleus
B. Right trigeminal nerve or nucleus
C. Right oculomotor nerve or nucleus
D. Right abducens nerve or nucleus

6. All of the following statements about blink reflex study are correct except

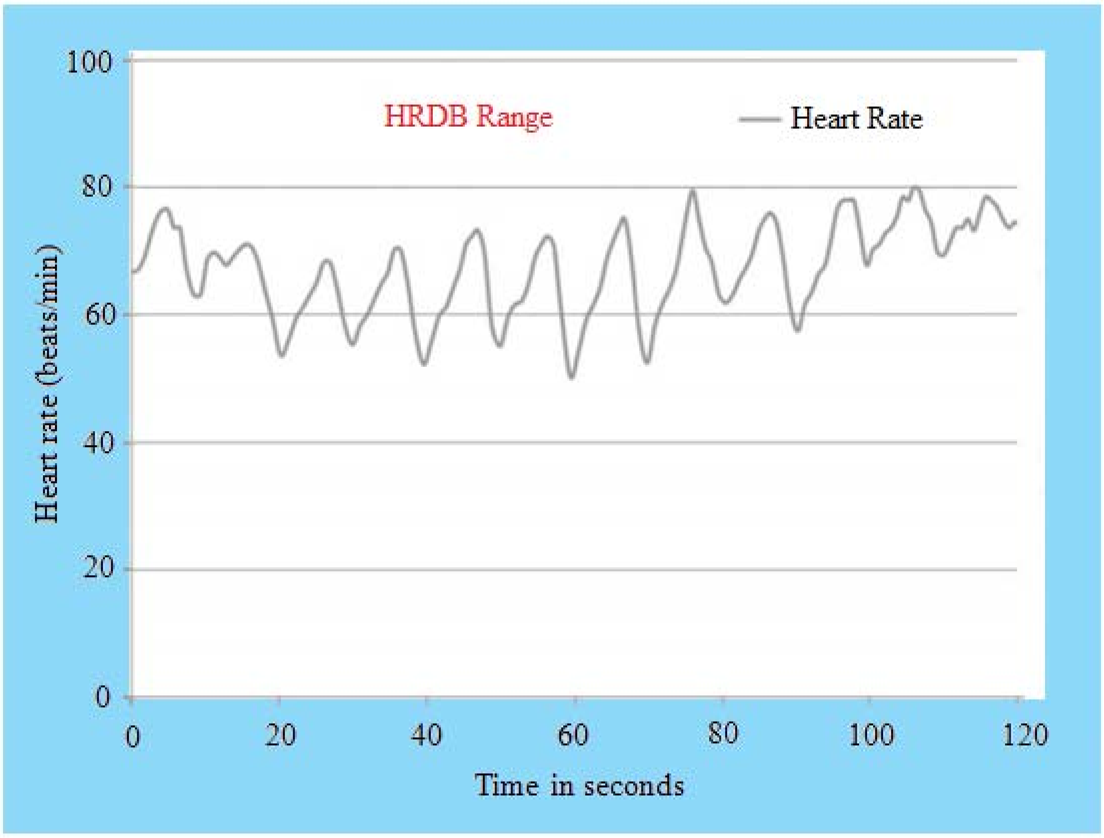
A. It is a polysynaptic reflex
B. Efferent and afferent fibers travel through different cranial nerves
C. Bilateral R2 responses are seen after stimulation
D. Bilateral R1 responses are seen after stimulation

7. The figure below shows a waveform obtained after a normal Valsalva testing in a patient. Which phase of Valsalva does the arrow point to?




A. Phase III
B. Phase II Late
C. Phase IV
D. Phase II Early

8. A 45-year-old male with syncope had autonomic testing. His heart rate deep breathing range was assessed based on the waveform shown below. The likely heart rate deep breathing range is




A. 8
B. 2
C. 18
D. 40

9. Which of the following is the best test to differentiate Parkinson's disease with autonomic failure from multiple system atrophy (MSA)?
A. Degree of orthostatic hypotension
B. Heart rate (HR) variability
C. Cardiac sympathetic imaging
D. Valsalva ratio

10. During a motor nerve conduction study, the sensitivity of the display was changed from 5 mV per division to 1 mV per division. How can this change affect the compound muscle action potential (CMAP)?
A. Increases the CMAP duration
B. Increases the CMAP amplitude
C. Increases the measured CMAP latency
D. Decreases the measured CMAP latency

11. Which of the following is true regarding cathode?
A. It is the positively charged terminal of a galvanic cell
B. It is the negatively charged terminal of a galvanic cell
C. It repels electrons
D. It represents the terminal into which the current flows

12. Which of the following situations will lead to a phase shift to the left?
A. Decreasing the low-frequency filter; decreasing the high-frequency filter
B. Decreasing the low-frequency filter; increasing the high-frequency filter
C. Increasing the low-frequency filter; decreasing the high-frequency filter
D. Increasing the low-frequency filter; increasing the high-frequency filter

13. While performing an electrodiagnostic study in an ICU setting, excess electrical artifact can be removed by undertaking all of the following steps except
A. Turn off all devices that do not need to be "on" during the study
B. Use adequate electrode gel
C. Use coaxial cables
D. Use submaximal stimulation for nerve conduction studies

14. While performing antidromic sensory studies, the technologist decreases the distance between the active and reference electrodes without making any changes to the distance between the stimulation point and active electrodes. This will likely result in which of the following changes to the sensory nerve action potential (SNAP)?
A. Increased duration
B. Increased peak latency
C. Increased onset latency
D. Decreased amplitude

15. Decreasing the time constant will cause the waveform to appear
A. Sharper
B. Smoother
C. Phase shifted to the right
D. Larger

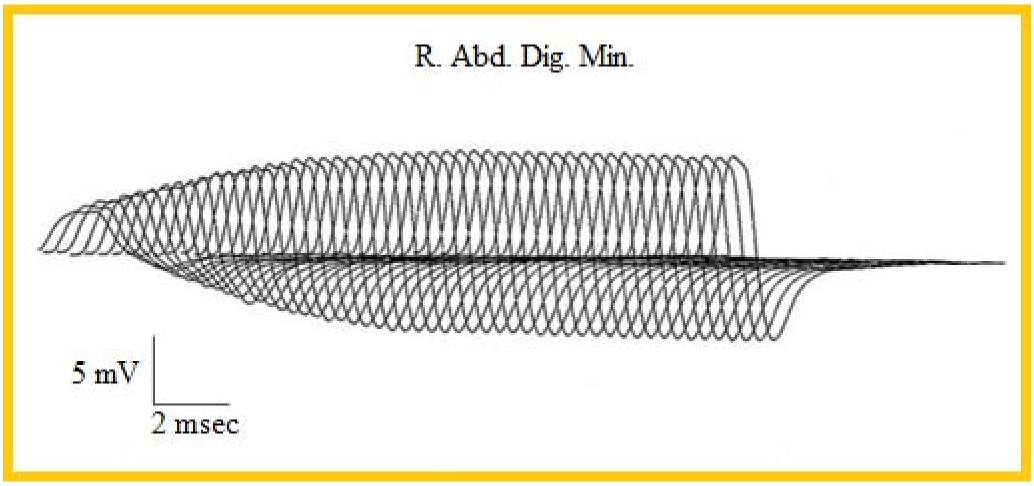
16. Which of the following outcomes is likely if the high-frequency filter cutoff is reduced from 10000 Hz to 500 Hz during needle EMG?
A. No change in motor unit action potential (MUAP) amplitude
B. Reduction in MUAP amplitude
C. Increase in MUAP amplitude
D. Any of the above, depending on the type of needle used

17. With sciatic nerve compression, which of the following findings is relatively common on electrodiagnostic testing?
A. Absent tibial response but normal peroneal and sural responses
B. Significantly decreased peroneal amplitude compared to tibial amplitude
C. Absent tibial and peroneal responses with preserved sural response
D. Normal tibial H-reflex

18. The conduction velocity of an action potential is least likely to be affected by which of the following?
A. Axon diameter
B. Axon temperature
C. Distance between nodes of Ranvier
D. Number of surrounding axon

19. Nerve conduction and EMG studies are appropriate initial diagnostic procedures in all of the following conditions except
A. A 5-year-old boy with high creatine phosphokinase (CPK), enlarged calf muscles, and positive Gower's sign
B. A 12-year-old boy with fatigue, weakness, and ptosis
C. A 15-year-old girl with slowly progressive distal weakness, atrophy, and sensory loss
D. 22-year-old man with subacute onset of lower extremity numbness and weakness

20. What does the waveform below show?




A. Slow repetitive stimulation and significant decrement
B. Fast repetitive stimulation and significant increment
C. Fast repetitive stimulation and significant decrement
D. Slow repetitive stimulation and significant increment

21. A forearm exercise test was performed in a man with suspected metabolic myopathy. Both ammonia and lactate levels were measured at regular intervals during the forearm exercise test. If the lactate level is elevated but not the ammonia level, it is suggestive of

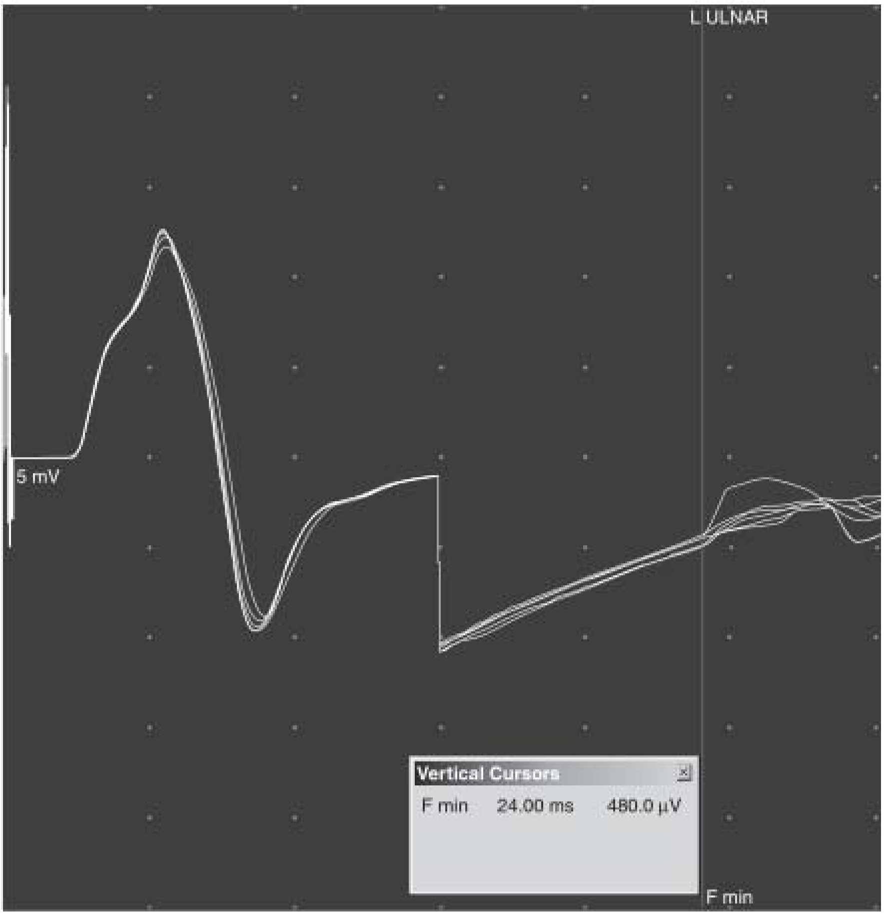
A. Myophosphorylase deficiency

B. Phosphofructokinase deficiency

C. Myoadenylate deaminase deficiency

D. Phosphoglycerate kinase deficiency

22. Which of the following is true about the waves illustrated in figure below?




A. They are obtained by submaximal long- duration (1-ms) nerve stimulation.

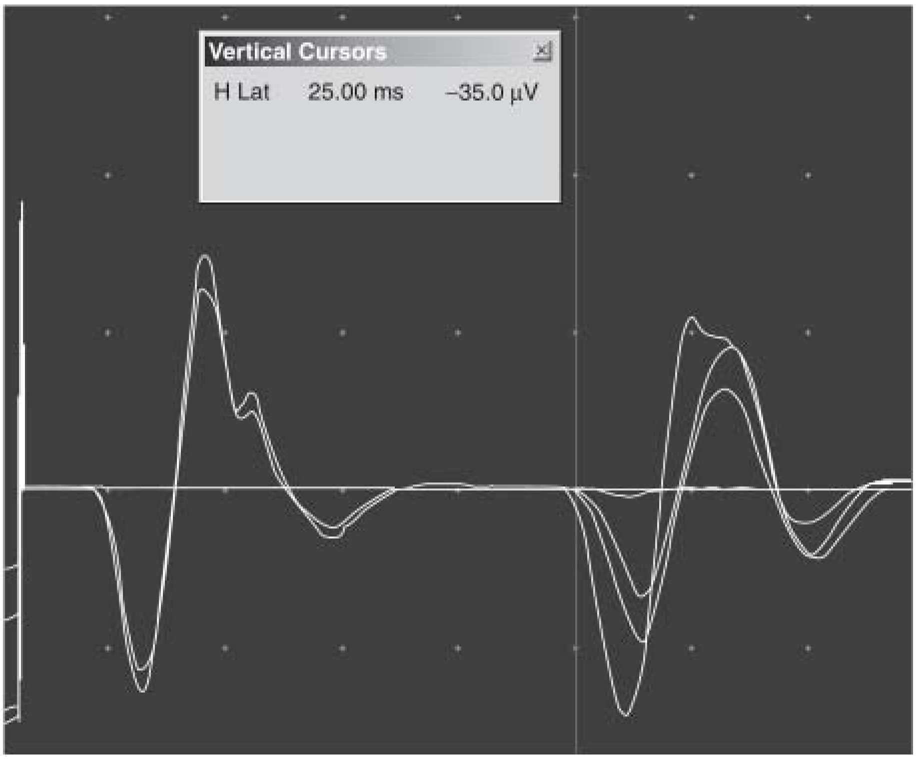
B. Sensory nerve fibers constitute the afferent pathway that generates these waves.

C. Their latencies are specifically affected in S1 radiculopathy.

D. They may be absent or have prolonged latency in acute inflammatory demyelinating polyneuropathy.

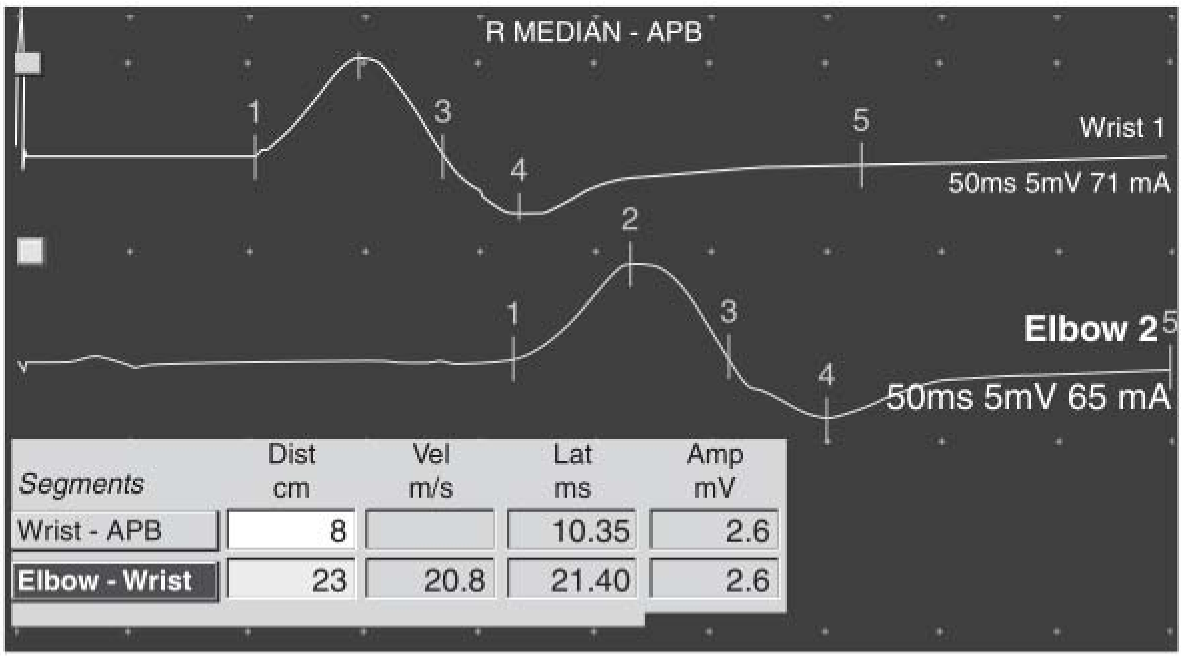
E. They are the electrical correlate of ankle jerk.

23. Which of the following is true about the waves illustrated in figure below?




A. They are obtained by supramaximal nerve stimulation
B. Motor nerve fibers are the afferent path-way that generate these waves
C. They can be obtained from sensory nerves
D. They are usually preserved in S1 radiculopathy
E. They are the electrical correlate of ankle jerk

24. Figure below illustrates a motor nerve conduction study of a median nerve, stimulating at the wrist and the elbow and recording at the abductor pollicis brevis.



What is the most likely diagnosis?
A. Carpal tunnel syndrome
B. Congenital demyelinating polyneuropathy
C. Acquired demyelinating polyneuropathy
D. Axonal polyneuropathy
E. Myasthenia gravis

## EMG Answers

1. D. Raise the low-frequency filter to 500 Hz.
While performing SFEMG, the low-frequency filter should be raised to 500 Hz so that distant low-frequency waveforms are not recorded. This allows the SFEMG needle to record only from a few muscle fibers close to the needle tip.

2. C. SFEMG is the most specific test for NMJ dysfunction.
SFEMG is not specific for NMJ diseases, and can be abnormal in neurogenic conditions. SFEMG is the most sensitive test for NMJ disorders and a normal SFEMG in a weak muscle is not consistent with myasthenia gravis. Jitter value increases with age.

3. B. Normal SFEMG in a weak muscle makes a NMJ dysfunction less likely.
A normal SFEMG in a weak muscle makes a neuromuscular junction (NMJ) dysfunction as the underlying cause of the weakness very unlikely. Abnormal SFEMG does not always mean NMJ disorder as this can be seen with neurogenic conditions as well. SFEMG is a sensitive but not very specific test for NMJ disorder. With increasing age, normal upper limit of jitter increases. Blocking is generally considered to be abnormal irrespective of the age.

4. D. Left facial neuropathy.
On right-sided stimulation, ipsilateral R1 and R2 responses are normal, suggestive of normal right trigeminal and facial nerves and rest of the reflex arc. However, the contralateral R2 is absent. On left-sided stimulation, ipsilateral R1 and R2 are absent but contralateral R2 is normal, suggestive of normal left trigeminal nerve function. Since only the motor responses on the left side are absent with normal afferent pathways, this study is suggestive of left facial neuropathy.

5. B. Right trigeminal nerve or nucleus.
A lesion in the right trigeminal nerve or nucleus leads to absence of ipsilateral R1, ipsilateral R2, and contralateral R2 responses with right trigeminal stimulation. When all the responses are absent, the likely lesion is in the afferent loop, such as the trigeminal nerve or nucleus. Unilateral facial nerve or nucleus lesion should not cause deficits on both sides. Oculomotor and abducens nerves do not have any role to play with blink reflexes.

6. D. Bilateral R1 responses are seen after stimulation.
Blink reflex study is a polysynaptic study. The afferent fibers are in the 5th cranial nerve and efferent fibers are in the 7th cranial nerve, similar to the corneal blind reflex. After stimulation, R1 response is seen only unilaterally whereas R2 responses are seen bilaterally. However, ipsilateral and contralateral R2 responses have different latencies.

7. B. Phase II Late.
The arrow points to Phase II Late. Only Phase II Late and Phase IV are considered the reflex responses in the Valsalva maneuver. In patients with adrenergic failure, these 2 responses are impaired. Generally, Phase IV becomes blunted followed by loss of Phase II Late response.

8. C. 18.
The heart rate deep breathing range is one of the parasympathetic markers of autonomic function. It is the mean change in heart rate over 5 respiratory cycles. In the waveform in the question, the maximum mean change over the 5 cycles is close to 18–20. One should pay attention to the Y-axis, which provides the magnitude of heart rate change.

9. C. Cardiac sympathetic imaging.
Cardiac sympathetic imaging is the best technique to differentiate Parkinson's disease with autonomic function from MSA. This distinction is important to make as the overall prognosis is significantly worse in MSA. Degree of drop in blood pressure on standing or tilt table does not help differentiate these 2 conditions. Cardiovagal markers such as HR variability or Valsalva ratio also do not help differentiate these 2 conditions.

10. D. Decreases the measured CMAP latency.
When the sensitivity changes from 5 to 1 mV per division, the earliest deflection from the baseline also changes, and this leads to a decrease in the measured latency. Decreasing the sensitivity does not affect the amplitude or the duration of a compound muscle action potential.

11. A. It is the positively charged terminal of a galvanic cell.
Cathode is the positively charged terminal of a galvanic cell, whereas anode is the negatively charged terminal. In a circuit, the electrons flow into the cathode and, by convention, the current flows out of the cathode.

12. D. Increasing the low-frequency filter; increasing the high-frequency filter.
Increasing both the low frequency and high frequency filter settings will lead to a phase shift to the left.

13. D. Use submaximal stimulation for nerve conduction studies.
Excessive electrical artifact is not uncommon while performing studies in ICU and various precautions will help minimize this artifact. Turning off unnecessary devices, preparing the skin, using electrode gel, and using appropriate cables will help minimize electrical artifact. Submaximal stimulation will not affect the electrical artifact and is not recommended.

14. D. Decreased amplitude.
When the distance between the active and reference electrodes is decreased, there will be excess phase cancellation, which can result in decreased SNAP amplitude, duration, and peak latency. Onset latency will not change because the difference between the stimulation point and active electrode is unchanged.

15. A. Sharper waveform.
Decreasing the time constant will result in a sharper waveform. A shorter time constant results in a higher cutoff frequency for the low-frequency filter based on the equation $Fc = 1/(2\pi\tau) \approx 0.16/\tau$, where Fc is the cutoff frequency and $\tau$ is the time constant. Note that Fc is the frequency above which greater than 70% of the input amplitude will pass. A higher cutoff frequency will result in attenuation of higher amplitude slow activity. This will result in smaller and sharper waveforms with a phase shift to the left.

16. B. Reduction in MUAP amplitude.
When the high-frequency filter cutoff is reduced, it reduces the rapidly changing waveforms and, in turn, results in reduction in MUAP amplitude. It may also decrease the number of phases in the motor unit potential.

17. B. Significantly decreased peroneal amplitude compared to tibial amplitude.
Even though the site of the compression is at the level of the sciatic nerve, the peroneal nerve fibers are more likely to be compressed than tibial nerve fibers, resulting in significantly decreased peroneal amplitude compared to tibial amplitude. Consequently, patients may only have a foot drop because of predominant peroneal

nerve involvement. Sural response would be affected only with a significant degree of tibial nerve involvement. Tibial H-reflex would be absent or prolonged compared to the opposite normal side.

18. D. Number of surrounding axon.
The number of surrounding axons does not affect the conduction velocity of the action potential. Thickly myelinated nerve fibers and nerve fibers with a larger diameter conduct faster than nerve fibers with thinly myelinated axons. A longer distance between the nodes of Ranvier leads to faster conduction velocity because of saltatory conduction. Lower temperature leads to slowing of the conduction velocity.

19. A. A 5-year-old boy with high creatine phosphokinase (CPK), enlarged calf muscles, and positive Gower's sign.

In a 5-year-old boy with high CPK, enlarged calf muscles, and Gower's sign, an electrodiagnostic study is not needed to confirm that this is likely a myopathic process; in this case, genetic testing for Duchenne muscular dystrophy is appropriate. In a patient with fatigue, weakness, and ptosis, electrodiagnostic studies will help localize the pathology to the neuromuscular junction (NMJ). In a 15-year-old with possible hereditary sensorimotor neuropathy, nerve conduction studies are very helpful to differentiate axonal from demyelinating processes and to guide further genetic testing. Similarly, in a 22-year-old with suspected Guillain–Barré syndrome, electrodiagnostic testing would be appropriate to confirm the diagnosis.

20. B. Fast repetitive stimulation and significant increment.
This waveform represents the classic finding of more than 100% increase in CMAP amplitude on fast repetitive stimulation. The frequency of stimulation is 50 Hz and is consistent with fast repetitive stimulation. These findings are suggestive of presynaptic neuromuscular junction (NMJ) dysfunction, likely Lambert–Eaton myasthenic syndrome.

21. C. Myoadenylate deaminase deficiency.
In myoadenylate deaminase deficiency, the lactate level increases during exercise but the ammonia level does not. In all the other options noted, ammonia level increases but the lactate does not, suggesting a glycogen storage disease or a disorder of glycolysis. In cases of suboptimal effort from the patient, neither ammonia nor lactate level increases.

22. D. They may be absent or have prolonged latency in acute inflammatory demyelinating polyneuropathy.

Figure illustrates the F wave response. The afferent and efferent pathways are carried by the stimulated motor nerve. The response is obtained by supramaximal stimulation of a motor nerve. F latency depends on the distal motor latency, the conduction velocity, and the height of the tested patient. In acute inflammatory demyelinating polyneuropathy, motor nerve demyelination dramatically reduces the nerve conduction velocity, which results in absence or prolonged latency of the F response.

23. E. They are the electrical correlate of ankle jerk.
Figure illustrates the H reflex. It is elicited by stimulating the tibial nerve in the popliteal fossa, recording the gastrocsoleus muscle. The circuit of H reflex involves Ia muscle spindles as sensory afferents and the motor neurons and their axons as efferents. It is obtained by submaximal stimulation of the tibial nerve. It is the electrical correlate of ankle jerk. H reflex may be absent or have prolonged latency in case of S1 radiculopathy and generalized neuropathy.

24. B. Congenital demyelinating polyneuropathy.
Figure illustrates a motor median nerve conduction study recording from the abductor pollicis brevis. The median nerve distal latency (normally 4.5 ms or less) was prolonged in the demylination range. The median nerve conduction velocity (normally 49 m/s) was reduced in the demyelination range. The absence of compound muscle action potential dispersion or conduction block is suggestive of congenital demylinating polyneuropathy.

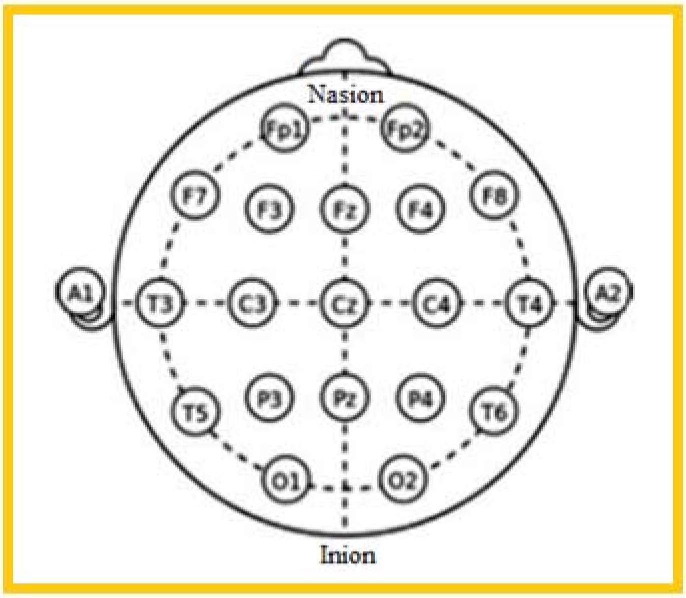
## III. EEG Questions

1. All of the following are advantages of using quantitative EEG (qEEG) except
A. It allows for rapid detection of seizures compared to review of raw EEG
B. It can provide a quick overview of seizure location, frequency, and duration
C. It can be used to assess response to therapy
D. It can replace review of raw EEG

2. A 55-year-old female was transferred from an outside hospital with a right proximal middle cerebral artery (MCA) aneurysmal subarachnoid hemorrhage (SAH) 2 days ago and is lethargic on exam. The critical care attending physician calls to find out the utility of doing continuous video-EEG (cEEG) monitoring in this patient. Which of the following statements would be the most appropriate response?

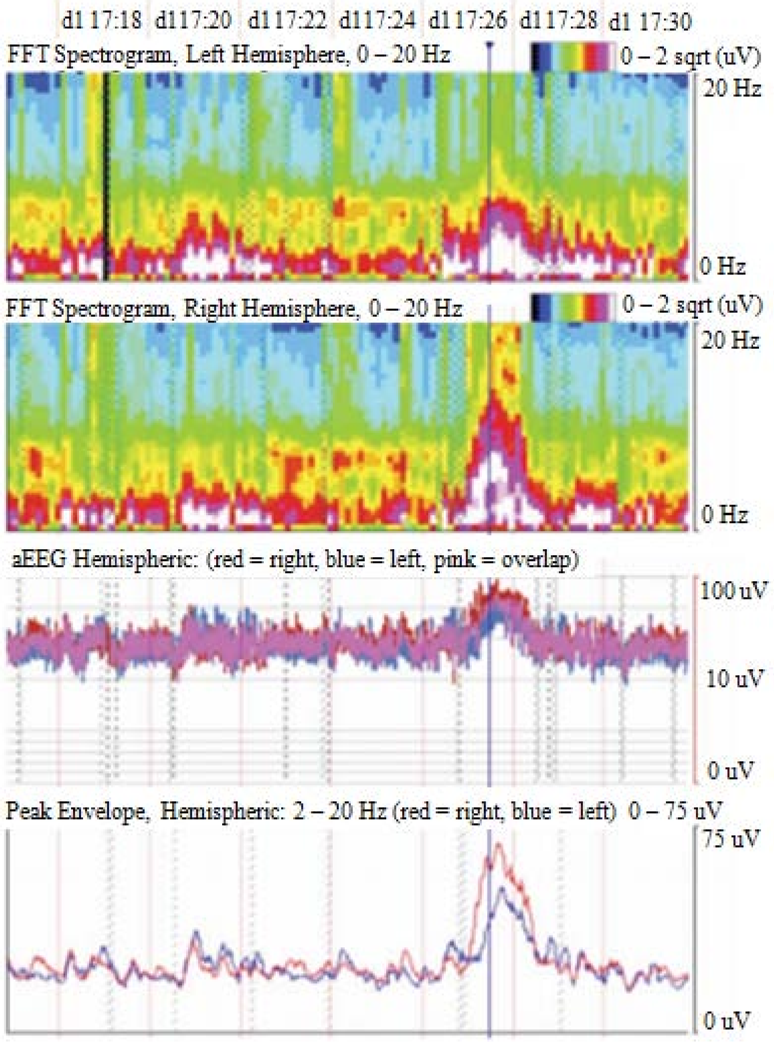
A. cEEG monitoring would not help detect nonconvulsive seizures since the majority are clinically apparent
B. cEEG monitoring cannot be used to detect delayed cerebral ischemia (DCI)
C. Decreasing relative alpha variability (RAV) would indicate improving perfusion to areas of ischemia
D. Decreasing alpha–delta ratio (ADR) would indicate decreasing perfusion to underlying cortex

3. Which electrode placement system is shown in the figure below?




A. International 10–10 system
B. International 10–20 system
C. Modified Combinatorial Nomenclature (MCN)
D. American Clinical Neurophysiology Society (ACNS) system

4. A 46-year-old male was found down and intubated at the scene. He was taken to the nearest facility, and the patient was too unstable to get head imaging. Continuous video-EEG monitoring was started. From top to bottom: fast Fourier transform (FFT) of left hemisphere, FFT of right hemisphere, amplitude-integrated EEG (aEEG), and peak envelope trend. Color bar indicates the power, black being the lowest and white being the highest. What is the correct interpretation of the following quantitative EEG (qEEG) panels at the blue vertical line just past time marker 17:26?




A. The increase in the peak envelope trend correlates with bihemispheric asymmetry, right more than left, indicating relative ischemia
B. The increase in the fast Fourier transform (FFT) spectrogram indicates that there is increasing higher power at the higher frequencies, indicating a state change from sleep to wakefulness
C. The deflection of the amplitude-integrated EEG (aEEG) is most likely indicative of a burst of activity in the background of relative suppression
D. The color spectrogram indicates that the activity, in this case likely a seizure discharge, is involving the right hemisphere more than the left hemisphere

5. A 35-year-old male was admitted to the neurological ICU after a severe traumatic brain injury. He was found to have fluctuating mental status in the setting of a subarachnoid hemorrhage (SAH). Continuous video-EEG (cEEG) monitoring was ordered. The EEG technician, a recent graduate, called the neurophysiology fellow to learn more about the various pros and cons regarding EEG electrode choice. Which of the following statements is true?

A. Metal electrodes lead to a “star-burst” effect on CT images due to the absorption of x-rays

B. All metal electrodes cause susceptibility artifact on MRI

C. Long leads and ferrous metals can lead to skin heating and burning during acquisition of MRI

D. Short-lead, silver, subdermal wire electrodes lead to significant artifact on both MRI and CT images

6. All of the following statements regarding continuous video-EEG monitoring (cEEG) in the ICU are true except

A. Monitoring can help characterize jerking events in terms of ictal and nonictal

B. There is no added benefit of cEEG monitoring if no seizures were identified in the first 24 hours of monitoring in any critically ill patient

C. It can help in prognostication after subarachnoid hemorrhage (SAH)

D. A patient with a witnessed generalized tonic–clonic seizure, felt to be due to hypoglycemia, is back to his baseline mental state (Glasgow Coma Scale (GCS) 15) and does not need cEEG.

7. Which of the following is false regarding the Main Term 2 of the European Clinical Neurophysiology Society’s established standardized critical care EEG terminology?

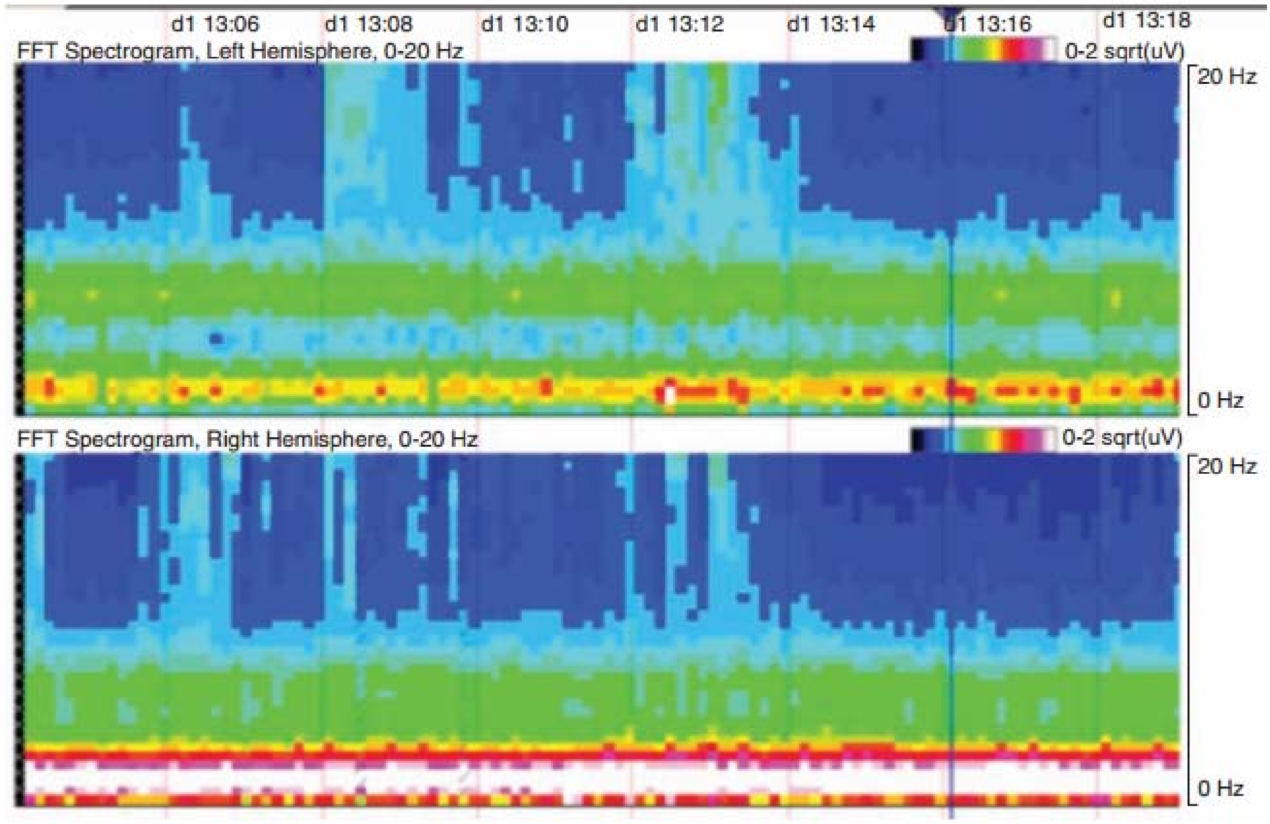
A. Periodic discharges (PDs) apply only to single discharges lasting less than 0.5 seconds and do not apply to bursts

B. The interval duration between PDs can have up to a 100% variation from 1 cycle to the next as long as the morphology is relatively uniform

C. Rhythmic delta activity (RDA) can be distinguished from periodic discharges in that RDA does not have an interval between consecutive waveforms

D. Spike wave (SW) consistently follows the pattern of a spike or sharp wave followed by a slow wave

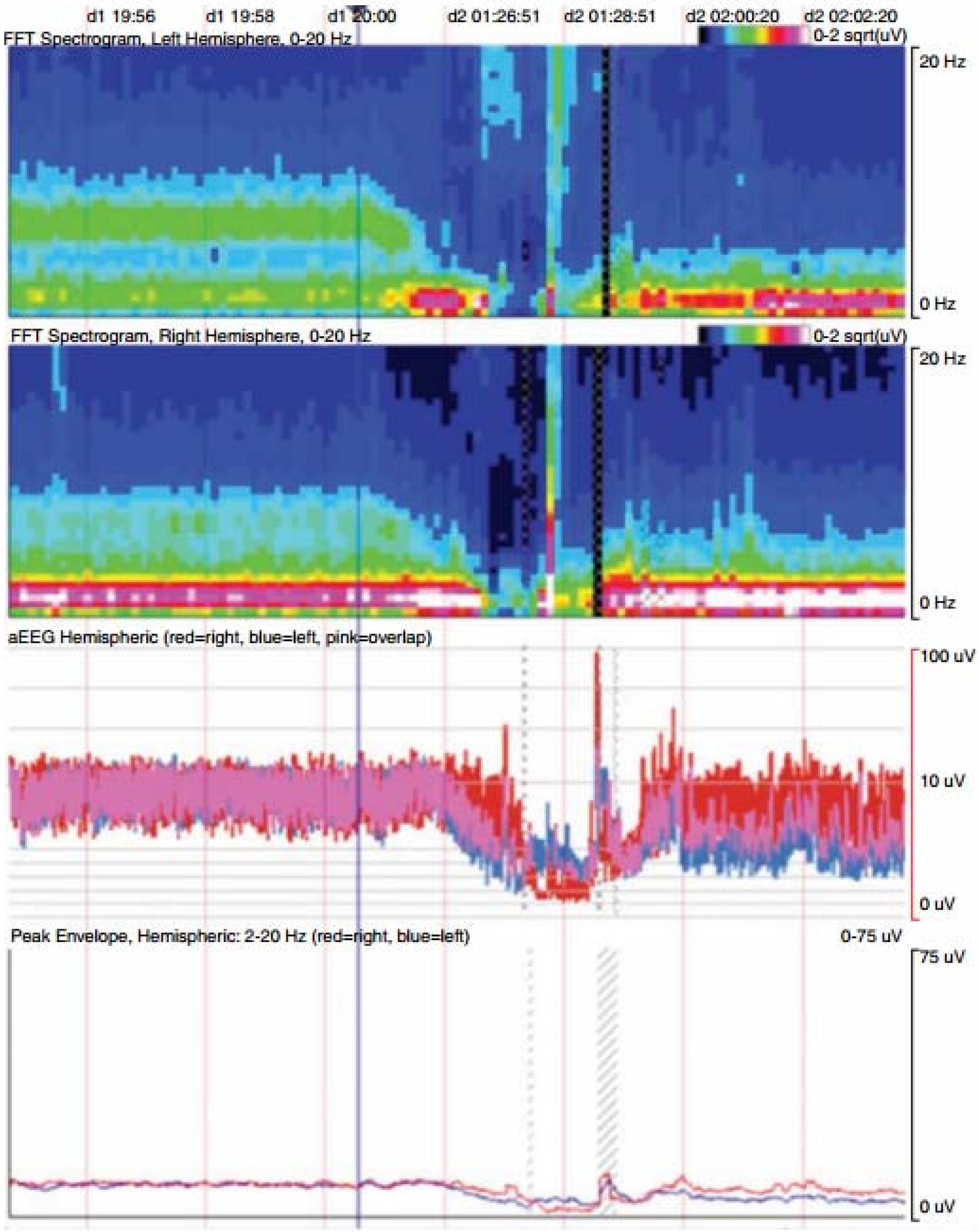
8. The following fast Fourier transform (FFT) spectrograms from a 50-year-old male show 0–20 Hz activity from the left hemisphere (top panel) and right hemisphere (bottom panel); the color bar indicates the power, black being the lowest and white being the highest. All of the following statements are correct interpretations at the time marker indicated by the vertical blue line except




A. There is a symmetric posterior dominant rhythm
B. The left hemisphere has more power in the alpha and beta frequencies than the right hemisphere
C. There is continuous high-amplitude delta slowing over the right hemisphere
D. There is continuous delta and theta activity over the left hemisphere

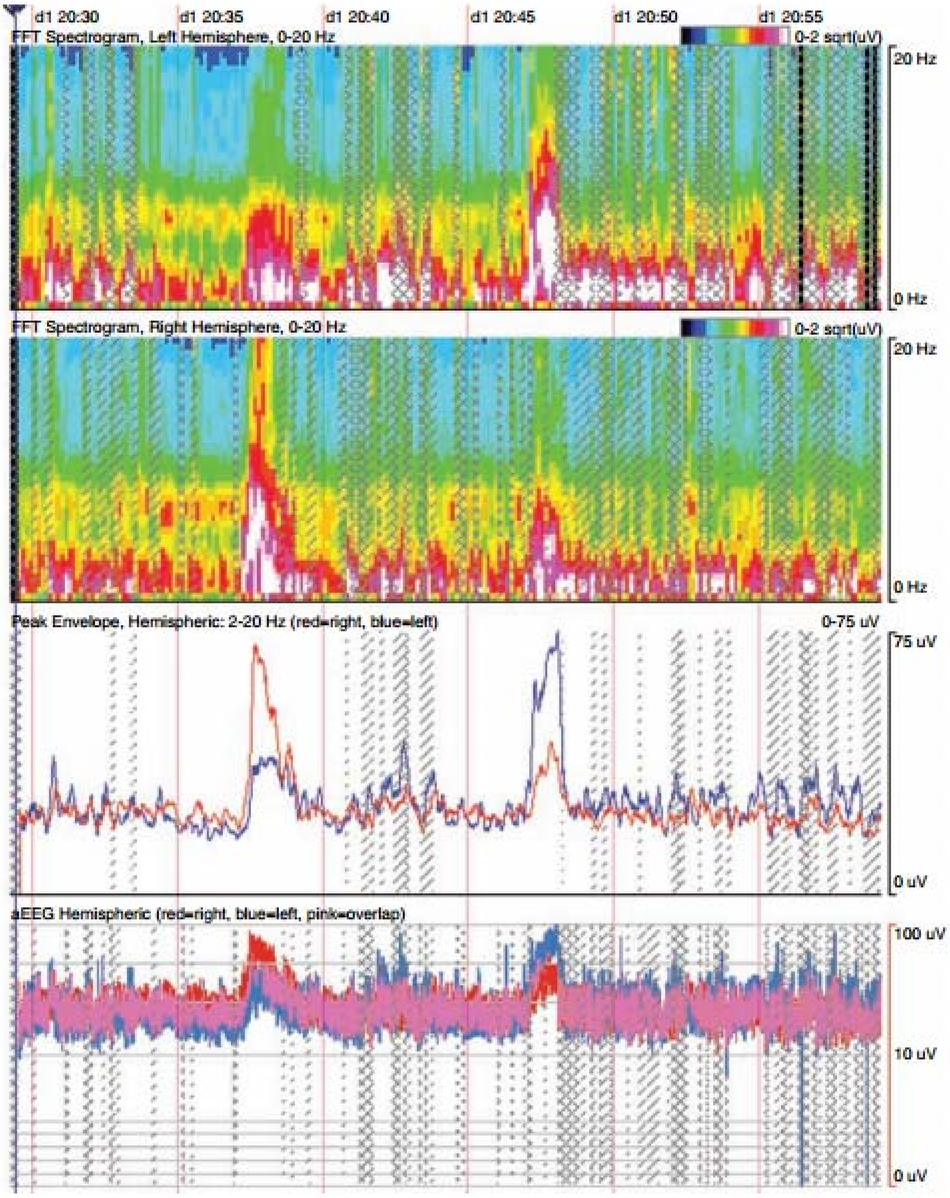
9. Which of the following is true regarding the Main Term 1 of the European Clinical Neurophysiology Society's established standardized critical care EEG terminology?
A. Generalized (G) refers to bilateral activity that can be symmetric or asymmetric
B. Lateralized (L) refers to only unilateral hemispheric or focal patterns
C. Bilateral independent (BI) refers to bilateral activity that is asynchronous
D. Multifocal (Mf) refers to patterns occupying at least 2 brain regions and involving both hemispheres.

10. The following quantitative EEG (qEEG) fast Fourier transform (FFT) spectrograms show 0–20 Hz activity from the left and right hemispheres (top 2 panels), amplitude-integrated EEG, and peak envelope; the color bar indicates the power, black being the lowest and white being the highest. Note that the red vertical lines represent 2-minute intervals; for illustrative purposes, 3 different time periods are spliced together. What is the best explanation of what occurred after the blue vertical line indicator?



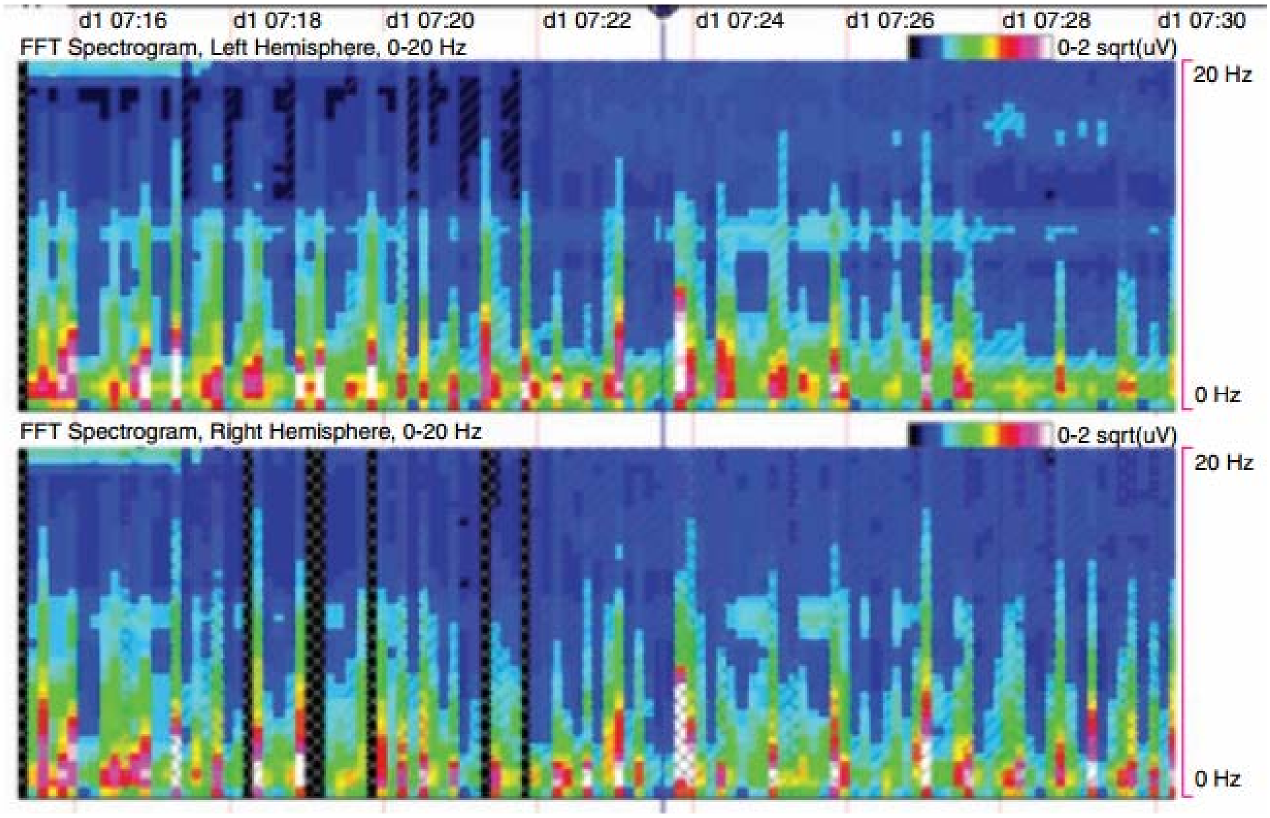

A. The patient had a seizure with postictal slowing afterwards
B. The patient had diffuse cerebral ischemia due to cardiac arrest with subsequent infarction
C. The patient was disconnected from continuous video-EEG (cEEG) monitoring temporarily to be taken to CT scan without any significant interim clinical event
D. The patient transitioned from a wakeful state to deeper stages of normal sleep

11. A 35-year-old woman was found down and was placed on continuous video-EEG (cVEEG) monitoring in the ICU. A clinical neurophysiology fellow was making rounds in the evening and saw the following quantitative EEG (qEEG panels). From top to bottom: fast Fourier transform (FFT) of left hemisphere, FFT of right hemisphere, amplitude-integrated EEG (aEEG), and peak envelope trend. Color bar indicates the power, black being the lowest and white being the highest. Which of the following is the most appropriate interpretation?




A. The patient has had two seizures, the first from the left hemisphere and the second from the right hemisphere
B. The patient has had two seizures, the first from the right hemisphere and the second from the left hemisphere
C. The patient has had three seizures, the first from the right hemisphere and the last 2 from the right hemisphere
D. The patient has had two primary generalized seizures.

12. A term infant was born by STAT cesarean section due to decreased fetal movements; the child arrived nonvigorous without respiratory effort and required intubation. The infant was placed on the hypothermia protocol and a high-frequency oscillatory ventilator (HFOV). Seizures were noted on cVEEG monitoring, and the baby was placed on phenobarbital and a midazolam drip. Top: fast Fourier transform (FFT) of left hemisphere bottom: FFT of right hemisphere. Color bar indicates the power, black being the lowest and white being the highest. Which of the following is most likely seen on the following quantitative EEG (qEEG) panel?




A. Periodic seizures
B. Burst-suppression-like pattern
C. Multiple sleep–wake cycles
D. HFOV artifact

13. All of the following EEG patterns are felt to be independent predictors of poor outcome (modified Rankin Scale greater than 4) for patients with subarachnoid hemorrhage (SAH) except
A. Presence of sleep spindles
B. Periodic (epileptiform) discharges
C. Nonreactive EEG background
D. Nonconvulsive status epilepticus

14. Which of the following is false regarding the modifiers of the European Clinical Neurophysiology Society's established standardized critical care EEG terminology?

A. Amplitude refers to the absolute height of a pattern and should be measured in a standard longitudinal bipolar montage (10–20 system) from peak to trough (not to baseline)
B. Prevalence refers to the percentage of the record occupied by a pattern and is classified as continuous if it occupies more than 90% of the record/epoch
C. Duration refers to the typical duration of a single occurrence of the pattern and is classified as brief if it is between 10 and 59 seconds
D. Plus (+) modifiers were designed to distinguish patterns that appear more ictal in morphology and can be added to descriptions of all Main Term 1 and 2 terms

15. Classify the following pattern using the European Clinical Neurophysiology Society's established standardized critical care EEG terminology


A. SI-GRDA
B. LSW
C. BIRDA
D. SI-GSW

16. Which of the following EEG patterns is least likely to be associated with status epilepticus (SE)?
A. Recurrent 5–7 Hz rhythmic temporal activity
B. Generalized periodic discharges occurring at a frequency of 2–3 Hz
C. Normal scalp EEG
D. Intermittent polymorphic delta activity

17. Many types of artifacts exist in the ICU setting of physiological and nonphysiological origin. Which of the following is NOT a typical description of the EEG pattern associated with the listed artifact?
A. Extracorporeal membrane oxygenation (ECMO) is associated with a 1–3 Hz square wave artifact
B. Ventilators can cause artifact that varies widely in morphology, amplitude, and polarity, but can be associated with a faster frequency artifact due to charged water molecules in the ventilator tubing that can be improved by suctioning
C. Mechanical chest percussion device can cause rhythmic 5–6 Hz activity in 1 electrode
D. Cardiopulmonary resuscitation (CPR) can lead to high-amplitude, rhythmic 1–2 Hz activity that is due to movement artifact and is not cerebral activity

18. Which of the following is a minimum requirement for recording high-frequency oscillations (HFOs)?
A. Microelectrodes
B. Depth electrodes
C. Subdural electrodes
D. Sampling rate of 1000 Hz

19. In patients with epilepsy, the high-frequency oscillations (HFOs) are
A. Absent outside the hippocampus and entorhinal cortex
B. Sampling rate of 1000 Hz
C. Considered pathologic if the frequency is greater than 250 Hz
D. Present only within the seizure focus

20. All of the following statements regarding the direct current (DC) shifts seen at seizure onset are true except
A. DC shifts can only be recorded using dedicated DC-coupled amplifiers
B. DC shifts can be recorded using an amplifier with a long-time constant
C. DC shifts are better seen by decreasing the low-frequency filter
D. DC shifts at seizure onset are useful in localizing the seizure onset zone.

21. Advantages of magnetoencephalography (MEG) over EEG include all of the following except
A. Good spatial resolution
B. Selectivity to activity in the Sylvian fissure
C. Relative insensitivity to the properties of extracerebral tissue
D. Selectivity to radial currents

22. In a spherical head model, magnetoencephalography (MEG) detects all of the following signals except
A. Those tangential to the cortical surface
B. Those perpendicular to the cortical surface
C. Those tilted 10–20 degrees from radial orientation to the cortical surface
D. Those within the cortical fissures

23. Which of the following statements best describes the utility of magnetoencephalography (MEG) in epilepsy?
A. Unlike EEG, MEG can differentiate between ictal and interictal spikes
B. MEG is not suitable for evaluation of epileptic foci in the cerebral convexity
C. MEG can identify time lags to differentiate between primary and mirror foci
D. MEG studies have shown significant epileptiform activity in the motor speech area in Landau–Kleffner syndrome

24. A single electrical stimulus applied to the motor cortex during transcranial electrical stimulation (TES)
A. Produces a single volley in the descending motor tracts
B. Produces D-waves in the pyramidal axons
C. Blocks I-waves in the pyramidal neurons
D. Produces M-waves in the pyramidal neurons

25. Myogenic motor evoked potentials (MEPs) recorded with transcranial electrical stimulation (TES) are characterized by all of the following except
A. Produced by summated D-waves
B. Best recorded using trains of high-intensity stimuli with an interstimulus interval of 2–3 ms
C. Highly variable across multiple trials
D. Highly likely to be suppressed by a combination of propofol and opioid total intravenous anesthesia

26. All of the following statements regarding the stimulating parameters used for transcranial electrical stimulation (TES) are true except
A. Fz/Cz electrode pair stimulates corticospinal tracts to the legs
B. C3/C4 electrode pair stimulates corticospinal tracts to the arms
C. C1/C2 electrode pair stimulates corticospinal tracts to both arms and legs
D. Laterally placed electrode pair selectively stimulates the corticospinal tracts to both arm and leg contralateral to the anode.

27. Motor evoked potentials (MEPs) during scalp transcranial electrical stimulation (TES) are generated by
A. Action potentials that are initiated at the axon hillocks of the cortical pyramidal neurons
B. Action potentials that are initiated in the cell bodies of the cortical pyramidal neurons
C. The outward transmembrane current under the anode
D. The inward transmembrane current under the cathode

28. All of the following statements regarding motor evoked potentials (MEPs) elicited by transcranial electrical stimulation (TES) are true except
A. D-waves are caused by action potentials in pyramidal cell axons
B. I-waves are caused by cortical synaptic activity
C. Myogenic waves are recorded ipsilateral to the anode
D. Anesthesia suppresses I-waves but not D-waves

29. Transcranial magnetic stimulation (TMS)
A. Is limited to stimulation of the motor cortex
B. Produces the strongest currents close to the inner table of the skull
C. Consistently activates brainstem
D. More likely produces motor evoked potentials consisting of D-waves

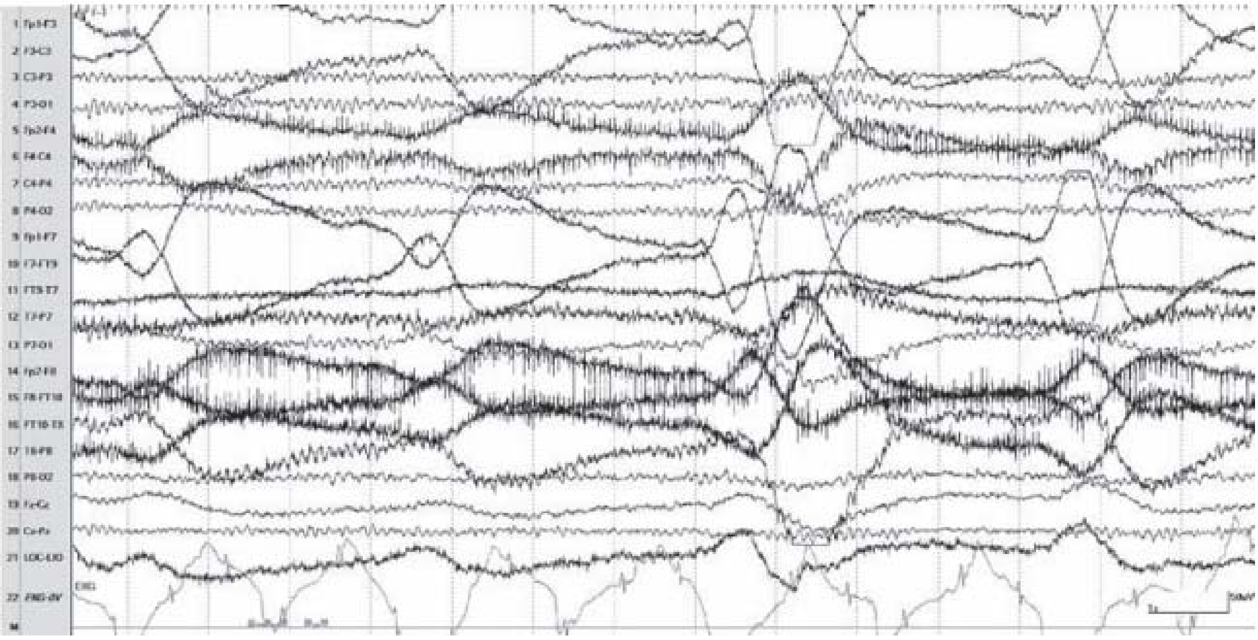
30. Transcranial magnetic stimulation (TMS) is not suitable for intraoperative monitoring of motor evoked potentials (MEPs) because of all of the following except
A. It does not effectively activate the motor cortex
B. It does not produce D-waves
C. It produces different MEPs with different orientation of the stimulating coil
D. It can interfere with the functioning of other operating room equipment

31. All of the following statements are true regarding the utility of transcranial magnetic stimulation (TMS) except
A. It is useful in the diagnosis of lesions involving corticobulbar tracts
B. It is useful in monitoring spinal surgeries under general anesthesia
C. It helps in understanding the mechanism of long-term potentiation
D. It has therapeutic benefit in major depression

32. Which sleep state is least likely to show epileptiform abnormalities?
A. N1
B. N2
C. N3
D. REM

33. In terms of neuropsychiatric effects, repetitive transcranial magnetic stimulation (rTMS)
A. Does not alter mood in nondepressed subjects
B. Worsens mood in depressed patients
C. Improves mania
D. Improves or worsens neuropsychological junction.

34. A 47-year-old female has a history of chronic alcohol abuse and seizures. She was noncompliant with her antiepileptic drugs (AEDs) and had a seizure resulting in a right parietal scalp contusion. She subsequently had another generalized convulsion a few hours later. What is seen on her EEG (filter 1–70 Hz) below?



A. Sweat artifact
B. Eye movement artifact
C. Ventilator artifact
D. Cable artifact

35. Which of the following situations will lead to a phase shift to the right?
A. Decreasing the low-frequency filter; decreasing the high-frequency filter
B. Decreasing the low-frequency filter; increasing the high-frequency filter
C. Increasing the low-frequency filter; decreasing the high-frequency filter
D. Increasing the low-frequency filter; increasing the high-frequency filter

36. What types of signals are used in the calibration process for EEG?
A. Square wave inputs
B. Sine wave inputs
C. Cosine wave inputs
D.Triangular wave inputs

37. Which of the following does not increase the EEG impedance?
A. Interface between the scalp and the electrode
B. The wiring from the electrode to the amplifier
C. Display of the acquired EEG waveform on the computer screen
D. Skull thickness

38. A 58-year-old woman has a history of staring spells since age 14 years. Her first generalized convulsion was at age 26 years, and she continues to have them intermittently. What is the most likely diagnosis based on the EEG (filter: 1–70 Hz) shown below?

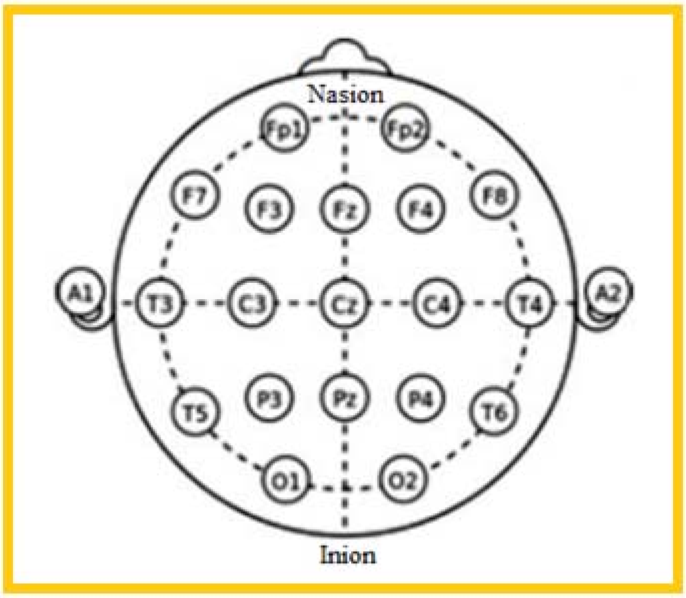
A. Childhood absence epilepsy (CAE)
B. Juvenile myoclonic epilepsy (JME)
C. Symptomatic generalized epilepsy
D. Partial epilepsy with secondary bilateral synchrony

39. EEG in a patient with progressively deepening coma can show
A. Reactive high-voltage delta activity
B. Reactive background attenuation with stimulation
C. Nonreactive high-voltage delta activity
D. All of the above

40. Absence seizures are characterized by all of the following features except
A. Rhythmic eye blinking
B. Repetitive oral automatisms
C. Loss of postural control
D. Impairment of working memory

41. The EEG frequency bands described by Hans Berger include
A. Alpha
B. Alpha and beta
C. Alpha, beta, and theta
D. Alpha, beta, theta, and delta

42. Which of the following statements best describes the 10–20 system of EEG electrode placement as shown below?




A. It is used only in European EEG laboratories
B. It mandates that 10 or 20 electrodes be used for the recording
C. It only refers to the location but not the name of the electrodes
D. Electrodes are placed at a distance from each other equal to 10% or 20% the total frontto-back or side-to-side distance

## EEG Answers

1. D. It can replace review of raw EEG.

qEEG can provide a number of advantages over review of raw EEG including allowing for rapid detection of seizures (a single qEEG screen typically consists of 1–4 hours vs 10–15 seconds of raw EEG per screen with conventional review); quick overview of seizure location, frequency, and duration; and assessment of response to therapy (eg, treatment of seizures or burst-suppression for management of high intracranial pressure). There are some limitations, including false positive seizure detections due to highamplitude, rhythmic artifacts commonly seen in the ICU (eg, cardiopulmonary resuscitation [CPR], suctioning, ventilator, extracorporeal membrane oxygenation [ECMO]) and false negatives due to missing brief, focal, low-amplitude seizures. Therefore, qEEG cannot replace expert review of raw EEG.

2. D. Decreasing alpha–delta ratio (ADR) would indicate decreasing perfusion to underlying cortex.

There has been increasing evidence that cEEG monitoring can be of utility in monitoring patients with SAH. In addition to detecting nonconvulsive seizures, which are difficult to detect clinically in patients with altered mental status as in this case, quantitative EEG (qEEG) measures could be used to detect for DCI, or infarction due to vasospasm that can typically occur 5–12 days (range: 3–21 days) after SAH. Normally, healthy individuals have high alpha variability, which fluctuates with sleep–wake cycles, eye opening/closure, and so on. When this variability decreases in the right setting, this could correlate with impaired thalamocortical pacemaker activity. In the setting of SAH, this could indicate ischemia. ADR is a measure of the percentage of alpha activity compared to the percentage of delta activity for a given time period. With decreasing cerebral blood flow (CBF), the amount of alpha activity will decrease and the amount of delta activity will increase. Thus, a decreasing ADR would indicate decreasing perfusion and likely ischemia or infarction.

3. B. International 10–20 system.
The International 10–20 system was developed to ensure standardized reproducibility so that a subject’s studies could be compared over time and subjects could be compared to each other. This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. The “10” and “20” refer to the fact that the actual distances between the adjacent electrodes are either 10% or 20% of the total front-to-back or right-to-left distances of the skull. Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letters F, T, C, P, and O stand for frontal, temporal, central, parietal, and occipital

lobes, respectively. Note that there is no central lobe; the “C” letter is used for identification purposes only. A “z” (zero) refers to an electrode placed on the midline. Even numbers (2, 4, 6, 8) refer to electrode positions over the right hemisphere whereas odd numbers (1, 3, 5, 7) refer to those over the left hemisphere. Two anatomical landmarks are used for the essential positioning of the EEG electrodes: nasion is the point between the forehead and the nose; inion is the lowest point of the skull from the back of the head and is normally indicated by a prominent bump.

4. D. The color spectrogram indicates that the activity, in this case likely a seizure discharge, is involving the right hemisphere more than the left hemisphere.

The quantitative EEG (qEEG) panels displayed are consistent with a seizure discharge lasting about 2 minutes, originating over the right hemisphere and spreading to the contralateral side. The FFT spectrogram is a frequency-based qEEG trend that displays a 3-dimensional representation of EEG power (which is proportional to the square of the amplitude) over time with respect to the various frequencies. Seizures are represented by increasing power that usually evolves from lower to higher frequencies. On the FFT spectrogram, increase in the color toward the red end of the color spectrum over both hemispheres indicates an increase in power at those frequencies. In this case, there appears to be an increase in power across many frequencies, right greater than left, which also supports a seizure discharge involving the right hemisphere greater than left hemisphere. Many artifacts (eg, muscle or electrode) typically present with increased power on the FFT spectrogram as well but the increase is more abrupt without evolution. aEEG is an amplitude-based qEEG trend that displays the minimum and maximum amplitude of the EEG background over a preset time interval (typically 1–2 seconds). On the aEEG, the increase in baseline amplitude and the narrowing of the aEEG band suggest a seizure discharge. The higher amplitude of the red band suggests that the seizure discharge may be asymmetric and higher in the right hemisphere. Many other changes on aEEG are nonspecific and often represent artifact. The peak envelope trend is an amplitudebased qEEG trend that displays the median amplitude of the EEG background over a preset time interval (typically 10–20 seconds). On the peak envelope trend, the upward deflection of the red tracing represents an increase in median amplitude over the right hemisphere, corresponding to a seizure. The delayed upward deflection of the blue tracing represents contralateral spread of the seizure discharge. Peak envelop trend may be more specific than aEEG but can miss seizures that are brief in duration. In general, qEEG trends draw attention to the time of the recording where more detailed analysis is needed but they cannot replace expert review of raw EEG.

5. C. Long leads and ferrous metals can lead to skin heating and burning during acquisition of MRI.

Long leads and ferrous metals can lead to skin heating and burning during acquisition of MRI. Moreover, the electrodes themselves may physically move, contributing to the incompatibility of these materials with MRI. Nonferrous metals, such as noble metals (eg, silver, gold, copper, and platinum) lead to less artifact and are more conducive to being used in MRI. Metal electrodes lead to a “star-burst” effect on CT images due to deflection, not absorption, of x-rays. Conductive plastic electrodes (coated with a thin silver layer) and many subdermal wire electrodes (eg, silver) do not lead to significant artifact, and can be used for both MRI and CT images. However, short-lead wires are preferred because the risk of coiling is less which minimizes MRI artifacts (the wires act less like an antenna); and risk to the patient is less (less current and heating). Unlike patients in the epilepsy monitoring unit (EMU), cEEG patients in the ICU may require frequent and/or urgent head imaging (eg, CT, MRI, angiography), and a more educated decision regarding electrode choice can lead to lower risk and cost while increasing efficiency (by not having to adjust or redo the electrode setup).

6. B. There is no added benefit of cEEG monitoring if no seizures were identified in the first 24 hours of monitoring in any critically ill patient.

In general, in about half of all studies, the first seizure is captured within the first hour of recording, and the longer the monitoring lasts, the higher the yield of capturing electrographic seizures. Although there may be little benefit of monitoring beyond 24 hours in noncomatose patients, there is some evidence to suggest that extending the monitoring at least another 24 hours in comatose patients may increase the yield about 10%. However, the actual length of continuous video-EEG (cEEG) monitoring in practice varies from center to center, and can deviate from what might be desired due to other constraints, including resource limitations. Many types of events are seen in the ICU setting (eg, tremor, focal twitching or jerking, aphasia), which are sometimes difficult to characterize solely on a clinical basis. cEEG monitoring can assist in characterizing if these events are ictal, and in some cases help narrow down the origin in cases where the events are not epileptic. cEEG monitoring can help with prognostication in such insults as SAH, intracranial hemorrhage, and postcardiac arrest. Although cEEG monitoring can greatly assist in detecting nonconvulsive seizures, it may not provide any substantial benefit in situations in which there was a clinically apparent seizure (generalized tonic clonic seizure in this case) due to a known cause (hypoglycemia in this case) with the patient’s mental state back to baseline.

7. B. The interval duration between PDs can have up to a 100% variation from 1 cycle to the next as long as the morphology is relatively uniform.

The European Clinical Neurophysiology Society established standardized critical care EEG terminology to create an objective EEG classification scheme. Main Term 2 has 3 classifications. PDs apply only to single discharges with relative uniform morphology lasting less than 0.5 seconds and do not apply to bursts. There is a quantifiable interval between the discharges that have less than 50% variation from 1 cycle to the next. RDA is repetition of a waveform with relatively uniform morphology and duration; it can be distinguished from periodic discharges in that RDA does not have an interval between consecutive waveforms. SW consistently follows the pattern of alternating spike or sharp wave followed by a slow wave.

8. A. There is a symmetric posterior dominant rhythm.
The FFT spectrograms in the question evaluate each hemisphere separately. In general, the 2 panels should appear similar, but that is not the case. The left hemisphere appears to have higher power than the right hemisphere in the alpha range frequencies. As an approximation, around 8–10 Hz, the left hemisphere is green while the right hemisphere is light blue, indicating lower power. In addition, around 10–12 Hz, the left hemisphere has light blue color while the right hemisphere has darker blue color, suggestive of an asymmetry of the posterior dominant rhythm. In addition, the beta frequencies appear to have equal or higher power in the left hemisphere. There is a thick band of bright white power in the delta range frequencies over the right hemisphere, suggestive of highamplitude delta slowing. The fact that the band remains white for the entire duration suggests that the slowing is continuous. Similarly, the left hemisphere has bands of continuous slowing in the delta and theta range, although the slowing is at a lower power.

9. C. Bilateral independent (BI) refers to bilateral activity that is asynchronous.

The European Clinical Neurophysiology Society established standardized critical care EEG terminology to create an objective EEG classification scheme using descriptive terms for frequently encountered EEG patterns in critically ill patients that are not biased regarding the clinical significance of a given pattern. Standardization allows for comparison of results between centers. Main Term 1 has 4 classifications. Generalized (G) refers to bilateral activity that is both synchronous and symmetric. If the activity is synchronous and asymmetric, then it falls under the term lateralized (L), which also includes unilateral hemispheric or focal patterns. If the activity is asynchronous, then it falls under the term BI, and the activity can be hemispheric or more focal. Mf refers to patterns occupying at least 3 distinct brain regions and involving both hemispheres.

10. B. The patient had diffuse cerebral ischemia due to cardiac arrest with subsequent infarction.

The most likely scenario is that the patient had diffuse ischemia with subsequent infarction due to decreased cerebral blood flow that occurred in the setting of cardiac arrest. From the FFT spectrogram panels, power in the alpha range diminished while the power in the theta range increased temporarily before diminishing itself with resultant higher delta power. This is synonymous with a lower or decreasing alpha–delta ratio (ADR; not shown). This occurred when the patient experienced bradycardia. This would be consistent with changes that would be expected when cerebral blood flow is reduced. Of note, there appears to be higher delta power in the right hemisphere (due to a prior right hemispheric tumor resection 20 years earlier). At about 01:27, there was an overall drop in power in both hemispheres as can be seen in the fast Fourier transform (FFT), aEEG, and peak envelope panels. This suggests decreased or absent blood flow to the brain, which occurred when the patient was in asystole. The patient remained asystolic for just over a minute before spontaneously reverting to sinus rhythm, at which point there is an incomplete reversal in the quantitative EEG (qEEG) trends. After the event, there was overall decreased power but an increase in delta activity, which lasted more than 30 minutes without any subsequent significant improvement, consistent with diffuse infarction. Although seizures can present with decreasing or increasing frequency power over time, the overall power tends to increase; however, that is not the case here. An exception may be in a case of ictal bradycardia or asystole, which would likely present with an overall increase in power prior to fairly rapid decrease in power correlating to the decrease in cerebral blood flow, which is not seen here. In addition, disconnecting a patient from cEEG monitoring leads to an overall decrease in EEG power, although the changes due to disconnecting and reconnecting would more likely occur abruptly rather than over several minutes. In addition, the pre-disconnection and post-disconnection trends would likely be similar (unless that patient had a clinical event while off cEEG monitoring). Sleep transitions can cause qEEG changes (eg, decreasing alpha power and increasing delta power) but they would not typically lead to overall suppression in power as seen here.

11. B. The patient has had two seizures, the first from the right hemisphere and the second from the left hemisphere.

The quantitative EEG (qEEG) panels show 2 seizures, the first (around 20:37) from the right hemisphere and the second (around 20:47) from the left hemisphere. There is a third area of increased power (around 20:43), which is fairly lateralized to the left hemisphere. Although from the fast Fourier transform (FFT), this could potentially represent an ictal discharge, the peak envelope and aEEG do not support this. In this case, there was an electrode artifact at O1, which is likely contributing to the changes seen. This supports the notion that qEEG trends help to focus where more detailed analysis is needed but they cannot replace expert review of raw EEG. Although there is increased power over both hemispheres, there is earlier onset in the hemisphere that ultimately has the higher power. The presence of higher power in the contralateral hemisphere later in time likely represents seizure spread.

12. B. Burst-suppression-like pattern.

A burst-suppression-like pattern is most likely seen. Note the time divisions of 2 minutes. This would correspond to an interburst interval of about 20 seconds. The times of overall low power, presenting with darker blue hues at the majority of frequencies, represent periods of relative suppression, while the vertical bars consisting of various colors in the delta to alpha frequencies represent the burst of activity consisting of mixed frequencies. Associated aEEG (not shown) would be expected to present with a bottom margin (ie, minimum voltage) in the range typically of 0–2 mV as well as a low upper margin (ie, maxiumum voltage), resulting in a small bandwidth (ie, thin band) during periods of suppression and higher margins and bandwidth (ie, thicker band) during the EEG epochs containing the bursts. The associated peak envelope trend (not shown) would be expected to present with alternating high and low peaks, resulting in a wavelike appearance with peaks and valleys. Although periodic seizures could occur as frequently as every 20 seconds, there would likely be a buildup or ramp down of power over a period of time, which is not seen here. In addition, the frequency makeup of the seizures would likely be relatively stereotyped between the ictal events. Hence, the corresponding vertical lines of green, red, and white colors would all be very similar if not the same, which is not the case here. Sleep transitions can cause quantitative EEG (qEEG) changes. In normal term infants, periods of continuous activity (ie, wakefulness) would transition to periods of alternating activity and periods of relative suppression (ie, tracé alternant). The pattern present in the qEEG panel would be too quick for sleep transitions and too slow for a tracé alternant or tracé discontinu pattern. HFOV artifact, if present, could produce a more continuous, high-frequency (faster than the 3–5 Hz seen in the example in the question) artifact in both hemispheres.

13. A. Presence of sleep spindles.
Absence (not presence) of normal sleep architecture, periodic (epileptiform) discharges, nonreactive background, and nonconvulsive status epilepticus are all

independent predictors of poor outcome (modified Rankin Scale greater than 4) in SAH.

14. D. Plus (+) modifiers were designed to distinguish patterns that appear more ictal in morphology and can be added to descriptions of all Main Term 1 and 2 terms.

The European Clinical Neurophysiology Society established standardized critical care EEG terminology to create an objective EEG classification scheme. Modifiers provide further descriptive information and include frequency, amplitude, prevalence, duration, sharpness, polarity, stimulus-induced, and plus (+) modifiers. They can be added to Main Terms 1 and 2, but the plus (+) modifiers can only be used with periodic discharges (PDs) or rhythmic delta activity (RDA), not with spike wave (SW). Amplitude refers to the absolute height of a pattern and should be measured in a standard longitudinal bipolar 10–20 system montage (not referential montage), from peak to trough (not to baseline). Prevalence refers to the percentage of the record occupied by a pattern and is classified as follows: less than 1% of the record/epoch (rare), 1%–9% (occasional), 10%–49% (frequent), 50%–89% (abundant), and greater than 90% (continuous). Duration refers to the typical duration of a single occurrence of the pattern and is classified as follows: less than 10 seconds (very brief), 10–59 seconds (brief), 1–4.9 minutes (intermediate), 5–59 minutes (long), and more than 1 hour (very long).

15. D. SI-GSW.
The best classification using the European Clinical Neurophysiology Society's established standardized critical care EEG terminology is SI-GSW. The activity is bilateral, symmetric, and synchronous, consistent with the Main Term 1 for generalized (G). If the activity were to be asymmetric, then lateralized (L) would be the most appropriate term. If the activity were to be asynchronous, then bilateral independent (BI) would be the best term. In addition, the pattern noted consists of a regularly repeating pattern of spike wave followed by a slow wave, consistent with the Main Term 2 for spike wave (SW). Although initially the activity appears to be rhythmic delta activity (RDA), this is not persistent but instead quickly evolves into SW. Periodic discharges (PD) are not correct since there is no interval between consecutive waveforms. The changes appeared to occur after external stimulation, making this consistent with the modifier stimulus induced (SI). Therefore, the terminology would be SI-GSW. This would also be consistent with the former term of stimulus-induced rhythmic, periodic, or ictal discharges (SIRPIDs) that was described in critically ill patients, which lies within the ictal–interictal continuum (ie, depending on the clinical scenario, may or may not represent an ictal pattern). In this case, the pattern lasts less than 10 seconds, was without any clinical change, and was

reproducible with stimulation, making it less likely to be ictal. That being said, the definition of an ictal EEG pattern in critically ill patients still remains elusive.

16. D. Intermittent polymorphic delta activity.

Intermittent polymorphic delta activity is least likely to be associated with SE. SE can be divided into convulsive SE (CSE) and nonconvulsive SE (NCSE) as well as generalized SE (GSE) or partial SE (PSE). PSE can be divided into simple PSE (SPSE) and complex PSE (CPSE). Recurrent 5–7 Hz rhythmic temporal activity is likely to be seen in CPSE. Generalized periodic discharges at 2–3 Hz are likely to be seen in GSE. Given that simple partial seizures can frequently present with scalp negative ictal EEG, it is feasible that SPSE could present with a normal EEG, especially if the focus is small or far from the scalp. Although continuous rhythmic delta activity may be seen in SE, particularly NCSE, intermittent polymorphic delta activity will be unlikely; the latter is typically a nonspecific finding in a variety of underlying conditions.

17. C. Mechanical chest percussion device can cause rhythmic 5–6 Hz activity in 1 electrode.

A mechanical chest percussion device can cause rhythmic 5–6 Hz activity in multiple (not just 1) electrodes. ECMO is associated with a 1–3 Hz square wave artifact. Ventilators can cause artifact that varies widely in morphology, amplitude, and polarity, but can be associated with a faster frequency artifact due to charged water molecules in the ventilator tubing that can be improved by suctioning. CPR can lead to high-amplitude, rhythmic 1–2 Hz activity that is due to movement, not cerebral activity. Of note, if CPR is being done, there is a high likelihood that the EKG channel will be affected as well. The difficulty in identifying artifact solely by EEG analysis can be reduced significantly by simultaneous video monitoring.

18. D. Sampling rate of 1000 Hz.

The term HFOs refers to EEG activity greater than 70 Hz (30–70 Hz band activity is usually considered as gamma). The 80–200 Hz activity is often referred to as ripples, whereas the 250–500 Hz activity is referred to as fast ripples. The sampling rate determines the recording of high frequencies. Theoretically, the maximum frequency of the oscillations that can be evaluated corresponds to one-half of the sampling rate. However, due to the limitations of the amplifiers used in the EEG systems, the maximum frequency that can be clearly evaluated tends to be roughly one-third of the sampling rate, such that a sampling rate of 1000 Hz allows evaluation of activity up to 333 Hz. Accordingly, a sampling rate of 1000 Hz (preferably 2000 Hz) is recommended for recording HFOs. Although initial studies recorded HFOs using microelectrodes, more recent studies have shown that HFOs can be recorded using clinical depth and subdural electrodes.

19. B. Sampling rate of 1000 Hz.

In patients with epilepsy, HFOs have been recorded from mesial temporal as well as neocortical structures. Although the initial studies focused on interictal HFOs, recent studies have shown that HFOs occur at seizure onset, and such ictal HFOs can be helpful in localizing the seizure onset zone. Interictal HFOs generally tend to be prominent within the seizure focus (seizure onset zone) but they are shown to occur outside, and even at a remote distance from the seizure focus. Initial studies using microelectrodes in rodents showed that only fast ripples (250–500 Hz) were pathologic, indicating epileptogenicity; however, several recent studies suggest that ripples (80–200 Hz) are pathologic as well in patients with epilepsy.

20. A. DC shifts can only be recorded using dedicated DC-coupled amplifiers.

The term DC EEG refers to a frequency response of the EEG with a minimum at 0 Hz. Although this is typically recorded using dedicated DC-coupled amplifiers, the routine alternating current (AC) amplifiers with long time constants (eg, 10 seconds) can adequately record the DC shifts as well. Since DC shifts are ultraslow fluctuations of the EEG signal, they are best seen by decreasing the low-frequency filter (high-pass filter) to significantly low values (eg, 0.016 Hz). Several studies have shown that DC shifts are useful in localizing the seizure onset zone, particularly on intracranial recordings that are relatively artifact free, unlike scalp recordings.

21. D. Selectivity to radial currents.

MEG has better spatial resolution than EEG in localizing the cortical events. MEG is sensitive to activity within the fissural cortex. In contrast to EEG, MEG signals are sensitive to the properties of the brain but insensitive to the properties of the skull and other extracerebral tissues. The MEG signals outside the head are less distorted than the EEG signals on the scalp. The MEG recording is reference free, whereas the recording of EEG signals depends on the location of the reference electrode. MEG has selectivity to tangential (not radial) currents in the presence of several simultaneous sources.

22. B. Those perpendicular to the cortical surface.
In a spherical model, only currents that are tangential to the surface will produce a magnetic field that can be detected by MEG. However, in reality, signals from the convexity may also be detected when the currents are closer to the detector. Currents that are perpendicular to the cortical surface cannot be theoretically detected by MEG. However, current sources that deviate from the radial orientation by only 10–20 degrees can be detected. MEG can also detect current sources within the cortical fissures.

23. C. MEG can identify time lags to differentiate between primary and mirror foci.

MEG cannot differentiate between ictal and interictal spikes. However, one can position an electrode array over the area of interictal MEG activity, calculate the forward solution, and monitor the ictal activity during EEG to ascertain whether the MEG interictal focus is responsible for the ictal activity as well. MEG is suitable for identifying the seizure foci in the convexity and can be used to guide placement of intracranial electrodes. In presurgical evaluation, it is important to know whether the interictal epileptic discharges are focal or multifocal, and whether the foci show any time lags. MEG current dipole analysis can identify such time lags and can be useful in differentiating between the primary and secondary (mirror) foci. MEG studies in patients with Landau–Kleffner syndrome have shown that the spike-and-wave discharges are indeed generated in the auditory cortex (not motor speech area); these continuous discharges are felt to explain the speech impairment in this disorder.

24. B. Produces D-waves in the pyramidal axon.
A single electrical stimulus applied to the motor cortex produces multiple (not single) volleys within the descending motor tracts, giving rise to D-waves and I-waves. The first volley (called a “D-wave”) reflects direct stimulation of the pyramidal axons that comprise the corticobulbar and corticospinal tracts. Subsequent volleys (called “I-waves”) reflect activation of the pyramidal neurons via excitatory synaptic input from other cortical neurons that were activated either directly or indirectly by the applied stimulus. The delay from the applied stimulus to an I-wave reflects the time required for the intervening synaptic transmission and represents an integral sum of the number of cortical synaptic transmission delays. This accounts for the relatively consistent intervals between the D-wave and the first I-wave and between successive I-waves. M-waves refer to myogenic motor evoked potentials (MEPs) recorded from the muscles (not pyramidal neurons) upon cortical stimulation.

25. D. Highly likely to be suppressed by a combination of propofol and opioid total intravenous anesthesia.

A train of multiple transcranial electrical stimulation (TES) stimuli produce multiple D-waves that can summate in the lower motor neurons to cause muscle contractions that elicit the myogenic MEPs (M-waves). Such repetitive stimuli applied to the cortex may also produce I-waves, which provide further excitatory drive to the anterior horn cells. If the interstimulus interval (ISI) between the stimuli in a train is too short, stimuli after the first may not effectively stimulate the corticospinal tract axons due to their refractory periods. On the other hand, if the ISI is too long, the excitatory postsynaptic potentials within the alpha motor neurons will decay during the long intervals between successive stimuli without resulting in temporal summation. An ISI of 2–3 ms has been shown to be useful for intraoperative monitoring of MEPs. Even with high-intensity train of stimuli, only a small fraction of the motor neuron pool is activated each time. With each trial, a different subset of the motor neuron pool gets activated, resulting in successive M-wave recordings with differing morphology. Due to this variability, signal averaging should not be applied to M-waves. Anesthesia, especially the use of halogenated inhalational agents with or without nitrous oxide, suppresses the myogenic MEPs; however, total intravenous anesthesia with propofol and opioid infusions seems to have less influence on them.

26. D. Laterally placed electrode pair selectively stimulates the corticospinal tracts to both arm and leg contralateral to the anode.

The electrical stimuli for TES can be given by a pair of electrodes (anode/cathode) inserted into the scalp. The Fz/Cz electrode pair predominantly stimulates the corticospinal tracts to the legs; C3/C4 preferentially stimulates the corticospinal tracts to the arms; and C1/C2 stimulates corticospinal tracts to both upper and lower extremities. A more laterally placed electrode pair can selectively stimulate the hemisphere ipsilateral to the anode, allowing recording of motor evoked potentials (MEPs) in the muscles contralateral to the anode.

27. A. Action potentials that are initiated at the axon hillocks of the cortical pyramidal neurons.

Upon stimulation of the cerebral cortex with an anode–cathode pair, current flow under the anode results in an inward, inhibitory transmembrane current in the superficial portion of the pyramidal neurons and an outward, excitatory current at the axon hillocks that produces the MEPs (ie, D-waves). Current flow under the cathode is in the opposite direction (toward it), caused by excitation of the superficial portion of the pyramidal neurons as well as the interneurons; this current flow results in hyperpolarization at the axon hillocks that blocks the initiation or propagation of action potentials that would give rise to D-waves. Under anesthesia, when I-waves are suppressed and the MEPs consist of D-waves, the myogenic MEPs elicited by TES are predominantly recorded from muscles contralateral to the anode.

28. C. Myogenic waves are recorded ipsilateral to the anode .
MEPs elicited by TES consist of D-waves that reflect direct stimulation of the pyramidal axons, which comprise the corticobulbar and corticospinal tracts, and I-waves, which reflect activation of the pyramidal neurons by excitatory synaptic activity. With inhibition of synaptic transmission under anesthesia, I-waves are suppressed but not the D-waves. In this case, the myogenic MEPs are predominantly recorded from muscles contralateral to the anode since the inward current flow under the anode comes out of the axon hillocks and blocks the generation of D-waves under the cathode. Thus, the myogenic MEPs are generated in the contralateral muscles innervated by the corticospinal tracts ipsilateral to the anode.

29. B. Produces the strongest currents close to the inner table of the skull.
TMS does not activate scalp pain fibers as strongly as transcranial electrical stimulation (TES), and is therefore useful for assessing central motor pathways in conscious subjects. However, TMS can also be applied to nonmotor regions in the brain convexity. TMS induces current flow in a toroidal manner through the brain tissue underneath the coil. The strongest currents are encountered closest to the inner table of the skull where they will be predominantly tangential to the cortical surface. Activation of deeper structures (eg, brainstem) is not likely as the magnetic field strength decreases with the square of the distance. Pyramidal cell axons are most effectively stimulated by radial currents flowing perpendicular to the cortical surface. However, depending on the position and orientation of the coil, TMS may induce predominantly tangential currents, which preferentially stimulate the horizontally coursing neurites within the cortex rather than the axon hillocks of the pyramidal neurons. Thus, MEPs produced by TMS may consist predominantly of I-waves rather than D-waves.

30. A. It does not effectively activate the motor cortex.
Since TMS activates motor cortex without activating scalp pain fibers as strongly as transcranial electrical stimulation (TES), it is extremely useful for assessing central motor pathways, especially in conscious subjects. TMS often induces tangential currents depending on the orientation and position of the coil, resulting in MEPs consisting of I-waves rather than D-waves. Since the I-waves are suppressed by surgical anesthesia, MEPs elicited by TMS are not suitable for intraoperative monitoring (IOM). Any minor change in the position and orientation of the stimulating coil may produce dramatic changes in MEPs; thus, in surgeries lasting several hours, it is difficult to maintain the coil in the same exact position relative to the patient’s head. The magnetic field–pulse induced by TMS can interfere with the functioning of other equipment in the operating room, necessitating extra shielding of the equipment.

31. B. It is useful in monitoring spinal surgeries under general anesthesia.
TMS is useful for eliciting motor evoked potentials (MEPs), which are useful in the diagnosis of dysfunction involving corticospinal and corticobulbar tracts. Repetitive TMS (rTMS)–induced changes in cortical excitability outlast the stimulation, and resemble those of long-term potentiation (LTP) and long-term depression (LTD) that are induced by repetitive electrical stimulation of the cortex or hippocampus. The ability of TMS to produce such lasting and focal changes in cortical excitability forms the basis of its therapeutic effect in major depression, chronic pain, and epilepsy. TMS is not useful for intraoperative monitoring since the MEPs (ie, I-waves) generated by it are attenuated by anesthesia.

32. D. REM.
The effect of sleep on epilepsy was recognized in the 1800s. Since then, more studies have been done to evaluate this further. It has been shown that REM sleep is the least likely and that N3 (slow wave sleep) is the most likely to show epileptiform discharges. The increased synchronization during slow wave sleep and the relative desynchronization during REM sleep are felt to be the underlying mechanisms.

33. D. Improves or worsens neuropsychological junction.
rTMS has been shown to alter mood in nondepressed subjects, have a greater impact on mood in depressed patients (although generally in a positive direction), induce mania or a hypomanic state in some subjects, and improve or worsen neuropsychological function with no consistent overall changes.

34. D. Cable artifact.
The EEG shows cable artifact caused by someone stepping on the cable between the jack box and the amplifier. Sweat artifact can present with very slow activity (usually 0.25–0.5 Hz) due to the sodium chloride and lactic acid from the sweat reacting with the electrodes producing the swaying. Such an artifact would have been attenuated in this example since the low frequency filter setting was 1 Hz. Occasionally, sweating can be misinterpreted as slow roving eye movements when sweat artifact is in the anterior channels. Eye movement artifact is produced because the eyeball acts as a dipole with the cornea relatively positive compared to the retina. With eye closure, the eyeball rotates about its horizontal and vertical axes as it moves superior and lateral, respectively (referred to as the Bell phenomenon). This phenomenon typically lasts less than 0.5 seconds, which is faster than what is seen on the EEG shown in this example. Ventilator artifacts have highly variable morphology (made up of single or multiple waveforms) and amplitude, but they recur with each respiration.

35. A. Decreasing the low-frequency filter; decreasing the high-frequency filter.

Decreasing both the low-frequency and high-frequency filter settings will lead to a phase shift to the right.

36. A. Square wave inputs.
Calibration maneuvers use square wave inputs and are done to assess the fidelity of the recording system.

37. C. Display of the acquired EEG waveform on the computer screen.
Display of the acquired EEG signal on the computer screen does not add to the EEG impedance. EEG impedance is a measure of the resistance along with the capacitive and inductive reactance. Impedance derives from any material through which the EEG signal passes from its generator to the analog-to-digital converter (ADC).

38. B. Juvenile myoclonic epilepsy (JME).
This patient most likely has JME given the EEG shows generalized spike-wave and polyspike-wave discharges in the setting of a normal background of 9 Hz. Her seizure onset is beyond the typical age for CAE, which is 4–10 years of age. It is unlikely that she has symptomatic generalized epilepsy given the normal EEG background. In addition, although there is a possibility that the patient has partial epilepsy (ie, frontal lobe epilepsy) with secondary bilateral synchrony, the history of staring spells, suggestive of absence seizures, makes this less likely.

39. D. All of the above.
The patterns in the question can be seen in different stages of coma. In general, the EEG becomes less reactive as the coma deepens.

40. C. Loss of postural control.
Absence seizures can be associated with some motor manifestations including rhythmic eye blinking, retropulsion of the head, and repetitive oral automatisms (swallowing, chewing, lip smacking, and lip licking). Postural control is usually maintained but swaying may be seen in the standing patient. It is felt that the loss of consciousness during the classic absence is due to transient impairment of the working memory attributed to the accentuation of spike-wave discharges in the frontal cortex. This phenomenon is believed to underlie the immediate restoration of the working memory along with consciousness at the end of the absence episode.

41. B. Alpha and beta.
The alpha and beta bands were described originally by Berger. The gamma rhythm was subsequently described by Jasper and Andrews to designate frequencies greater than 30 Hz. The term “delta” was initially introduced to designate all frequencies

below the alpha range by Walter, who subsequently introduced the term “theta” to specifically designate the 4–7.5 Hz activity.

42. D. Electrodes are placed at a distance from each other equal to 10% or 20% the total frontto-back or side-to-side distance.

The 10–20 system is an internationally recognized method to name and apply the location of scalp electrodes that ensures standardized reproducibility over time and between subjects. The “10” and “20” refer to the actual distances between adjacent electrodes, which are either 10% or 20% of the total front-to-back or right-to-left distance of the skull.

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