7
Normal Variant EEG Patterns

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Summary

The object of this chapter is to familiarize the reader with a number of commonly encountered normal variants of brain-derived EEG activity. The term "normal variant pattern" refers to those rhythms or waveforms that have features reminiscent of either interictal or ictal EEG abnormalities. However, these patterns have been found in a substantial proportion of tracings from healthy subjects and, therefore, are not currently thought to represent pathological entities. It is, therefore, vital that such patterns be appropriately recognized by the EEG reader as normal variants and not erroneously confused for pathological patterns. This chapter addresses four main categories of variant EEG activity:

1. Rhythmic patterns.
2. Epileptiform patterns.
3. Lambda and lambdoids.
4. Age-related variants.

EEG artifacts derived from sources other than brain-derived activity will not be reviewed.

Key Words: Benign; EEG; epileptiform; rhythm; variant.

1. RHYTHMIC VARIANT PATTERNS

There are six main types of rhythmic variant EEG patterns:

1. Alpha variant.
2. Mu rhythm.
3. Rhythmic temporal theta burst of drowsiness ("psychomotor variant").
4. Subclinical rhythmic electrographic (theta) discharges in adults (SREDA).
5. Midline theta rhythm.
6. Frontal arousal rhythm (FAR).

1.1. Alpha Variant

This pattern was described first by Goodwin in 1947. There are two types of alpha variants, "slow" and "fast." The slow (subharmonic) alpha variant appears as an abrupt rhythm usually at half the frequency of the patient's more typical waking background rhythm, and often of greater voltage (Fig. 1). The fast (harmonic) alpha variant may appear as a notched or bifurcated form of the patient's usual waking background rhythm, so that a superimposed harmonic rhythm of twice the alpha frequency occurs. Alpha variants are blocked with eye opening and exhibit a posterior predominance, just as with normal alpha rhythms. Alpha variants vary in their prevalence within a subject's tracing, alternating with periods of normal-appearing alpha

From: *The Clinical Neurophysiology Primer*
Edited by: A. S. Blum and S. B. Rutkove © Humana Press Inc., Totowa, NJ

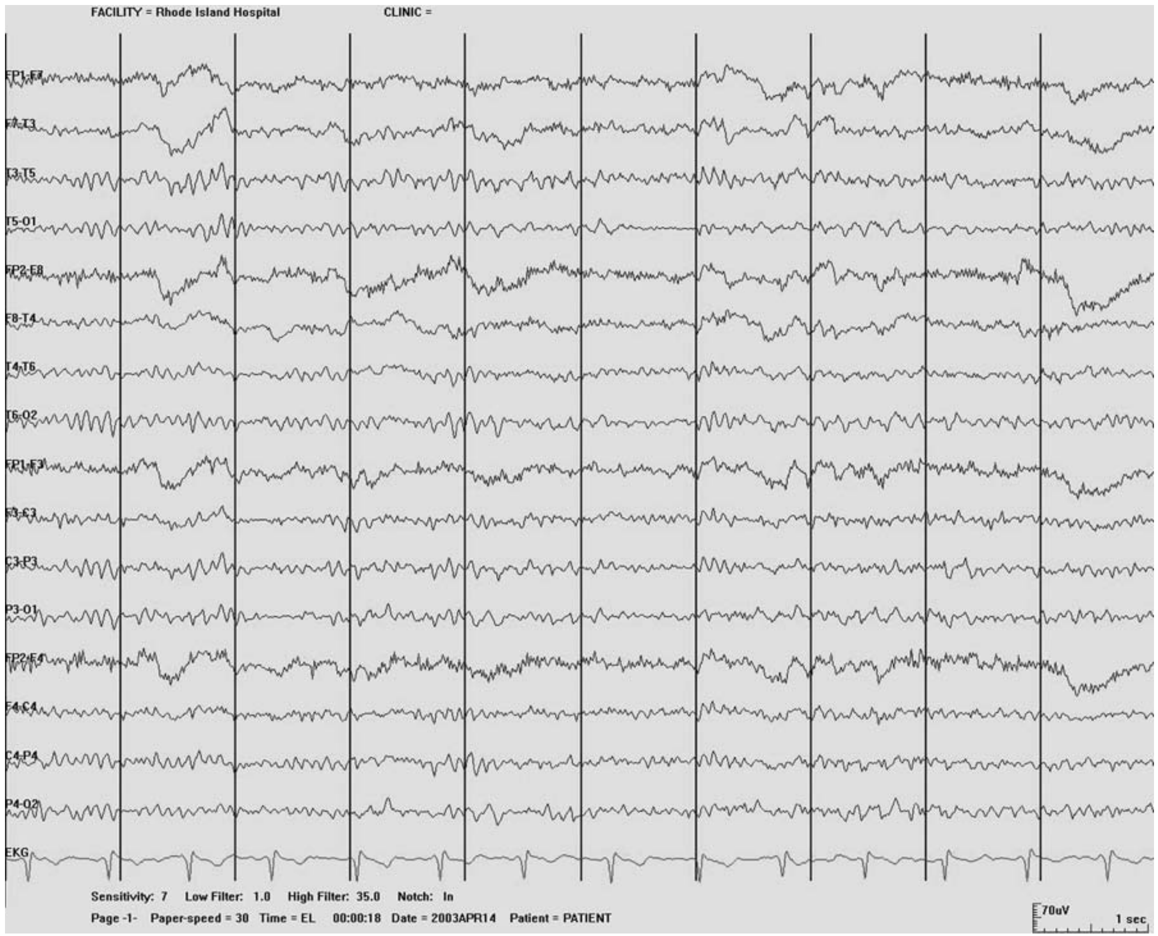

Fig. 1. Slow alpha. This subject is 46 yr of age. Note how the posterior background rhythm shifts from a bilateral 11-Hz rhythm earlier in the figure to a somewhat notched biposterior 5- to 6-Hz rhythm late in the figure.

activity. Alpha variants have been regarded as a physiological variation of the more familiar posterior background alpha activity, and do not predict increased convulsive tendency.

1.2. Mu Rhythm

Numerous terms have been applied to the mu rhythm, including arcade, comb, and wicket rhythms, owing to its morphology. Individual waveforms have an arciform morphology. This occurs in waking over the central regions, especially the C3, Cz, and C4 contacts (Fig. 2). It is closely associated with the sensorimotor cortex, hence the term "mu," for motor. Mu exhibits a frequency in the alpha range, typically at 9 to 11 Hz. Niedermeyer observed this rhythm in approx 14% of adolescents' EEG tracings, and less often in younger children and the elderly. Similar to the alpha activity of the occipital cortex, it exhibits physiological reactivity. It attenuates with contralateral limb movement or just planned movement of the contralateral limb. With direct cortical recording methods, a 20-Hz beta activity may be observed from the sensorimotor cortex, with similar reactivity. Thus, the scalp-recorded mu is likely a subharmonic of this underlying rhythm.

Mu is usually observed bilaterally with shifting predominance; it may, however, be asymmetrical and asynchronous. Mu activity is augmented in the setting of a focal skull breach. This could, for instance, explain some instances of highly lateralized mu rhythms. Exclusively lateralized mu should raise a suspicion of an abnormality in the hemisphere lacking mu activity. Sometimes, focal mu activity in the setting of a bony defect of the skull may be so sharp and of higher voltage as to falsely mimic an epileptogenic focus.

1.3. Rhythmic Temporal Theta Bursts of Drowsiness ("Psychomotor Variant")

Gibbs et al. called this pattern the "psychomotor variant" because it was thought to represent a temporal lobe or psychomotor seizure. This concept has been more recently discarded because this pattern is observed in asymptomatic healthy individuals and exhibits poor correlation with patients with true temporal lobe or psychomotor seizures. This pattern has also been called "rhythmic mid-temporal discharges" describing its character, location, and frequency.

This pattern may be present in waking or early drowsiness and usually in tracings of adults and adolescents. It wanes with deepening sleep. As its name implies, this particular pattern is found in the mid-temporal head regions, but can spread parasagittally. It is comprised of 5- to 7-Hz rhythms in bursts or trains lasting often longer than 10 s and sometimes beyond a minute (Fig. 3). This variant rhythm can exhibit variable morphologies, but is often sharply contoured. It is usually monomorphic; it does not evolve significantly in frequency or amplitude, as occurs in most ictal patterns. Rhythmic mid-temporal discharges can occur bilaterally or independently with shifting hemispheric predominance. This pattern is uncommon; its incidence is approx 0.5%, according to Gibbs et al.

1.4. Subclinical Rhythmic Electrographic Discharges in Adults

This variant pattern involves sharply contoured 5- to 7-Hz activities with a wide distribution, mainly over temporo-parietal derivations. It is usually bilateral, but can be asymmetrically disposed. SREDA can appear as repetitive monophasic sharp waves or as a single discharge followed seconds later by sharp waves that gradually accelerate to form a sustained, rhythmic train of theta activity. This may last from 20 s to several minutes, usually 40 to 80 s. Because of its duration and evolution, SREDA can easily be misinterpreted as an ictal pattern, even by experienced readers. Nevertheless, SREDA has not been shown to have any consistent

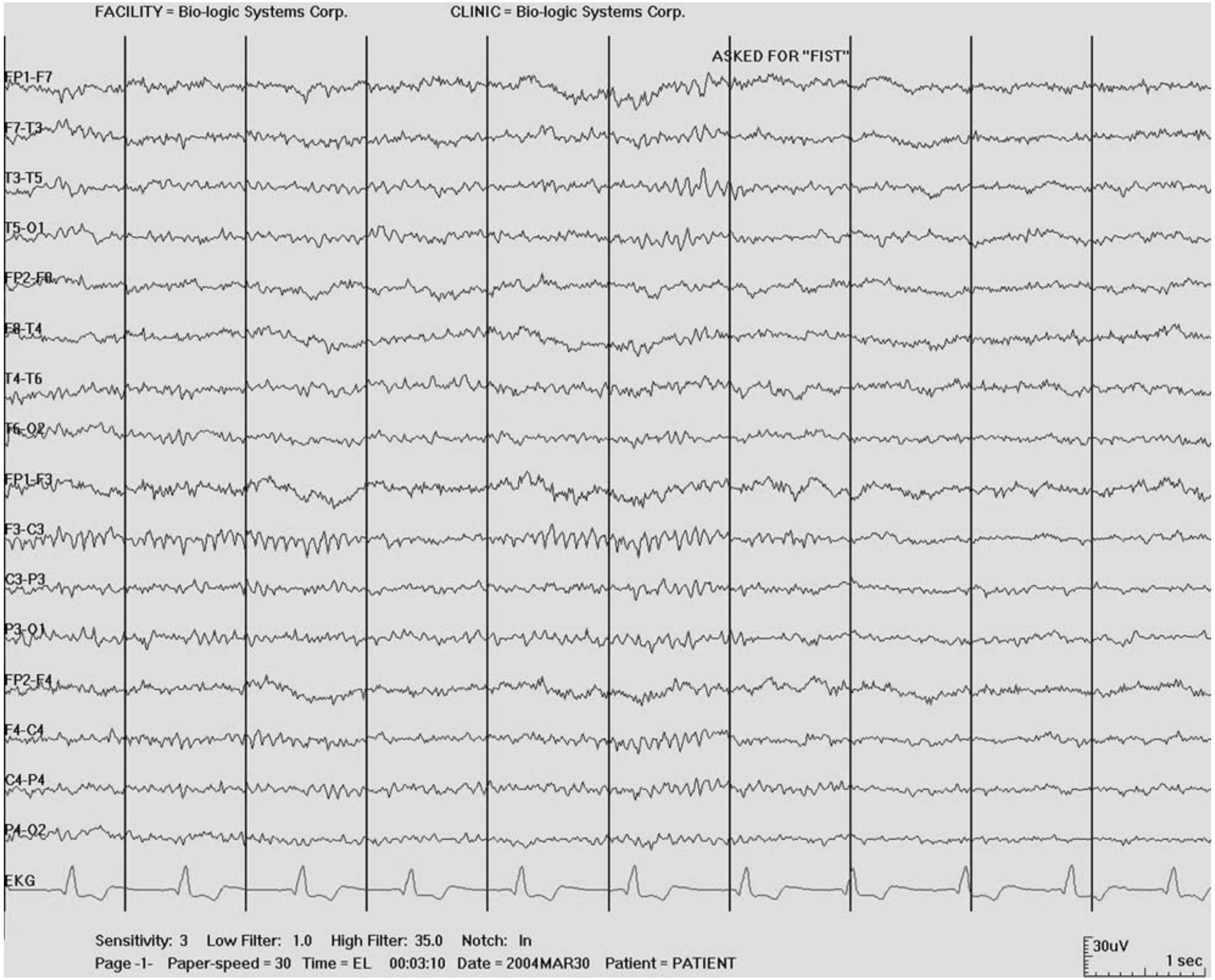

Fig. 2. Mu. This subject is 27 yr old. Note the prominent mu rhythm over the C3 contact. This blocks efficiently when the subject is asked to make a fist with the contralateral hand, as indicated.

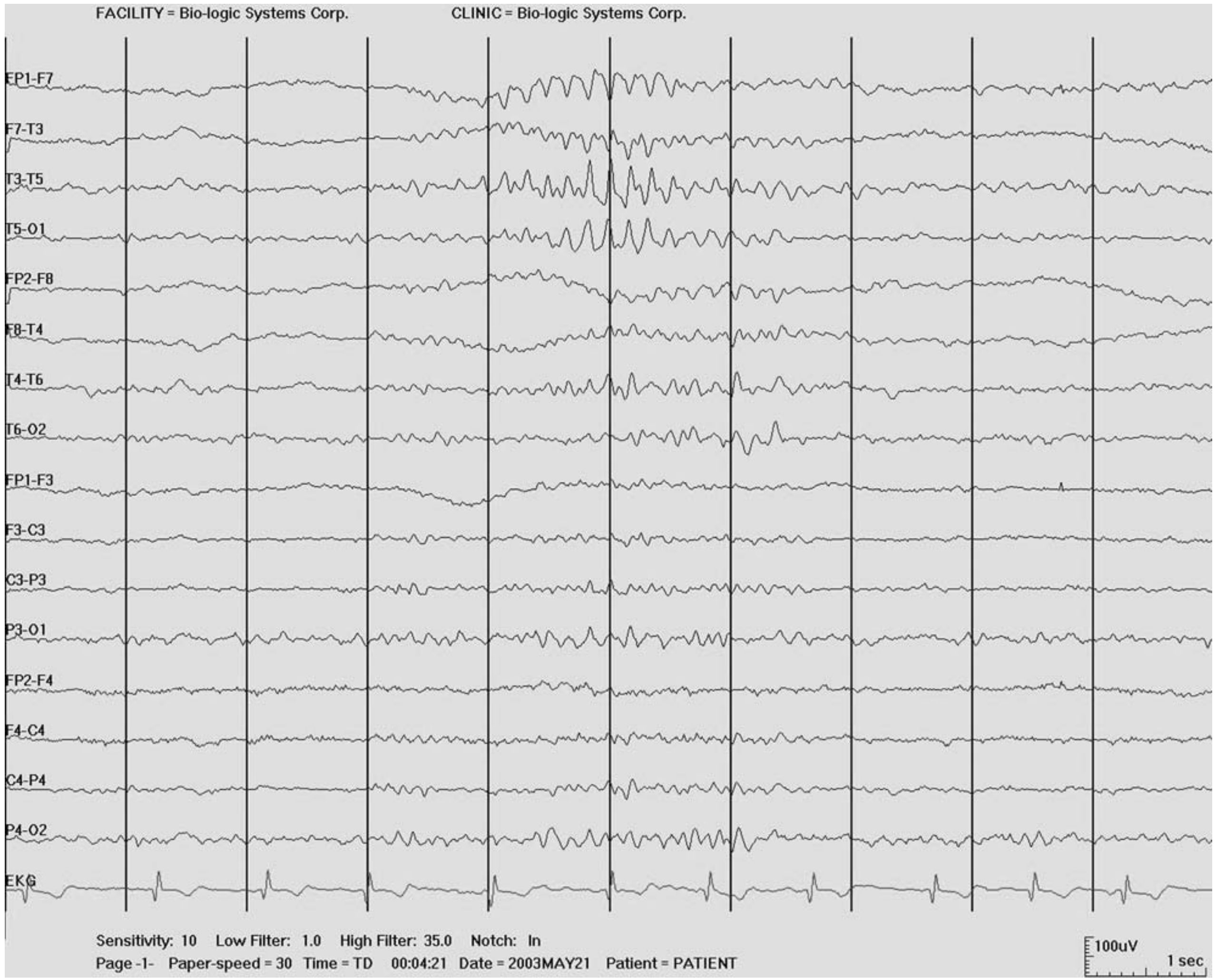

Fig. 3. Psychomotor variant. The subject is 20 yr of age. Note the run of monomorphic sharply contoured theta activity lasting 2 to 3 s over the left temporal channels.

correlation with seizures. SREDA is more typically seen in older adults, and more common at rest, drowsiness, or during hyperventilation.

1.5. Midline Theta Rhythm

The midline theta rhythm is most prominent at Cz but may spread to nearby contacts. This 5- to 7-Hz frequency exhibits either a smooth, arc-shaped (mu-like) or spiky appearance. The duration is variable and it tends to wax and wane. It is more common in wakeful and drowsy states and reacts variably to limb movements, alerting, and/or eye opening. This rhythm is now regarded to be a nonspecific variant, although it once was considered a marker of an underlying epileptic tendency.

1.6. Frontal Arousal Rhythm

FAR involves trains of 7- to 10-Hz activities in the frontal head regions. These rhythms may be notched and may last up to 20 s. FAR has been described as an uncommon rhythm that appears during sleep-to-wake transitions, especially in children. FAR disappears once the subject is fully awake. This pattern was, at one time, associated with children with minimal cerebral dysfunction, but this specific association has been subsequently doubted. This pattern is still considered to be a nonspecific finding without pathological significance.

2. EPILEPTIFORM VARIANT PATTERNS

There are 4 major types of epileptiform variant patterns:

1. 14- and 6-Hz positive bursts.
2. Small sharp spikes (benign epileptiform transients of sleep [BETS]).
3. 6-Hz spike and wave (phantom spike and wave).
4. Wicket spikes.

2.1. Fourteen- and 6-Hz Positive Bursts

Previously called “14- and 6-Hz positive spikes” or “ctenoids,” these variants occur as bursts of rhythmic arched waves, similar to sleep spindles, with a smooth negative component and a spike-like positive component (Fig. 4). As the name implies, these trains occur at 14 and 6 Hz. The bursts last only 0.5 to 1 s. Such bursts are best captured on referential montages (because of the greater interelectrode distances). They are maximal at the posterior temporal head regions and usually occur independently from bilateral hemispheres with shifting predominance. This variant appears in 10 to 58% of healthy subjects, but is influenced by age, montage, and duration of drowsiness and sleep. This pattern is more prevalent in children and adolescents.

2.2. Small Sharp Spikes/BETS

As these names imply, small sharp spikes or BETS are low in amplitude (~50 μV) and brief (~50 ms). Their morphology can be monophasic or diphasic. When diphasic, the ascending limb is quite abrupt and the descending limb slightly less so. They may exhibit a subtle following slow wave. BETS are isolated and sporadic. They appear during drowsiness and light sleep in adults. They are usually unilateral but can appear independently (and rarely synchronously) from bilateral regions (Fig. 5). On a transverse montage, their field often illustrates a *transverse oblique dipole* (opposite polarities across the opposing hemispheres), an atypical finding in bona fide epileptiform discharges. Other distinguishing features

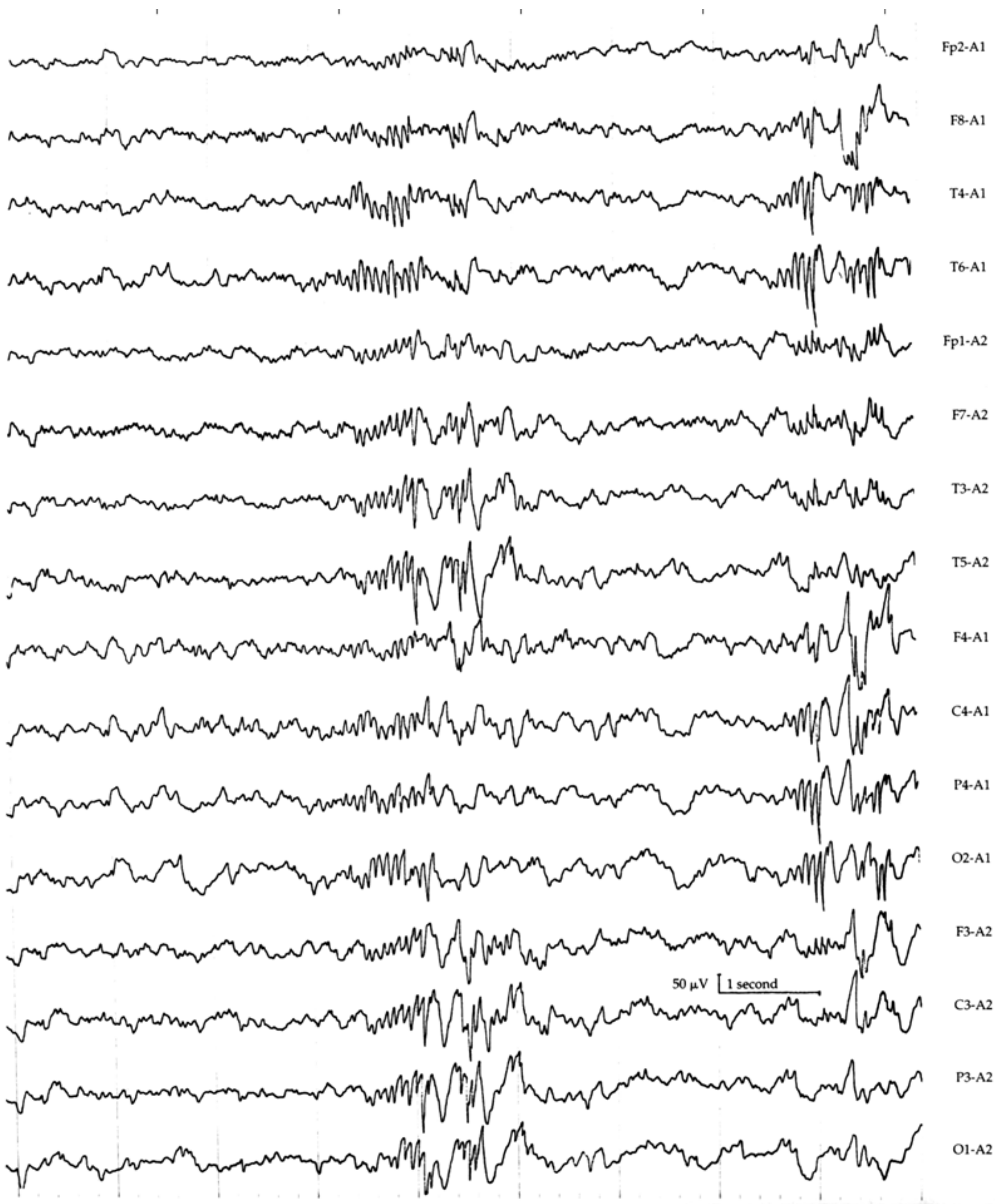

Fig. 4. Fourteen- and 6-Hz positive bursts. Note the bursts of spiky morphologies with surface positivity, here seen bilaterally with shifting laterality. They are best detected with long distance referential montages. Reprinted from Goldensohn et al., 1999 with permission.

between BETS and epileptiform activity are that BETS do not run in trains, distort the background, or coexist with rhythmic slowing, and BETS diminish with deepening sleep, whereas epileptiform discharges worsen with deeper sleep stages. White et al. reported the incidence of BETS to be comparable in healthy subjects (24%) as in symptomatic patients (20%). Thus, BETS seem unrelated to the diagnosis of epilepsy.

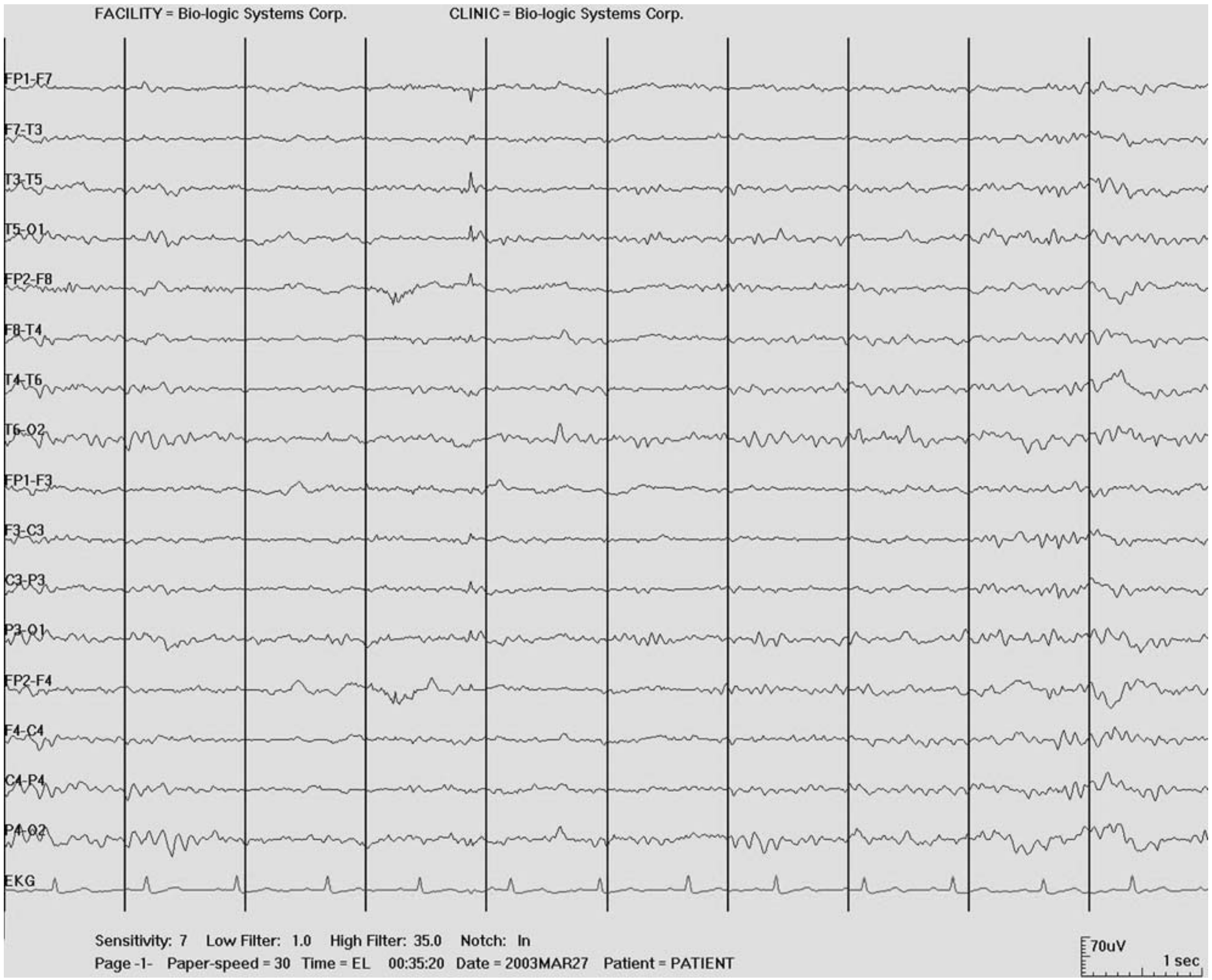

Fig. 5. Benign epileptiform transients of sleep (BETS). This tracing is from a 45-yr-old subject. Note the diminutive and very sharp diphasic transient seen broadly across the left temporal channels with spread to the left parasagittal chain of electrodes in the context of early sleep.

2.3. Six-Hertz Spike and Wave ("Phantom" Spike and Wave)

These rhythms have a frequency ranging from 5- to 7-Hz. They occur in brief bursts lasting 1 to 2 s, rarely up to 3 to 4 s. The spike component can be difficult to recognize because it is not only very brief but also of very low amplitude and, thus, has a fleeting quality. This subtle characteristic has given rise to the pithy term, "phantom" spike and wave. By contrast, its slow-wave component is broader in duration, higher in amplitude, and more widespread in distribution.

This pattern appears in waking or drowsiness in adolescents and adults. However, it is absent from slow-wave sleep. Silverman reported its overall incidence to be 2.5%. It usually has a diffuse, bilaterally synchronous distribution. At times, it is asymmetric or more regional.

Phantom spike and wave can appear quite similar to the 6-Hz positive spike burst. Infrequently, a transition may be seen on the same subject's EEG between these two types of variants. This pattern is thought by most to represent a benign finding. However, its morphology may be easily confused with an epileptiform pattern. Its failure to persist into slow wave sleep and its monomorphic quality permit its distinction from bona fide epileptiform discharges.

2.4. Wicket Spikes

This variant pattern appears as single spike-like waves or as intermittent trains of arc-like monophasic waves at 6- to 11-Hz (Fig. 6). Amplitudes range from 60 to 200 µV. Wicket spikes commonly appear from temporal channels and can be bilateral and synchronous or with shifting predominance. They occur mainly in drowsiness and light sleep in adults older than 30 yr of age.

When wicket spikes occur in isolation, they may be mistaken for an epileptiform discharge. Several features help differentiate isolated wicket spikes from pathological spikes. A similar morphology of the isolated wicket spike to those in a later train or cluster argues for the variant pattern and against an epileptiform discharge. The absence of a following slow-wave argues for the variant and against an epileptiform discharge. An unchanged background also argues more for the variant and against an epileptiform event.

3. LAMBDA AND LAMBDOIDS

3.1. Lambda

Lambda waves are sharp monophasic or biphasic waveforms that resemble the Greek letter lambda. They have a duration of 160 to 250 ms, an amplitude of 20 to 50 µV, and usually appear over bi-occipital leads, although occasionally may be unilateral (Fig. 7). Lambda waves depend on rapid saccadic eye movements with eyes open. This variant pattern is usually generated when the patient scans a complex patterned design in a well-illuminated room, for instance, dotted ceiling tiles in the laboratory. They block by staring at a featureless white surface or by closing the eyes. They are much more common in children 2 to 15 yr of age than in adults.

Slow lambda of youth, also known as shut-eye waves and posterior slow wave transients associated with eye movements, are associated with eye blinks in children. They appear over occipital channels as single, broad monophasic or diphasic, mainly surface negative waves. These morphologies last 200 to 400 ms and have an amplitude of 100 to 200 µV. They may be asymmetric. They are usually found in children younger than 10 yr of age.

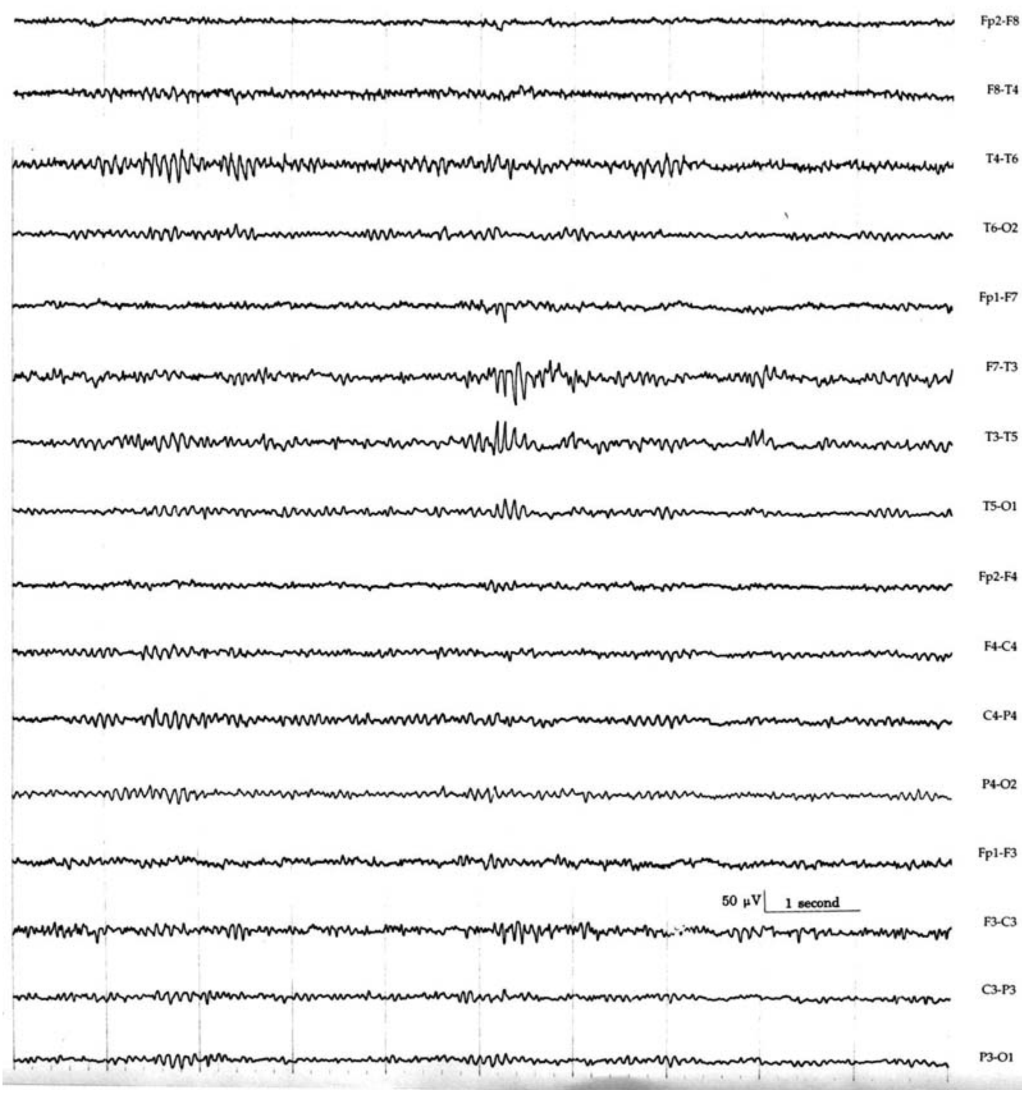

Fig. 6. Wicket spikes. Wicket spikes are often seen over temporal channels in drowsy or sleep recordings in adults. Reprinted from Goldensohn et al., 1999 with permission.

3.2. Lambdoids

Lambdoids, also called positive occipital sharp transients of sleep (POSTS) have a check-mark (biphasic) morphology with initial surface positivity and often appear in trains up to 4 to 5 Hz (Fig. 8). POSTS are usually synchronous but can be asymmetric in size. There are most commonly seen between 15 and 35 yr of age, and usually in light sleep. They may appear before the alpha rhythm completely evaporates in drowsiness. POSTS are a commonly encountered variant pattern on routine EEGs.

Slow lambdoids of youth**,** also known as cone-shaped waves or O-waves, are high voltage, diphasic slow transients seen over the occipital contacts and frequently with the occipital delta activity in deeper sleep states (Fig. 9). As the name implies, they are cone-shaped. They can be seen up to 5 yr of age.

Fig. 7. Lambda. This is from a 42-yr-old subject. Note the bilateral triangular-shaped morphologies over the occipital derivations evident with eyes open in waking.

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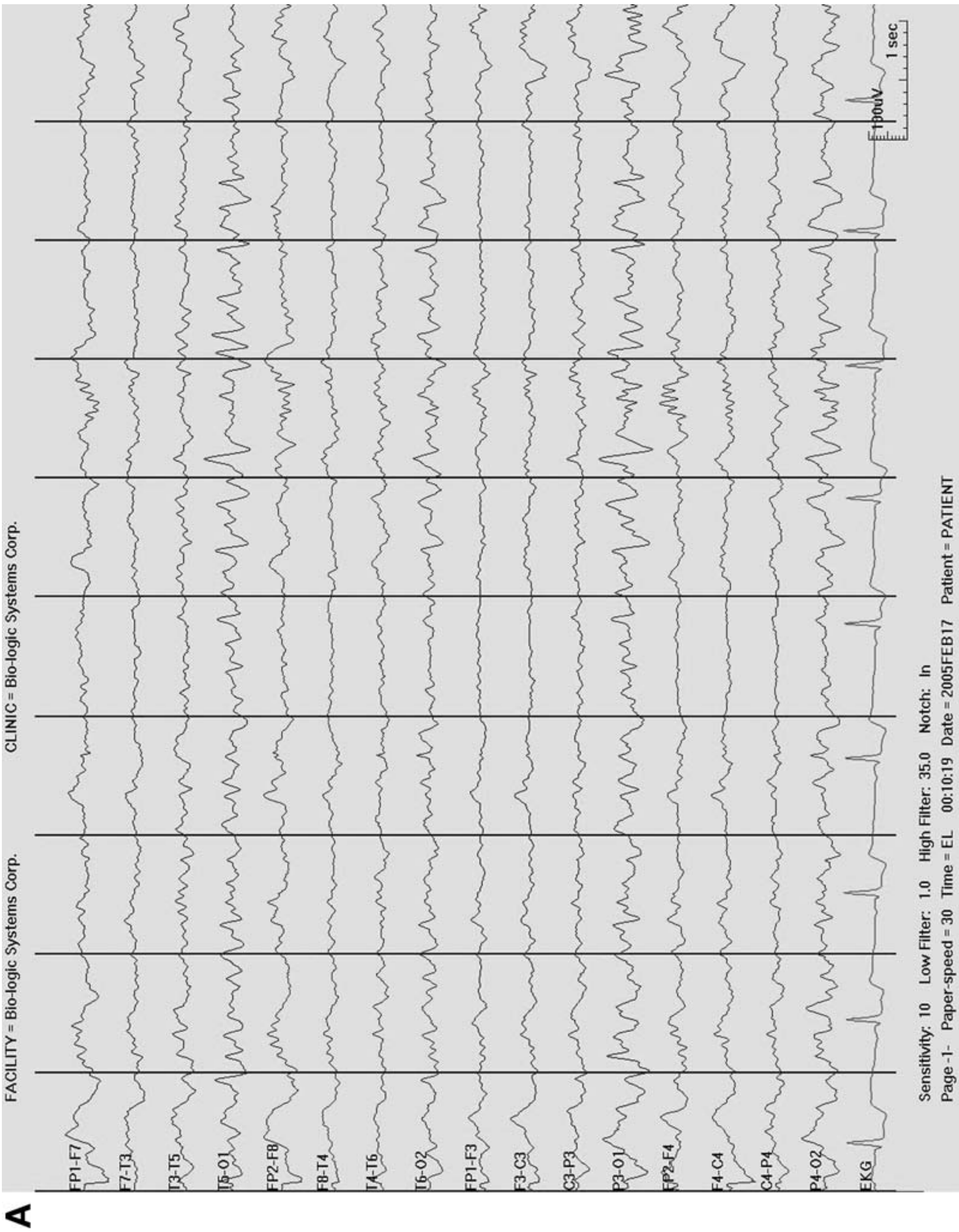
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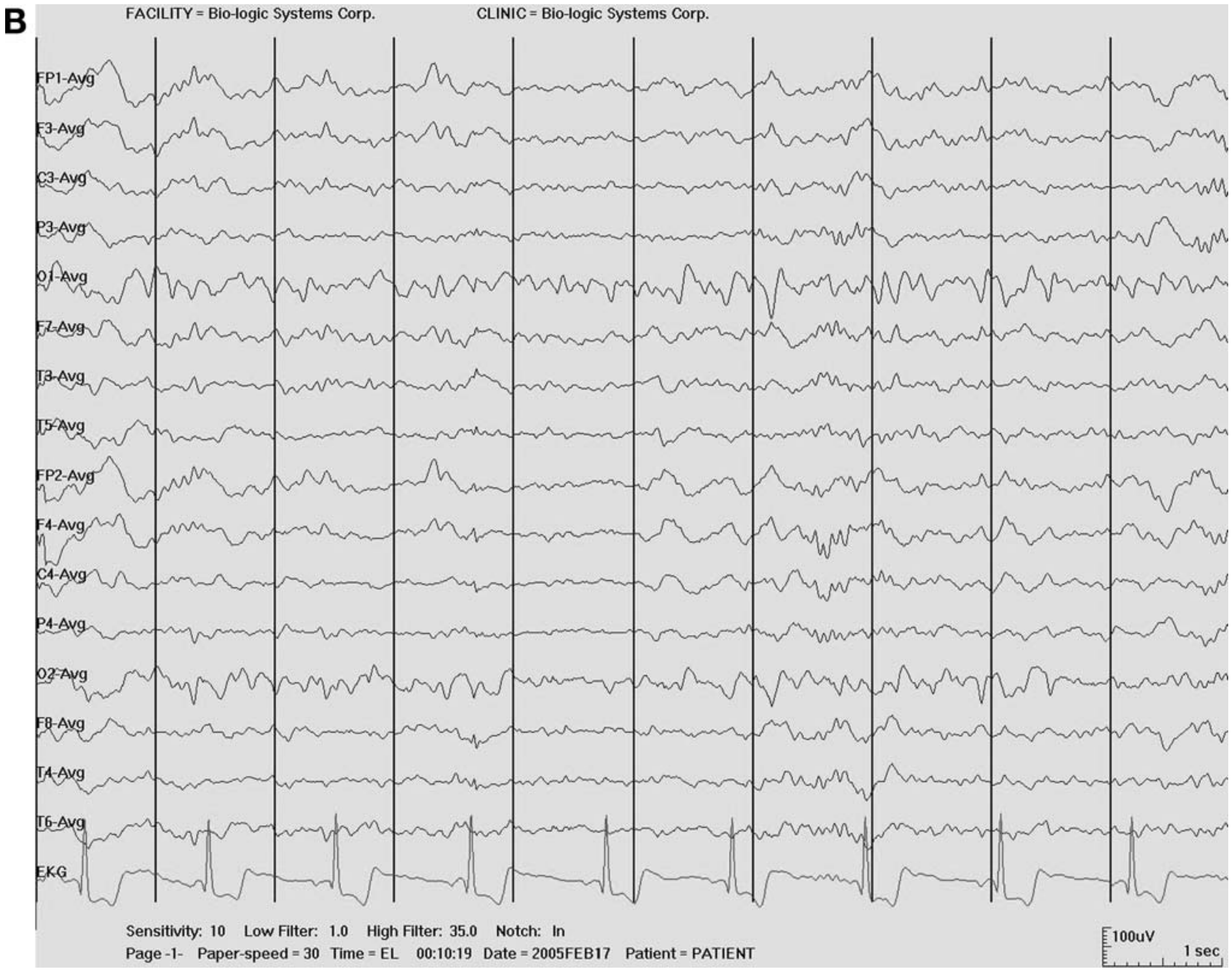

Fig. 8. Positive occipital sharp transients of sleep (POSTS). These derive from a drowsy 26-yr-old subject. (**A**) Illustrates POSTS occurring in a biposterior train at 2 to 4 Hz. In this anterior–posterior bipolar montage, POSTS have a check-mark appearance. The initial deflection is surface positive. This is better demonstrated in (**B**), which illustrates the same fragment reformatted in an average-reference montage. Note the frequent positive waveforms over the bi-occipital contacts.

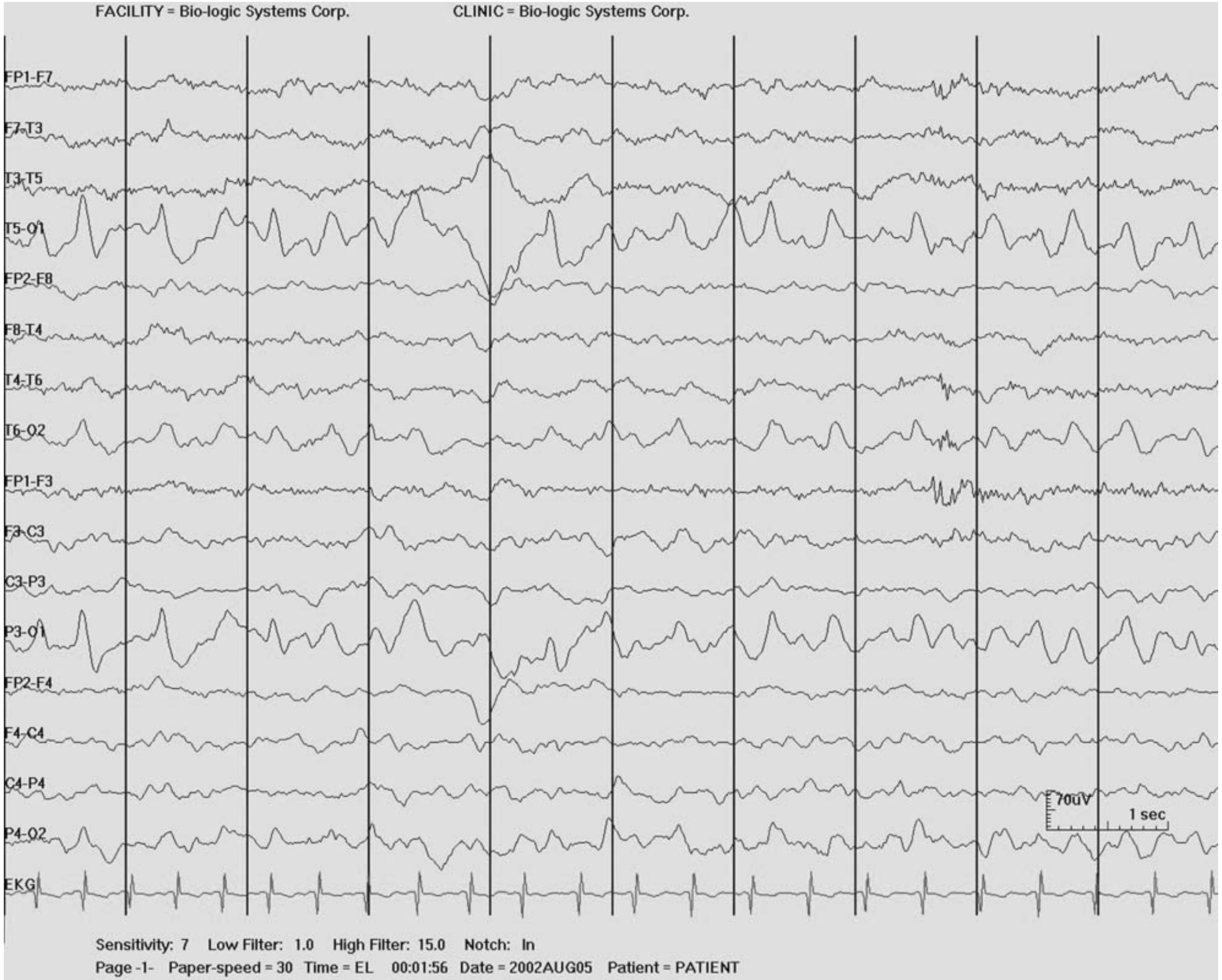

Fig. 9. Cone-shaped (O) waves. This is from a 3-mo-old child during sleep. Note the frequent high amplitude cone-shaped morphologies evident over the bi-occipital contacts in this tracing.

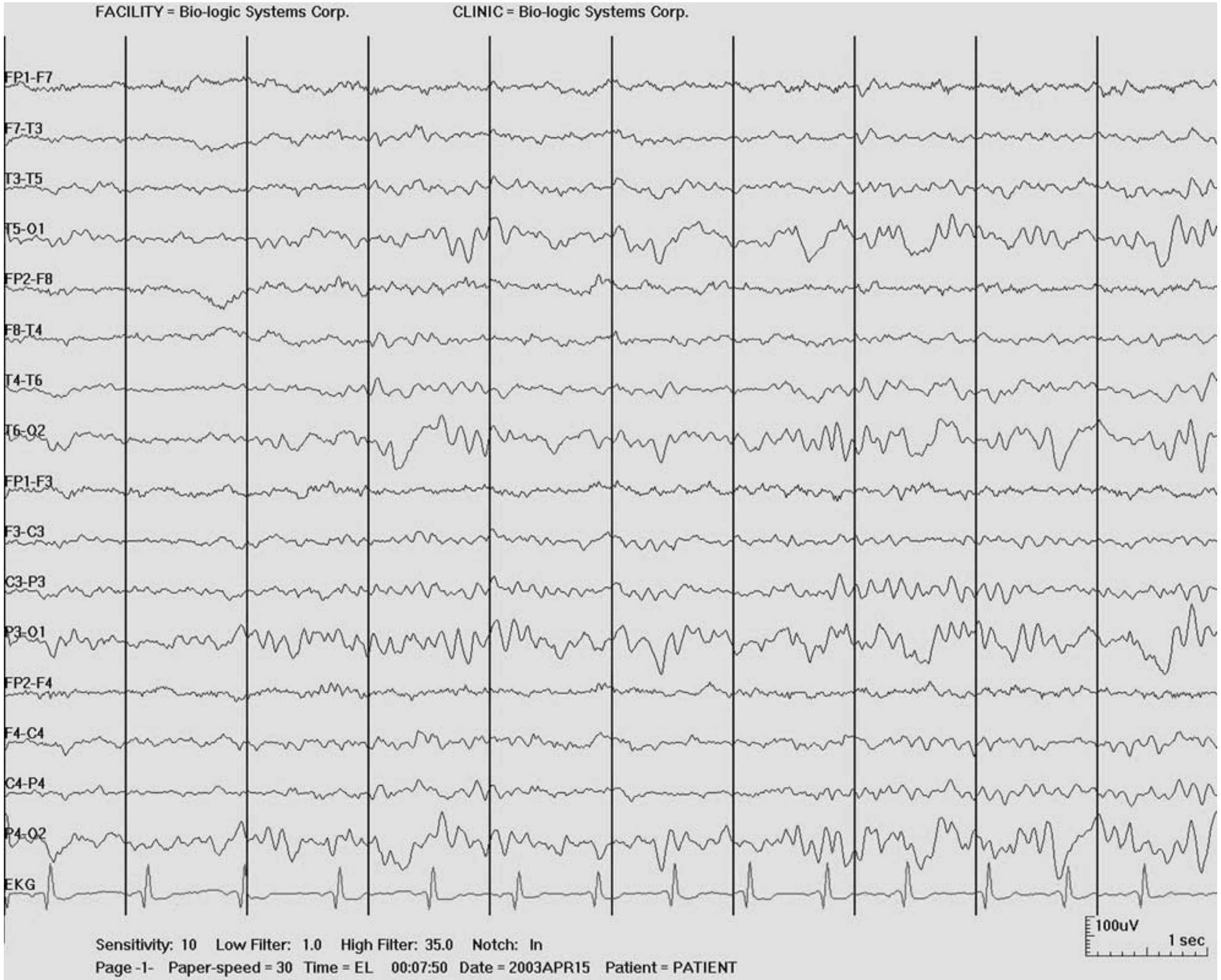

Fig. 10. Posterior slow waves of youth (youth waves). This is from the tracing of an 11-yr-old girl. Note the complex waveforms seen over the biposterior contacts. They illustrate the fused waveforms involving a delta waveform with a superimposed or "fused" alpha rhythm on top.

4. AGE-DEPENDENT VARIANTS

Posterior slow waves of youth, also called youth waves, posterior fused transients, and sail waves, are triangular, 2- to 4-Hz waveforms that coexist with other waking background rhythms (Fig. 10). They commonly form a complex that consists of the slow delta component with superimposed and following faster rhythms of the waking background rhythm, hence the term "fused." They are best seen over the posterior head regions in waking. These waves are occasionally asymmetric. These waveforms behave just like normal waking background rhythms in that they block with eye opening, increase with hyperventilation, and disappear in drowsiness. Youth waves usually appear between the ages of 8 to 20 yr, maximally in early adolescence.

Hyperventilation-induced slowing refers to a build-up of diffuse theta and delta activities in response to hyperventilation for several minutes during the EEG. This build-up may be abrupt or gradual and is often rhythmic and of high amplitude (up to 500 µV); it should resolve within 1 min after cessation of the patient's hyperventilation effort. This slowing is more prominent posteriorly in children and more anteriorly in young adults. This phenomenon is highly age dependent. It is extremely common in children and adolescents, becoming less common in young adults and thought by many to be uncommon after the age of 30 yr. As such, many laboratories regard this finding as a nonspecific abnormality in tracings of those older than 30 yr of age. Focal slowing or epileptiform activity evoked during hyperventilation is, however, pathological in nature.

Temporal theta in the elderly is a commonly encountered age-dependent pattern. This is a 4- to 5-Hz activity involving temporal channels and is thought by some to represent a subharmonic of the 8- to 10-Hz background rhythm common in the elderly. However, this rhythm is distinct from the alpha rhythm in that it persists with eye opening and even into drowsiness and light sleep. Hyperventilation augments this pattern's voltage and persistence. Temporal theta in the elderly usually occurs as very brief fragments lasting only two to three waves, rarely more than seven. Some have observed them to be more prevalent over the left hemisphere. Their significance remains controversial. Some regard these waveforms as normal variants but others have suggested that they may signify underlying vascular insufficiency, possibly subclinical in nature. Low-voltage intermittent temporal theta activity in asymptomatic elderly individuals has been estimated to occur with an incidence of approx 35%.

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REVIEW QUESTIONS

1. Alpha variant may:
   A. Be a subharmonic (slow) frequency of normal alpha.
   B. Be a harmonic (fast) frequency of normal alpha.
   C. Block with eye opening.
   D. Be sporadic, intermingling with normal alpha or may predominate.
   E. All the above.
2. Mu has features that may include:
   A. Predominantly found at the C3 and/or C4 contacts.
   B. An arciform appearance.
   C. Blocking with contralateral upper extremity use or planned use.
   D. More common in adults vs children.
   E. All of the above.
3. Which one of the following statements concerning the psychomotor variant pattern is false?
   A. It is also known as rhythmic temporal theta bursts of drowsiness.
   B. It is typically seen in patients with temporal lobe ("Psychomotor") epilepsy.
   C. It usually exhibits a 5- to 7-Hz frequency.
   D. It usually occurs in restful wakefulness or in drowsiness.
   E. None of the above is false.
4. The 14- and 6-Hz positive bursts (14- and 6-Hz positive spikes or ctenoids) are best described as:
   A. More common in children and adolescents, declining in prevalence with advancing age.
   B. Maximal over the posterior temporal regions, especially on referential montage.
   C. Similar in morphology to sleep spindles with a sharp, spike-like positive component and a smooth, rounded negative phase.
   D. Exhibiting a brief duration of 0.5 to 1 s.
   E. All of the above.
5. BETS (small sharp spikes) typically:
   A. Have an amplitude of 50 μV and a duration of 50 ms.
   B. May be monophasic or diphasic with an abrupt ascent and a steep descent.
   C. May include a diminutive following slow wave.
   D. Appear in isolation, not in trains.
   E. All of the above.
6. Which of the following statements regarding phantom spike and wave are true?
   A. It persists into slow-wave sleep.
   B. This pattern often presents in lengthy trains up to 40 to 80 s.
   C. It resembles the 6-Hz positive spike burst variant, and both may coexist in the same tracing.
   D. The pattern is fleeting or "phantom-like," in that it may be easily blocked by eye opening.
   E. All of the above.

7. Lambda waves can be:
   A. Seen only with the eyes open.
   B. Seen when the patient scans a complex pattern and block when looking at a featureless object.
   C. Seen in the posterior (occipital) head regions.
   D. More common in children rather than adults.
   E. All of the above.
8. POSTS are:
   A. Usually seen in light sleep and typically just before the alpha rhythm disappears.
   B. Seen over a wide age range, including children to the elderly.
   C. Demonstrate a check-mark morphology.
   D. Usually synchronous over the occipital regions, but may show asymmetric amplitudes.
   E. All of the above.
9. Posterior slow waves of youth (youth waves):
   A. Block with eye opening.
   B. Accompany the posterior alpha rhythm.
   C. Typically increase with hyperventilation and decrease in drowsiness.
   D. Are triangular-contoured, with a frequency of 2 to 4 Hz.
   E. All of the above.
10. Temporal theta in the elderly:
    A. Is usually at 4 to 5 Hz .
    B. Typically occurs in brief runs of two to three waves, rarely greater than six to seven waves.
    C. Persists despite eye opening and despite drowsiness or light sleep.
    D. Is more common over the left hemisphere and may represent asymptomatic or subclinical cerebrovascular insufficiency in the elderly.
    E. All of the above.

REVIEW ANSWERS

1. The correct answer is E.
2. The correct answer is E.
3. The correct answer is B.
4. The correct answer is E.
5. The correct answer is E.
6. The correct answer is C.
7. The correct answer is E.
8. The correct answer is E.
9. The correct answer is E.
10. The correct answer is E.