Newborn EEG interpretation is considered a particularly challenging area. An understanding of the appearance of the normal newborn EEG was achieved considerably later than for EEGs of childhood and adulthood. In fact, before the 1960s, it was not generally accepted that there was scientific or clinical value to be found in the analysis of the EEGs of newborns.

The relatively slower progress in the field of neonatal electroencephalography has been related to several factors. In almost any laboratory, the number of newborn EEG studies performed is considerably smaller than the number of studies performed in older age groups. Thus any given reader likely has less clinical experience reading tracings from the neonatal age group compared with older children. Also, to establish the basic foundations of neonatal EEG interpretation one must know the appearance of the normal neonatal EEG, which, in turn, requires that we know which patients are neurologically normal. Neurologic normality is more difficult to ascertain in newborns because of the inherent limitations in our ability to assess newborns neurologically; the question of whether certain findings in the newborn EEG may be normal has remained controversial. In general, newborns are considered neurologically “normal” when the history, examination, and other neurological studies are normal. This definition is more difficult to apply in practice because most babies who have had an EEG have had it for some clinical indication, and the presence of an indication immediately brings up the possibility that something is amiss. Finally, there was an early bias toward believing that typical premature tracings were abnormal because their discontinuous appearance resembled patterns such as burst-suppression that are known to be abnormal in older individuals.

The Concept of Postconceptional Age

The EEG of newborns is strikingly different from that of older children and adults. In fact, the best known elements of the mature EEG (posterior rhythm, sleep spindles, vertex waves) do not make their first appearance until 6 to 8 weeks after term. In the context of electroencephalography, a newborn’s degree of prematurity is stated in terms of postconceptional age (CA). The CA at birth is equivalent to the gestational age and is usually estimated using the date of the mother’s last menstrual period, but other information such as early fetal ultrasounds and the baby’s physical examination can be used to modify the estimate. By definition, a full-term newborn has a CA of 40 weeks and newborns delivered before 37 weeks are considered premature. Note that a 3-week-old newborn who was delivered at 38 weeks gestational age is considered to have a CA of 41 weeks for the purposes of EEG interpretation. The current CA is derived by adding the gestational age at birth to the current age in weeks (time since birth or “legal age”). One of the underlying assumptions of neonatal electroencephalography is that the expected appearance of a healthy newborn’s EEG is based on its CA. Whether it was born prematurely or not, the EEG is generally assumed to evolve at the same rate whether the baby is inside or outside the womb. Certain pathological processes may, however, interrupt this orderly maturation. Therefore, a normal baby born at 41 weeks CA is generally expected to have an EEG structure similar to that of a normal 5-week-old baby who was born 36 weeks CA.

From extreme prematurity to term to the postterm period, the appearance of the neonatal EEG evolves dramatically. In fact, on the basis of the various EEG features described here, an experienced neonatal electroencephalographer should be able to estimate the CA of a newborn to within approximately 2 weeks from the appearance of the EEG record. It has been claimed that when the CA estimate suggested by an otherwise normal neonatal EEG differs from the estimate based on the baby’s physical examination, the EEG-based assessment is more likely to be correct. Figures 13-1 and 13-2 show the striking changes in the appearance of the cortical surface between 31 weeks CA and 40 weeks CA (term). It should come as no surprise that the appearance of the EEG evolves rapidly in premature babies.

Recording Technique

Opinion varies as to whether a full or reduced electrode set should be used for neonatal recordings. Some authors assert that the head is smaller, and therefore it is reasonable to apply fewer electrodes to the smaller
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head of the newborn. The opposing view holds that if the neonatal brain is conceptualized as a shrunken version of the adult brain, each lobe, gyrus, and cortical circuit is proportionally smaller, and the electric fields of discharges will be correspondingly smaller, requiring the usual (nonreduced) number of electrodes to achieve the same anatomic resolution of electric fields. Our laboratory uses a full complement of electrodes from the 10-20 system in newborns and even in most premature infants; reduced electrode sets are only used for premature infants with the smallest head sizes. Although reduced (double-distance) electrode applications have been shown to record the majority of normal and abnormal EEG activity and may also be better tolerated by the premature infant whose scalp skin is more sensitive, occasionally a highly focal seizure discharge or other highly focal finding may be missed. In addition, difficulties with artifact identification represent a hidden pitfall of the use of sparser electrode arrays. When a deflection is seen in a single channel, denser electrode arrays help determine whether an electric field surrounds the event, increasing or decreasing the chances that it is of cerebral origin as opposed to an electrical artifact.

Additional leads are applied to help assess sleep state; to some extent, a neonatal EEG recording resembles a polysomnogram. The added leads may include a nasal thermistor to measure respirations, ocular leads (one placed just above the outer canthus of one eye and the other just below the outer canthus of the other eye), and a submental electrode to monitor chin muscle (EMG) activity. Additional leads may include a strain gauge placed on the abdomen to record respiratory muscle effort and limb leads to document movements. Notations made by the recording technologist on the EEG record should also carefully document the appearance of the baby. Notations such as “appears asleep,” “has hiccups,” “feeding,” “eyes closed,” or “moving” help the reader assess sleep state and evaluate artifacts (see Figure 13-3).

Traditionally, newborn EEGs have been recorded at “half” paper speed (15 mm/sec). Although this practice may have originally been motivated in part by the urge to save paper on long recordings, the compression of the EEG resulting from slow paper speeds can make it easier to identify some discontinuous or bursting patterns, both normal and pathological. Certain delta patterns are easier to appreciate when displayed at slow paper speeds. For these reasons, slow paper speeds are still preferred by many readers for review of newborn EEG recordings. Ideally, a neonatal EEG record should include all stages of sleep—wakefulness, quiet sleep, and active sleep—which often requires recording times over 1 hour to allow assessment of sleep architecture.

A “QUICK TOUR” OF THE MAJOR NEONATAL EEG SLEEP STAGES

Similar to the “quick tour” of the adult EEG shown in Chapter 2, “Visual Analysis of the EEG,” what follows is a brief overview or “tour” of the main sleep stages of the

Figure 13-1  A T2-weighted magnetic resonance imaging scan of the brain of a normal baby at 31 weeks CA shows the relatively smooth appearance of the cortical surface and the rudimentary gyral pattern seen at this gestational age. The small amount of cerebrospinal fluid over the surface of the hemispheres appears white in this sequence. Prematures between 24 and 30 weeks CA have an even less developed cortical folding pattern.

Figure 13-2  A T1-weighted magnetic resonance imaging scan of a term baby (40 weeks CA) shows a significant increase in the complexity of the gyral pattern compared with the 31 week CA brain shown in the previous figure. At term, the complexity of the cortical gyral pattern approaches that of the adult pattern. The cerebrospinal fluid over the brain surface appears dark in this scan sequence. This scan also shows a subgaleal hematoma over the right parietal area (arrow). The white signal encircling the head represents scalp fat rather than bone; this scalp hemorrhage lies outside the bony cranium. Such extra-axial collections may decrease the recorded voltages over affected areas.
newborn EEG and also how the technique of neonatal EEG recording differs in a few ways from that of older patients. Because the appearance of the newborn EEG evolves considerably through prematurity and approaching term, no single tracing can demonstrate all of the key findings.

In children and adults, the appearance of the EEG itself more or less defines sleep state. In newborns, however, one EEG background may be associated with several sleep states, and individual sleep states are associated with a variety of EEG backgrounds. Information from polysomnographic channels and behavioral observations are often necessary to define the current sleep state. We start by reviewing the five main background patterns of the newborn EEG, followed by the three main newborn sleep stages and how the described background patterns relate to the different sleep stages.

THE FIVE COMMON EEG BACKGROUND PATTERNS SEEN IN NEWBORNS

The features that we are most accustomed to seeing in the waking and sleep EEGs of older patients, such as the posterior rhythm, sleep spindles, and vertex waves, are not seen in newborns. Rather, specific types of EEG background patterns and elements are seen at different stages of maturity. These five principle EEG background patterns were originally described by the “French School” of neonatal electroencephalography. Although this system has not remained in common usage in all laboratories, it remains a useful construct for interpreting and describing neonatal EEGs. Inherent to the categorization of EEG backgrounds into these five groups is both the benefits and disadvantages of simplification, trading off ease of use with the problem of loss of nuance, in addition to the inevitability of encountering patterns that may not easily fit into one of the proscribed categories. Nevertheless, this system works surprisingly well, especially for normal or near-normal newborn EEGs near term. Additional characteristic waveforms that appear at specific CAs and are superimposed on these patterns, referred to as EEG graphoelements, are described later.

Normal neonatal EEG background patterns may be either continuous or discontinuous. The first step in classifying a background pattern is assessment of the degree of continuity. A discontinuous pattern is a pattern in which EEG activity seems to alternately “turn on” and “turn off” for varying amounts of time. In a continuous pattern, there are no recognizable
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regional pauses in activity (see Figure 13-4). The first three background patterns described here are continuous patterns, and the final two patterns are discontinuous patterns.

**The Low-Voltage Irregular Pattern**

As the name implies, this pattern consists of continuous low-voltage irregular (LVI), mixed frequencies, with delta and theta activity most prominent. Voltages generally range from 15 to 35 μV. An example is shown in Figure 13-5. As described later, the LVI pattern is seen during both wakefulness and active sleep. The LVI pattern is not expected to be seen during quiet sleep.

**The Mixed (M) Pattern**

The M pattern is similar to the LVI pattern, but with somewhat higher voltages and a more prominent contribution of slow activity. Continuous mixed frequencies are seen with a mixture of voltages (see Figure 13-6). The M pattern can be seen during any sleep stage. During active sleep, the LVI pattern is most characteristic, but the somewhat higher voltages of the M pattern may also be seen. Similarly, during wakefulness either the LVI or M pattern may be seen. In quiet sleep, the tracé alternant and high-voltage slow (HVS) patterns (described next) are most characteristic, but the M pattern may also be seen. Because it is possible to see the M pattern in any stage of wakefulness or sleep, polysomnographic findings and observed behaviors are key to correct determination of sleep stage.

**The High-Voltage Slow (HVS) Pattern**

The HVS pattern is characteristic of quiet sleep; it only rarely makes an appearance in other sleep stages. Like the LVI and M patterns, the HVS pattern consists of continuous, irregular mixed frequencies, but with higher voltages (50–150 μV). Delta frequencies are more prominent (see Figure 13-7). As described below, discontinuous patterns (tracé discontinu and tracé alternant) are the primary patterns of quiet sleep from the earliest post-conceptional stage to 38 weeks CA. As the baby gets closer to term, the tracé alternant pattern is replaced by the HVS pattern.

The LVI, M, and HVS patterns all consist of continuous irregular, mixed frequencies. The main distinguishing feature among these three continuous patterns is voltage.

**The Tracé Discontinu Pattern**

The tracé discontinu pattern (French for “discontinuous tracing”) is a pattern of early prematurity, seen primarily at 30 weeks CA and before. As the name implies, tracé discontinu is a highly discontinuous pattern consisting of very high voltage polymorphic...
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Figure 13-5 An example of a low-voltage intermixed (LVI) pattern is shown, with relatively nondescript mixed frequencies. The LVI EEG pattern is characteristic of both wakefulness and of active sleep. The triangular deflections seen in the top (ocular) channel represent rapid eye movement sleep (dots) indicating that this is an example of active sleep. LUE, left under eye; RAE, right above eye.

Figure 13-6 The mixed or “M pattern” is similar to the low-voltage intermixed (LVI) pattern, but with higher voltages. The M pattern may be seen in any of the sleep stages, including wakefulness, quiet sleep, and active sleep. Assignment of sleep state when the M pattern is present depends on other recording parameters such as technologist observations and information from the polysomnographic channels.
bursts, often containing large numbers of sharp features that may even resemble high voltage polyspikes (see Figure 13-8). The dramatic bursts of tracé discontinu are separated by equally dramatic flat periods that may exceed 10 to 20 seconds in length in the most premature babies (see Figure 13-9). Because of its resemblance to burst-suppression, a well-known pathologic pattern in adult EEG, it took some time for neonatal electroencephalographers to confirm that this was a normal pattern of early prematurity.

The Tracé Alternant Pattern

Tracé alternant (French for “alternating tracing”) is the hallmark pattern of quiet sleep in newborns. Tracé alternant is a discontinuous pattern consisting of bursts of mixed activity lasting 2 to 8 seconds with interspersed flatter periods referred to as “interbursts” lasting 4 to 8 seconds (see Figure 13-10). Generally, the bursts and interbursts are of similar duration. The bursts normally contain a variety of activity, including sharp transient activity and also delta brush activity in more premature babies (described later).

When tracé alternant makes its first appearance after the 30 weeks CA, the quiet interburst periods are longer and flatter than at later CAs. Also, early on, the bursts show the least amount of synchrony between the two hemispheres. As the baby approaches term, the tracé alternant pattern evolves in three ways. First, the bursts are not as widely separated (the interburst intervals are shorter). Second, the periods between the bursts evolve from being relatively flat showing only small amounts of activity to showing increasing amounts of activity, so much so that as term approaches, it may become difficult to tell where a burst ends and a quiet period begins. Finally, the degree of interhemispheric synchrony of the tracé alternant bursts increases toward term, although it may never reach complete synchrony. The pattern shown in Figure 13-11 has, indeed, achieved complete synchrony, although this does not always occur. Even after term the degree of interhemispheric synchrony of tracé alternant is never required to exceed 75%, meaning that in normal babies, a small amount of asynchrony may always be seen.

The differences between tracé alternant and tracé discontinu are both qualitative and quantitative. Quantitative differences include longer interburst intervals, more sharp activity within bursts, and near complete synchrony in tracé discontinu compared with tracé alternant. Qualitatively, in tracé discontinu the interburst intervals are expected to be essentially flat, whereas varying amounts of continuous activity are expected during the interburst intervals of tracé alternant. Between 30 and 34 weeks CA, the evolution of tracé discontinu to tracé alternant during quiet sleep occurs on a continuum.

Figure 13-7  This segment of high-voltage slow (HVS) pattern was obtained during quiet sleep in a term newborn. Voltages are higher than were seen in the previous two patterns, but frequencies remain mixed and the waves are irregular. The HVS pattern is particularly associated with quiet sleep.
Figure 13-8 When first encountered, the tracé discontinu pattern may appear highly abnormal to the reader accustomed to interpreting adult EEGs. High-voltage bursts containing large amounts of polymorphic activity, often very sharp as in this example, are seen synchronously in both hemispheres. The bursts are separated by quiet periods of varying duration. LUE, left under eye; RAE, right above eye.

Figure 13-9 In this example of tracé discontinu the interburst periods are particularly lengthy; note the time scale at the bottom of the figure. The plentiful spikes seen within the bisynchronous bursts are considered a normal feature of the tracé discontinu pattern. At the earliest CAs, the flat periods between bursts can be quite lengthy, sometimes exceeding 20 seconds. LUE, left under eye; RAE, right above eye.
Figure 13-10 The distinctive, discontinuous pattern of tracé alternant is shown. In this example (A), most of the bursts are bisynchronous with bursting activity and suppressions occurring in each hemisphere more or less at the same time. Some amount of asynchrony is noted, however. The lower panel (B) shows the same page of EEG as was shown in Panel A, now with shading marking the approximate beginning and end of each burst. Note each burst contains a fair amount of sharp activity. The regular respirations and lack of eye movements confirm that this is an example of normal quiet sleep.
The Evolution of Interhemispheric Synchrony

In contrast to tracé alternant, the tracé discontinu pattern is almost completely synchronous between the hemispheres. This leads to a distinctive sequence in the evolution of interhemispheric synchrony through the weeks of prematurity. In the most premature babies, there is nearly complete interhemispheric synchrony, and the tracé discontinu pattern persists (up to about 30 weeks CA). When the tracé alternant pattern first appears (at approximately 30 weeks CA), the pattern is initially significantly asynchronous. This is followed by a gradual return of interhemispheric synchrony as the tracé alternant matures as the baby approaches term. Therefore the EEG is synchronous in early prematurity, becomes moderately asynchronous in “middle” prematurity, and becomes synchronous again near term.

SLEEP STAGES IN THE NEWBORN NEAR TERM

The three main sleep stages of the newborn near term are active sleep, quiet sleep, and wakefulness. Fundamentally, the concept of “asleep” is defined by the outward appearance of the baby, with clinical sleep considered a state of persistent eye closure and wakefulness of eyes open.
Active Sleep

During active sleep, the baby is seen to squirm, grimace, and have an agitated appearance, yet the eyes are closed. In fact, the movements may lead an observer to think that the baby is on the verge of waking up. Respirations are irregular, and occasional respiratory pauses may be seen. Rapid eye movements of sleep are seen, both on the eye channels of the EEG and by casual observation of the baby’s eyelids; movements of the corneal bulge can be seen through the baby’s eyelids. The chin EMG lead picks up phasic bursts of muscle activity that correspond to facial muscle movements, such as grimacing or other movements. However, in between facial movements, chin EMG activity is low. The EEG shows an LVI pattern that is similar to what is seen during wakefulness (see Figure 13-12). Although most active sleep stages are typically associated with an LVI pattern, the first period of active sleep occurring as a baby falls asleep may show a somewhat higher voltage EEG pattern compared with later active sleep stages, such as an M pattern.

Active sleep in neonates is analogous to REM (dream) sleep in children and adults, although there are two interesting distinctions. First, although older subjects experience a form of paralysis during dream sleep, presumably so that dreams are not physically acted out, as the name implies, babies move actively during active sleep. Second, whereas the first REM sleep stages typically start only after a considerable time asleep in children and adults, newborns enter active sleep as their first sleep stage at the time of transition from wakefulness to sleep. REM sleep at sleep onset is not expected in adults, except in patients with narcolepsy in whom this phenomenon is one of the hallmarks of the syndrome.

Quiet Sleep

The term quiet sleep derives from the quiet appearance of the baby during this sleep stage. Respirations are deeper and regular, and there are few, if any, limb movements. Outwardly, the baby appears to be in a deep sleep state. REMS are not seen (see Figure 13-9). The chin EMG lead, perhaps surprisingly, shows a high level of tonic muscle activity, with comparatively more EMG activity than is seen between body movements in active sleep. After term, quiet sleep evolves into slow-wave sleep.

The EEG pattern seen during quiet sleep before term is the distinctive tracé alternant pattern, a discontinuous pattern over each hemisphere with periods of high-voltage mixed activity followed by periods of relative quiescence. As the baby approaches term, an HVS pattern gradually replaces the tracé alternant pattern during quiet sleep stages. During this transitional period, which occurs during the weeks just before and after term, some babies manifest an HVS pattern at the
beginning of a quiet sleep epoch, which may then transition to a tracé alternant pattern with deepening quiet sleep within the same epoch.

**Wakefulness**

In wakefulness, the baby’s eyes are open and the activity level may vary considerably, from relaxed wakefulness (often seen just after feeding) to states of considerable agitation and crying. Breathing can be mildly irregular when the baby is calm to very irregular when the baby is more active. Recorded eye movements are irregular and include voluntary tracking and searching movements. These searching movements during wakefulness are usually easy to differentiate from REMS of active sleep which are faster and are more prominent to the horizontal plane.

The EEG pattern during wakefulness usually consists of an LVI pattern that may include a large amount of superimposed motion artifact depending on the baby’s level of activity (see Figure 13-13). A somewhat higher voltage, M pattern may also be seen. The EEG patterns seen during wakefulness can be quite similar to those seen during active sleep, and at times it can be difficult for the reader to determine whether a page of EEG represents active sleep or wakefulness. This distinction is usually not difficult to make for the EEG technologist who is directly observing the baby and knows whether the baby’s eyes are open or closed, the key factor in making the distinction. This situation highlights the importance of the technologist making frequent observational notes while recording newborn EEGs.

**Transitional Sleep and Indeterminate Sleep**

For completeness’s sake, two additional sleep states are defined. The term *transitional sleep* is used for periods when the EEG transitions from one sleep state to another, including elements of both. Some babies spend a considerable amount of time in these transitional states. The term *indeterminate state* is used for stages that cannot be assigned clearly to any of the aforementioned groups.

Table 13-1 summarizes the features of the three main sleep states of the newborn after they have become well differentiated.

**TYPICAL EVOLUTION OF NEONATAL SLEEP STAGES NEAR TERM**

**Sleep State Cycling in the Newborn**

Typical sleep state cycling is depicted thus (W = wakefulness, AS = active sleep, QS = quiet sleep):

\[ W \rightarrow AS \rightarrow QS \rightarrow AS \rightarrow QS \rightarrow AS \rightarrow W \]

Figure 13-13  A page of wakefulness is shown with the EEG showing an M pattern. The technologist’s observation that the baby’s eyes are open and the moderate amount of muscle and motion artifact imply wakefulness. Eye movements are seen in the eye channel (labeled “LUE-RAE”), however they do not clearly have the classic “sharp” or triangular morphology of horizontal rapid eye movement sleep and likely represent voluntary or searching eye movements.
Active sleep is usually the first sleep stage on falling asleep followed by quiet sleep. Periods of active sleep and quiet sleep then alternate until the next waking period. Periods of transitional sleep that may include the features of both sleep states may be interposed between well-defined active sleep and quiet sleep epochs. Newborns normally sleep for as many as 20 hours out of a 24-hour day. Each complete sleep cycle lasts approximately 60 minutes but with wide variation. Typically, newborns spend about half of their sleep time in active sleep and half in quiet sleep. The fraction of sleep time spent in dream sleep decreases with age; adults spend only about 20% of the night in REM sleep.

After remaining in active sleep for approximately 20 to 25 minutes, if the baby remains asleep, a transition to quiet sleep is expected. The changes associated with the transition from active sleep to quiet sleep are more dramatic than those associated with transition from wakefulness to active sleep. First, as the baby’s sleep quiets, muscle and motion artifact disappear from the record. The respiratory pattern becomes very regular, and eye movements are rare. A tracé alternant pattern then appears (or HVS in infants closer to term). The baby thereafter alternates between quiet sleep and active sleep until arousal. Between sleep epochs, brief transitional states may be seen with elements of both types of sleep present at the same time (e.g., irregular breathing accompanying a tracé alternant pattern).

EEG Architecture in More Premature Infants

The orderly sleep structure described in the previous section is a characteristic of infants nearing term. Very premature newborns, however, lack this sleep structure. The earliest EEGs in clinical practice are recorded in babies at 23 to 24 weeks gestational age, which is considered near the limit of viability. In fact, EEGs are only occasionally obtained in such premature infants, partly because of the extreme fragility of their skin but also because seizures are believed to be uncommon at these very early CAs. At these early gestations, the predominant EEG background is tracé discontinu, consisting of bilateral complex bursts separated by prolonged periods of electrical quiescence. The period of electrical quiet may last longer than 20 seconds. Between 24 and 30 weeks CA, there is a tendency for the quiet periods to become shorter and the amount of activity during the interburst to increase. It may come as a surprise to learn that there is no reliable relationship between sleep state and EEG appearance before 30 weeks CA; the tracé discontinu pattern is seen during both wakefulness and sleep, even though periods of wakefulness and sleep are clinically distinguishable.

The Emergence of Continuity

The first state seen with continuous activity in the premature appears at approximately 30 weeks CA. At that time, the continuous LVI or M patterns (with REMs) are first seen during active sleep. Continuous activity during wakefulness first becomes well established at approximately 34 weeks CA. The final sleep stage to manifest continuous activity is quiet sleep. As described earlier, the discontinuous tracé alternant pattern is typically seen during quiet sleep, but at approximately 38 weeks CA the continuous HVS pattern makes its first appearance. During this transition, both tracé alternant and HVS patterns may be seen during quiet sleep at different times in the same baby. Even though the HVS pattern predominates during quiet sleep after term, fragments of the discontinuity related to the tracé alternant pattern may be seen during quiet sleep up to 46 to 48 weeks CA. After 48 weeks CA, any discontinuity in the EEG is considered abnormal. In summary, the EEG first becomes continuous at 30 weeks CA in active sleep, at 34 weeks CA in wakefulness, and at 38 weeks CA in quiet sleep.

AN ORDERLY APPROACH TO NEONATAL EEG INTERPRETATION

The first step in visual analysis of a page of newborn EEG is asking the question, what state is this? As the EEG is sequentially examined from beginning to end, the reader attempts to identify the various sleep states described in Table 13-1: wakefulness, active sleep, and quiet sleep. Do the sleep stages have the expected structure according to the baby’s reported CA? For example, in a baby nearer to term, during wakefulness is there an LVI or M pattern? Often the presence of motion artifact in the tracing and technologist comments confirm that the child is awake and active. As the baby falls asleep, the reader will expect to see a first sleep stage, most likely
active sleep. Because wakefulness and active sleep are both associated with either an LVI or M pattern, the transition may not be obvious based on the EEG alone. Active sleep is marked by closed eyes and the appearance of REMs. After a period of active sleep, does the EEG become discontinuous (tracé alternant)? Does the baby quiet, and do respirations become regular with disappearance of REMs, marking the onset of quiet sleep? The presence of this type of normal sleep architecture is considered a positive clinical sign. Although the absence of expected sleep architecture may be related to CNS pathology, it is important to keep in mind that there are many other possible explanations for disrupted sleep architecture (noises, medications, procedures), especially on hospital inpatient units. In the absence of other explanatory circumstances, the fewer features of normal sleep stage structure noted, the greater the worry of brain pathology.

**EEG GRAPHOELEMENTS**

During the late 1950s and early 1960s, in addition to describing neonatal sleep states, the “French school” of electroencephalography described certain specific waveforms in the normal newborn EEG that appeared and disappeared at specific CAs, calling these features graphoéléments. The concept of EEG graphoelements remains useful. Familiarity with the different neonatal EEG graphoelements and the CAs and sleep states during which they are expected to appear helps the reader “date” the EEG in terms of apparent CA. It also helps to avoid labeling normal elements as abnormal.

**Temporal Sawtooth Waves**

Temporal sawtooth waves are seen in the EEG most prominently between 26 and 32 weeks CA, declining thereafter. They are a hallmark finding of the EEG between 28 and 30 weeks in particular. Temporal sawtooth waves appear as 4- to 6-Hz sharply contoured theta waves of varying voltage seen in each midtemporal area (see Figure 13-14). Because sleep states are not yet well defined at these CAs, they are not particularly associated with a specific state.

**Delta Brushes**

The delta brush is one of the most distinctive waves of prematurity. Delta brushes have also been called beta-delta complexes and ripples of prematurity. They consist of a delta wave with superimposed fast activity that may have a wide range of frequencies, from 8 to 22 Hz (see Figure 13-15). Delta brushes show a predilection for the posterior quadrants (central, temporal, parietal, and occipital areas) and are not often seen frontally.

Delta brushes make their first appearance at 26 to 28 weeks CA at a time when sleep stages are not well differentiated. They are initially seen in the central areas. They reach their peak density in the EEG at about 34 weeks CA, by which time they are also prominent in the occipital areas. When quiet sleep becomes a distinct sleep stage, delta brushes are particularly seen as a part of the tracé alternant pattern of quiet sleep; they are only rarely seen during well-established active sleep or wakefulness. By 39 to 40 weeks CA delta brushes have all but disappeared and should be absent.
by 44 weeks CA. Similarly, by this CA the tracé alternant pattern has been replaced by the HVS pattern during quiet sleep.

**Sharp Transients**

In the wider world of electroencephalography, spikes and sharp waves have the connotation of both being abnormal and associated with seizures. In neonatal electroencephalography, both of these biases must be reversed. First, not only may sharp activity in the EEG be normal, certain sharp discharges are actually expected in newborn EEGs as normal graphoelements. Second, when abnormal sharp activity is seen in newborns, such discharges may be associated with brain injury but not specifically with seizures as they are in older individuals. Therefore even abnormal sharp waves in babies are not considered an epileptiform abnormality. To avoid the negative connotation of the terms “spike” and “sharp wave,” such discharges in the newborn EEG are generally referred to as *sharp transients*.

**Frontal Sharp Transients**

Frontal sharp transients, also referred to by the original French term *encoches frontales*, consist of high-voltage, usually bilateral, frontal sharp waves (see Figure 13-16). They may have a biphasic morphology, and the primary phase
has negative more often than positive polarity. Occasionally unilateral examples are seen, but when one-sided, the number of discharges seen on each side should remain similar. Encoches frontales are seen most often in quiet sleep and are only rarely seen in active sleep or wakefulness; large numbers of frontal sharp transients during wakefulness or active sleep are considered abnormal. These transients first appear at about 34 weeks CA and become less common after term. They should not be seen at all after 48 weeks CA.

**Temporal Sharp Transients**

Temporal, central, or centrotemporal sharp transients with negative polarity occur in normal newborn EEGs and may be seen during both the LVI and higher voltage M, tracé alternant, or HVS portions of the tracing (see Figure 13-17). In fact, such sharp activity is an expected feature of the discontinuous neonatal EEG patterns, tracé alternant and tracé discontinu; sharp activity may be especially plentiful within the bursts themselves. The sharp transients described here are those that occur outside the context of the bursts.

There is probably no lower CA limit of normal for temporal sharp transients. Temporal sharp transients are a particularly common feature of the newborn EEG between 35 and 42 weeks CA. After 44 weeks CA, they are uncommon, and they are considered abnormal after 48 weeks CA.

**The Emergence of Vertex Waves and Spindles**

Sleep spindles appear in the EEG between 6 and 8 weeks after term (44–46 weeks CA), and vertex waves of sleep follow soon after at 8 weeks or thereafter. During infancy and up to 18 to 24 months of age, there is a tendency for sleep spindles to occur asynchronously over each hemisphere. After 2 years of age, sleep spindles occur synchronously over both hemispheres. During the transitional stage between spindle asynchrony and synchrony during the second year of life, the spindles may be asynchronous in light sleep but become more synchronous as Stage II sleep deepens. Spindle duration tends to be longer in infants (several seconds) and shortens toward adulthood (approximately 2 seconds).

**When Are Sharp Transients in the Temporal, Frontal, and Other Areas Considered Abnormal?**

Establishing strict criteria of normality for neonatal sharp transients that occur outside of tracé alternant bursts has not been easy. It has already been stated that some amount of frontal and temporal sharp transient activity should not just be “passed” as normal but is actually an expected feature of the newborn EEG. However, it has been shown statistically that abnormal babies manifest higher numbers of sharp transients than do normal babies. This pair of facts suggests that there may be some specific upper limit to the number of sharp transient activity a baby may have beyond which a tracing should be considered abnormal. An exact limit, however, has been difficult to define. As readers of neonatal EEGs gain experience, they become accustomed to the number of sharp transients that are usually seen in a newborn record, giving a benchmark against which to decide how many is “too many.” One sharp transient per minute has generally been considered to be clearly within the normal range, though exceeding this frequency by some amount is not necessarily considered abnormal. When it is felt that a tracing clearly shows too much sharp transient activity, the abnormality is referred to as “excess neonatal sharp transients.” The reader must take care not to be overly aggressive in calling neonatal EEG tracings abnormal solely on the basis of the abundance of these discharges, keeping in mind that a baseline number of these transients is considered completely normal.

Normal neonatal sharp transients can probably be seen in any brain area, although there is a tendency for transients to be more widely distributed at earlier CAs and to concentrate in the central, temporal, and frontal areas nearer term. Transients seen in the midline electrodes are more often associated with abnormality.

**Other Features of Abnormal Sharp Transients**

Apart from the frequency of their appearance, certain other features are felt to mark sharp transients as abnormal. These include very high voltage (>150 μV), asymmetrical appearance (considerably more on one side than the other), polyphasic rather than the usual monophasic or diphasic morphology, repetitive discharges in one location, and, sometimes, positive polarity (discussed later). Certain locations are felt to have a higher association with abnormality than others. Sharp transients occurring in the midline, such as at the Cz electrode, are more often seen in abnormal babies. Some authors feel occipital sharp transients are abnormal, but others do not. When a sharp transient is deemed abnormal, it is felt to mark a nonspecific brain injury rather than an epileptiform abnormality. Figure 13-18 shows excessively repetitive sharp transients in the left temporal area of a baby who experienced a stroke in that area.

**Central and Temporal Positive Sharp Waves**

When first described, central positive sharp waves in newborns were felt to be strongly associated with intraventricular hemorrhage (IVH). These central positive sharp waves are now understood to be associated with multiple disorders; however, they are particularly characteristic of injury to the deep white matter structures in premature infants, including IVH and periventricular leukomalacia. The positive polarity of such sharp waves is indicated by the distinctive phase reversal seen in bipolar montages in which the peaks of the sharp wave point away from (rather than toward) each other (see Figure 13-19). Temporal positive sharp waves have...
Figure 13-16 A single frontal sharp transient is seen (arrow) in this double-distance montage.

Figure 13-17 A temporal sharp transient is seen, maximum in the T7 electrode (arrow). Normal temporal sharp transients usually occur singly, are of low to moderate voltage and should be seen to the same extent over each temporal lobe throughout the record. (Image courtesy of Dr. Sanjeev Kothare.)
Figure 13-18  Multiple sharp transients are seen over the left hemisphere (dots) but not over the right. Although not of particularly high voltage, the repetitive and asymmetric nature of these transients marks them as abnormal. This baby experienced a stroke in the left hemisphere.

Figure 13-19  A positive sharp wave is noted in the right midtemporal area with a positive phase reversal seen in T4 (arrow). Neonatal positive sharp waves have been associated with deep white matter lesions.
also been associated with IVH and hypoxic-ischemic injury in the past; however, they have also been described in normal infants, possibly related to the sharp temporal theta discharges (sawtooth waves) that have already been described.

BACKGROUND ABNORMALITIES OF THE NEONATAL EEG

Of all the parameters that can be examined with regard to the neonatal EEG, the feature most predictive of a baby’s final developmental outcome is the EEG background. The topic of neonatal EEG background was comprehensively reviewed by Holmes and Lombroso (1993). Various background abnormalities encountered in the neonatal EEG are described next, generally in order of decreasing severity.

Electrocerebral Inactivity and Voltage Depression

Electrocerebral inactivity (ECI) implies a complete lack of electrical activity recorded from the brain. The term should be reserved for recordings that have been performed with stringent technique (The proper recording techniques for possible ECI tracings and the concept of brain death are discussed in more detail in Chapter 12, “EEG Patterns in Stupor and Coma,” but are summarized here as they pertain to newborns). Recording technique includes the use of double-distance electrodes, proper electrode impedances, confirmation that the EEG apparatus is connected properly by tapping the individual electrodes, and that the baby has received noxious stimulation to try to elicit EEG activity. The tracing must be of adequate duration and the cutoff frequency for the low filter should be set adequately low ($\leq 1$ Hz). Sensitivities of 2 $\mu$V/mm should be used, at least for a portion of the tracing. At such high amplifier gains, it can sometimes be difficult to distinguish true brain wave activity from electrical artifact. Synonyms for ECI include electrocerebral silence and “isoelectric” EEG (see Figure 13-20).

Note that the presence of an ECI tracing is not equivalent to the diagnosis of brain death. The diagnosis of brain death must be backed up by multiple elements of the neurologic examination and sometimes by specific types of neuroimaging; the specific legal definition used to declare brain death depends on the jurisdiction and is particularly difficult to apply in the case of newborns. It should not be surprising that an EEG showing ECI is not equivalent to brain death. The scalp-recorded electroencephalogram records electrical activity from the cortical surface, but the diagnosis of brain death implies complete inactivity of both the brain surface and deeper brain structures, such as the brainstem (medulla, pons, and midbrain), structures that are distant from scalp EEG electrodes. In fact, in most settings, an EEG recording is not absolutely required to establish the diagnosis of brain death.

![Figure 13-20](image-url) This page of EEG shows absence of any definite electrocerebral activity in an asphyxiated newborn. At the high amplifier gains used for such recordings, artifacts may become prominent in the tracing. In this example, the low-voltage electrocardiogram artifact noted in several channels would not be mistaken for brain waves because of its rhythmic, monomorphic features.
Not infrequently, the reader will encounter an EEG in which no definite electrocerebral activity can be identified but that has not been recorded with the strict technique described here and in Chapter 12, "EEG Patterns in Stupor and Coma." Such tracings may be described as "flat" or as showing "no definite electrocerebral activity," but in these cases, the more absolute designation of ECI should not be used. In such cases, the report should also indicate that the strict technique necessary to make a diagnosis of ECI was not used for the recording.

Of course, when the diagnosis of ECI is made, the lack of electrocerebral activity must persist throughout the whole tracing, and the recording must be of sufficient duration. It is important to note that some babies experience a complete but transient suppression of EEG voltages after a seizure. The EEG tracing may similarly flatten and recover after a transient hypoxic-ischemic insult. In such cases of transient flattening, however, the EEG only remains flat for several minutes, and activity in such cases should be seen to recover soon after. Occasionally, a seizure may have occurred by chance just before a recording was started, and the fact that observed voltage suppression is a postictal change is not obvious. In such cases, some electrical activity should return after several minutes. Rarely, high levels of sedative agents may also flatten the EEG.

The large majority of babies with an ECI pattern have a poor neurologic outcome, including death and severe disability. The longer the pattern persists, the more certain the poor prognosis.

Voltage depression in the form of low voltage, invariant patterns are also associated with a poor neurologic prognosis, but the outcome is somewhat more variable. In such records, voltages are persistently less than 20 µV and sleep cycling cannot be discerned (see Figure 13-21). When serial EEG studies document improvement in the pattern, the prognosis may also be improved.

Apart from suspecting widespread cortical damage as the explanation for low-voltage records, the electroencephalographer must consider other possible explanations. These include causes of diffuse scalp swelling, such as caput succedaneum or extensive subgaleal hematomas and extra-axial fluid collections, such as subdural hematomas or hygromas or pus collections.

**Burst-Suppression Patterns**

Burst-suppression patterns consist of high-voltage bursts across the brain, in some patients bilaterally synchronous and in others interhemispherically asynchronous. The bursts are separated by flat periods (see Figures 13-22, 13-23, and 13-24). Generally, burst-suppression patterns are persistent (i.e., they are not governed by a sleep-wake cycle), and they are not responsive to outside stimuli. The diagnosis of burst-suppression in the neonate is made considerably more difficult because the normal discontinuous patterns in very premature newborns, tracé discontinu and tracé alternant, bear some resemblance to burst-suppression. It is usually not difficult to distinguish burst-suppression from tracé...
alternant, a pattern that has more interburst activity and that may include normal forms such as delta brushes. Tracé alternant should not be invariant. In fact, any pattern that cycles on and off should not be labeled burst-suppression, which is typically a monotonously persistent pattern. Tracé discontinu can be more difficult to distinguish from burst-suppression in very preterm infants. The diagnosis of burst-suppression in this conceptional age group should only be made with hesitation and should be confirmed by serial recordings. So-called “permanently discontinuous” patterns probably represent a variant of burst-suppression.

With some exceptions, burst-suppression is associated with a dismal neurologic outcome. Babies who show improvement on a 1-week follow-up EEG tend to do considerably better than those who do not. Aside from being associated with hypoxic-ischemic or hemorrhagic injury, a burst-suppression pattern is also the hallmark finding in several epileptic syndromes of infancy, including early myoclonic encephalopathy, early infantile epileptic encephalopathy, and pyridoxine-dependent seizures (these disorders are discussed in more detail in Chapter 10 “The EEG in Epilepsy”). High therapeutic levels of barbiturates may also contribute to the appearance of a burst-suppression pattern in newborns, but this effect is probably not common.

**Electrographic Seizure Activity**

The presence of electrographic seizure discharges in the EEG background is generally considered an ominous prognostic sign; however, newborns who manifest seizure activity can be divided into different prognostic groups. The most distinctive of these groups is the newborn with repetitive seizures arising from the same location. Unilateral seizures are highly suggestive of a focal lesion, such as neonatal stroke or cerebral dysgenesis. The prognosis in these babies depends on the nature of the underlying lesion.

Among those children with seizures arising from both hemispheres, children who only manifest sporadic seizure activity, as a group, have a better prognosis than those who have unremitting electrographic seizure activity (electrographic status epilepticus). In severely asphyxiated babies, continuous electrographic seizure activity may even progress to an ECI pattern, although some babies may show considerable improvement. Most babies with continuous seizures on EEG do not survive or do poorly.

**Amplitude Asymmetries**

When a persistent amplitude asymmetry is seen, the extra-axial causes of voltage asymmetry listed earlier (such as fluid collections in the various extra-axial spaces) should be excluded by the clinician. Asymmetries of 25% or more are generally considered significant. It is good practice to confirm a potential voltage asymmetry with a referential montage. Large voltage asymmetries may be caused by strokes, hemorrhages, or cerebral dysgenesis. Marked asymmetries may be associated with a poor prognosis, which is usually a function of the underlying lesion.

Generalized slowing and focal slowing are uncommon findings in newborn EEGs. The impression of focal slowing over one hemisphere may actually represent a voltage asymmetry, and the possibility that it is
This unremitting burst-suppression pattern differs from the previous example in that the bursts occur asynchronously over each hemisphere. The lack of sleep cycling, either clinical or electrographic, during the rest of this recording confirms that this is a burst-suppression pattern rather than a normal sleep pattern.

A summary of the background patterns and EEG graphoelements is shown according to CA. Note that the tracé discontinu pattern is seen in all sleep stages before 30 weeks CA, before which differentiation between wakefulness and sleep can only be made on the basis of the baby’s clinical appearance and specific sleep stages are hard to differentiate. The continuous background patterns, LVI, M, and HVS, are highlighted in lighter blue to emphasize the stages during which continuous activity is seen. HVS, high voltage slow; LVI, low voltage irregular; M, mixed pattern; TA, tracé alternant; TD, tracé continu.
the opposite side that is abnormal because of low voltage should also be considered.

When amplitude asymmetries are transient, they may not be clinically significant. An unusual example of asymmetry is seen in premature in whom one hemisphere may appear to “fall asleep” by attenuating before the other. This relatively uncommon phenomenon should only be seen once in a recording, in which case it is not considered abnormal.

Abnormal Sleep Architecture

It is difficult to appreciate sleep architecture abnormalities until 34 weeks CA. Sleep structure abnormalities range from a complete lack of sleep cycling to more subtle disruptions in expected sleep patterns. In many EEG records with abnormal sleep structure, the normal sleep architecture may be only one of many abnormalities present, and the coexisting abnormalities may have more prognostic significance. Abnormal sleep structure as a sole finding may have other possible explanations, such as sleep interruptions related to the intensive care unit environment, administered medications, and so forth. Furthermore, lack of normal sleep cycling as a sole abnormal finding will often improve by the time of a follow-up tracing. Therefore this is considered one of the milder background abnormalities, and many babies whose only EEG abnormality is abnormal sleep structure will eventually do well. Conversely, in a baby for whom there is worry of significant neurologic injury, the presence of normal sleep cycling can be considered a reassuring sign.

Immature Patterns and EEG Dysmaturity

The array of EEG sleep patterns and graphoelements described earlier allows the reader to estimate the CA of an individual to within approximately two weeks. Note is made of which sleep states are continuous or discontinuous, the presence of various EEG graphoelements, and the degree of interhemispheric synchrony, as described earlier. The duration of interburst intervals and the amount of activity present during interbursts may also provide clues as to CA. When the CA estimate based on the history and examination does not match the CA suggested by the EEG, it is worthwhile to reexamine the baby’s clinical gestational age assessment. When the clinically derived CA seems secure but significantly exceeds the CA suggested by the EEG, this is referred to as EEG dysmaturity or simply as an immature pattern.

Immature patterns represent a nonspecific abnormality and are considered to be among the mildest background abnormalities. The EEG should be more than 2 weeks “dysmature” before clinical significance should be presumed. Examples of EEG dysmaturity could be a tracing of a 38-week CA baby that still shows copious delta brush activity (as might be seen at 34 weeks) or excessively asynchronous tracé alternant patterns near term (a stage by which the pattern should have become nearly completely synchronous). Babies whose only EEG abnormality is an immature pattern are presumed to have sustained a mild and possibly reversible neurologic insult, and a large number of such babies are neurologically normal at follow-up. A summary of sleep stage patterns and EEG graphoelements is shown in Figure 13-25.

ELECTROGRAPHIC SEIZURE DISCHARGES

Because many newborn EEGs are obtained with the goal of excluding or confirming the presence of seizures, the EEG reader is frequently called on to assess the EEG tracing for seizure activity. In contrast to the EEGs of older children and adults, the background of the normal newborn EEG contains little rhythmic activity. Familiar rhythmic forms such as the posterior rhythm and sleep spindles seen in the EEGs of older individuals have not yet appeared in the newborn EEG. The main continuous EEG background patterns of newborns, LVI, M, and HVS, consist of irregular activity; the discontinuous patterns of tracé discontinu and tracé alternant have even less of a tendency toward rhythmicity. Except in rare examples, as discussed subsequently, electrographic seizure activity in newborns consists of rhythmic activity. This fact makes identification of neonatal seizures considerably easier. Any rhythmic activity of sufficient duration in the newborn EEG is suspect. Although the discharge duration required by others to declare a rhythmic discharge an electrographic seizure has varied, an 8-second lower limit for ictal rhythmic discharges in neonates is reasonable.

Typically, neonatal seizure discharges consist of rhythmic waves in a focal distribution, sometimes with sharp features and sometimes not. The morphology of the discharge can range from repetitive sharp waves, spikes, or even polyspikes, to a rhythmic sinusoidal pattern (see Figure 13-25). In some cases the discharge can be so focal as to be confined to a single electrode (see Figure 13-26) but even the most focal discharge will usually affect other electrode contacts throughout its course. During its evolution, a neonatal seizure discharge may migrate from one location to another in the involved hemisphere and may also appear to “spread” to the opposite hemisphere as in Figure 13-27, although an independent, simultaneous onset in the opposite hemisphere may also explain this appearance. Neonatal seizure discharges generally fire at a rate of 1 to 3 Hz and occasionally faster, although it is more common for seizure discharges to fire at the lower end of this range. Especially when the discharge is accompanied by clonic activity, the rate of the jerking is usually nearer one per second than the top end of this range.

It is said that newborns cannot have truly generalized seizures, and this is probably the case. For instance, generalized spike-wave discharges are not seen in the newborn. Presumably the cortical circuitry of very young
Figure 13-25  An electrographic seizure discharge is seen in the left temporal area, maximum in the left midtemporal electrode (T3). In this example, the discharge consists of a repetitive polyspike rather than a rhythmic sharp wave or slow wave. The discharge begins at the beginning of the first page (A) and increases in amplitude and complexity throughout its course (B).
bodies is not organized in a fashion capable of mounting generalized discharges. Mimics of generalized discharges can occur, however. In some cases, a baby may have a seizure discharge ongoing in both hemispheres at once. In many such cases, the discharges are not truly synchronous and the discharges are actually bilateral but independent (see Figure 13-28). Clinically, a seizure is occasionally seen with bilateral extremity jerking, suggesting a generalized discharge. In some such cases, the EEG may show a unilateral discharge in which the outflow causes bilateral synchronous limb movement, although the movements may be of different intensity on each side. In other cases, close inspection reveals that the jerking movements are not synchronous but bilaterally independent.

Neonatal seizures that consist of nonrhythmic discharges occur more rarely. For instance, high-voltage single generalized polyspikes may result in whole body myoclonic jerks. Tonic seizures and clonic seizures in newborns are usually associated with rhythmic seizure discharges.

**CLASSIFICATION OF NEONATAL SEIZURES**

The neonatal seizure classification system in most common use today was described by Volpe (see Table 13-2). This 1989 classification includes subtle seizures, clonic seizures (focal and multifocal), tonic seizures (focal and generalized), and myoclonic seizures (focal, multifocal, and generalized).

**Types of Clinical Seizure Activity and Their Relationship to EEG Seizure Discharges**

The clinical diagnosis of seizure activity in newborns is not straightforward, especially for the “subtle” category of seizure manifestations because not all apparent clinical seizure behaviors described in the classification are consistently accompanied by an electrographic seizure discharge. The odds that an apparent clinical seizure event is associated with an EEG seizure discharge depends on the type of behavior observed.
Not surprisingly, simultaneous video/EEG recordings of babies at risk for seizures have shown that clonic activity is highly correlated to electrographic seizure activity. In contrast, whole body tonic stiffening, a dramatic clinical behavior that resembles the tonic phase of tonic-clonic seizures in older subjects, does not have a strong association with EEG seizure discharges in newborns. Whole body stiffening may actually represent nonepileptic posturing in the setting of CNS dysfunction or perhaps a brainstem release phenomenon in a baby in whom cerebral cortex is not able to carry out its usual role in suppressing such behaviors. Focal limb tonic stiffening, however, is highly correlated with EEG seizure activity. Focal and multifocal myoclonic jerks are usually nonepileptic, but generalized myoclonic jerks have a higher rate of association with seizure discharges on the EEG (see Mizrahi and Kellaway).
The most important difference between the 1989 neonatal seizure classification and the International League Against Epilepsy (ILAE) seizure classification used for older children and adults is the addition of the somewhat controversial category of “subtle seizures.” Subtle seizures described in neonates include movements such as “swimming,” “boxing,” or “hooking” movements of the upper extremities; “bicycling” movements of the lower extremities; orobuccolingual movements such as sucking or lipsmacking, eye opening, or complex eye movements; and pure apneas. Controversy has arisen regarding this family of behaviors as they are frequently not associated with a concurrent EEG seizure discharge. Therefore, the epileptic nature of these “subtle seizure” behaviors has not been firmly established, and many may represent the

<table>
<thead>
<tr>
<th>Clinical Seizure</th>
<th>Association With Electrographic Seizures</th>
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<tbody>
<tr>
<td>Subtle</td>
<td>Variable</td>
</tr>
<tr>
<td>Clonic</td>
<td>Common</td>
</tr>
<tr>
<td>Focal</td>
<td>Common</td>
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<tr>
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<td>Tonic</td>
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<td>Focal</td>
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<td>Generalized</td>
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<td>Myoclonic</td>
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<td>Focal, Multifocal</td>
<td>Common</td>
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<tr>
<td>Generalized</td>
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Adapted from Volpe, 1989.
unmasking of automatic reflex behaviors at times when the cerebral cortex is unable to suppress these reflex sequences. This question is of considerable importance because if these behaviors are nonepileptic, they would not require specific treatment with antiseizure medications. The clinical picture of newborns with subtle seizures becomes even more complicated considering that, even if nonepileptic, these behaviors may be the result of cortical injury and may coexist with true EEG seizure discharges occurring at other times in the same baby.

Among these subtle behaviors, apneas are perhaps the most difficult behavior to diagnose correctly. The great majority of apneas in newborns are not related to seizure activity. Occasionally, however, an epileptic seizure may manifest as a pure apnea in a newborn unaccompanied by clear motor or other behavioral change. Whether apneas in the newborn require EEG investigation depends on the clinical context.

REFERENCES


