ANSeR educational support document: Differentiating seizures from false detections.

Introduction

ANSeR (the **A**lgorithm for **N**eonatal **S**eizure **R**ecognition) is a program designed to analyze the EEG of newborn babies in real-time to detect the rhythmic patterns of seizures. Its purpose is to act as a support tool for clinicians to improve early detection of seizures and provide an accurate measure of ongoing seizure burden, such that anticonvulsants can be administered promptly and appropriately.

Seizures have several features but the most distinct is their rhythmicity. Unfortunately there are several types of artifact and other sources that can also create rhythmic patterns and can mimic this aspect of seizures. These artifacts can cause 'false detections'. Consequently when ANSeR makes a 'detection', this should be viewed by the clinician as a prompt to review that segment of the raw EEG. At that point a decision will need to be made as to whether the detection is a true seizure or a false detection.

The purpose of this document is to describe some common features of seizures and false detections to increase the ability of clinicians to differentiate them.

ANSeR

The ANSeR interface is illustrated below in Fig 1. The bottom panel displays the EEG and the upper panel shows the output of ANSeR, a graph of the probability of seizure. When the graph breeches a threshold (the sensitivity of this threshold is currently adjustable), a 'detection' is made, the trace turns from blue to red, an annotation appears in the detection list and the system will alarm.

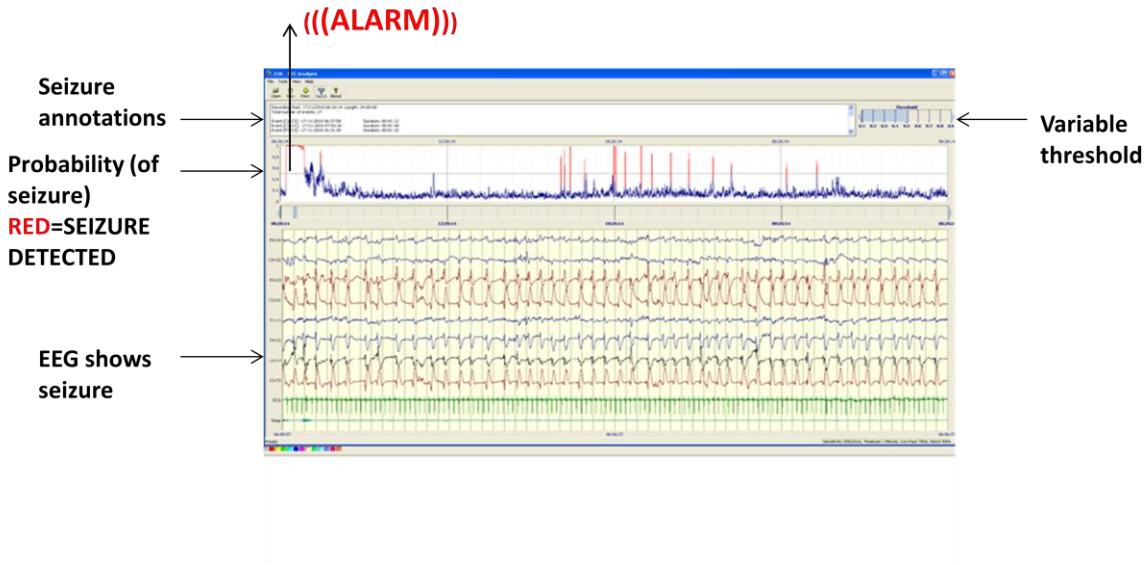


Fig 1. The ANSeR EEG reader and seizure detection output

The EEG at the time of a detection can be checked by dragging the cursor on the time display either to the red portion of the seizure detection trace or by looking at the start time of the seizure in the annotation box and dragging the cursor to that time (time is displayed as you drag).

Neonatal seizures.

Definition

Seizures in neonates are defined as *'sudden, repetitive, evolving stereotyped waveforms with a definite beginning, middle, and end'*(1). To be defined as a seizure a minimum duration of 10 seconds is widely accepted. Discharges of shorter duration are termed 'brief interictal rhythmic discharges' (BIRDs) and are of uncertain significance.For two runs of seizure activity to be considered as separate seizures, a minimum period of 10 seconds of non seizure activity should exist between them.

Seizures in new-born babies tend to be shorter than those in children and adults and for this reason the classification of status epilepticus as exceeding 30 minutes does not apply. A commonly accepted definition of status epilepticus for neonates is more than 30 minutes of seizure activity (not necessarily continuous) in an hour(2).

Recognizing seizures

The majority of neonatal seizures are subclinical with one study showing that 85% of seizures show no clinical signs (3).When clinical signs do occur they **can** include generalized, multifocal or focal clonic limb movements, cycling movements, tonic stiffening, lip smacking or oculomotor signs and/or more subtle physiological signs such as desaturation/apnea, raised blood pressure and tachycardia. However many of these signs may occur in the absence of seizures and repetitive movements such as clonus, jitteriness and tremor can also be mistaken for seizures. Consequently clinical signs are unreliable for seizure detection (4).

The aEEG has been used for seizure detection however studies have shown that up to 50% of seizures may be missed using aEEG(5) and the deflections on the aEEG trace caused by transient artefacts such as movement may cause similar deflections to those during seizures. aEEG is therefore also unreliable for determining seizures.

EEG remains the gold standard for seizure detection.

Morphology

In general terms, on the EEG, neonatal seizures have a tendency to evolve in amplitude,frequency, morphology and propagation (appear at increasing number of electrodes as seizure 'spreads' across brain).This 'evolution' of featuresis one of the clues that can be used to differentiate seizures from other rhythmic artifacts such as respiration and pulse artifact.**N.B.Some seizures show little or no evolution and the absence of the evolving features does not rule out a seizure.**

Amplitude and propagation

The evolution in amplitude and propagation is likely due to progressive recruitment of neurons peripheral to site of seizure onset. Note how the seizure in Fig 2 starts on the left hemisphere (red traces) and spreads to the right hemisphere (blues traces) with time and increases in amplitude as the seizure progresses.

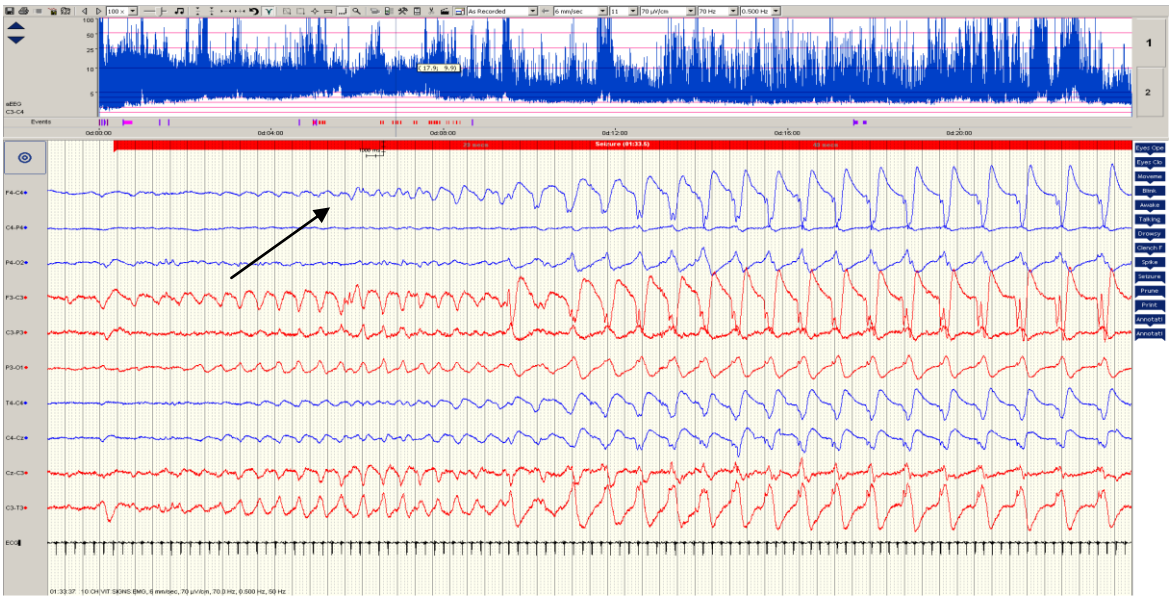
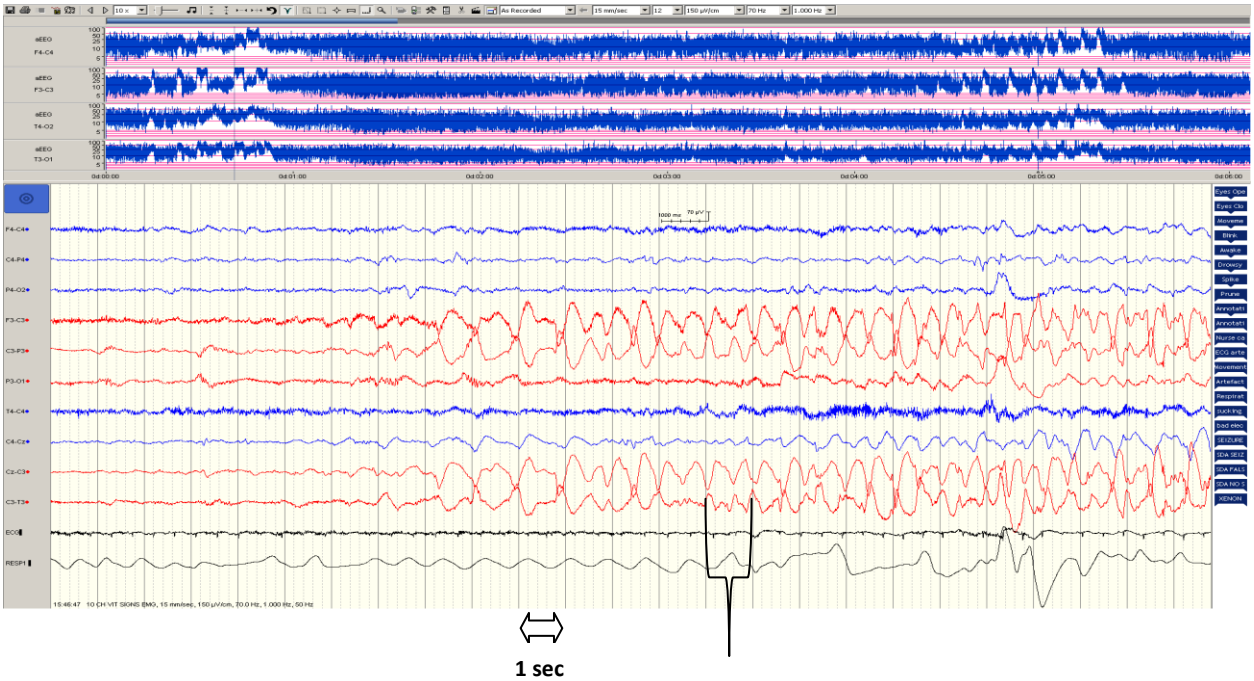


Fig 2. Evolution in seizure amplitude.

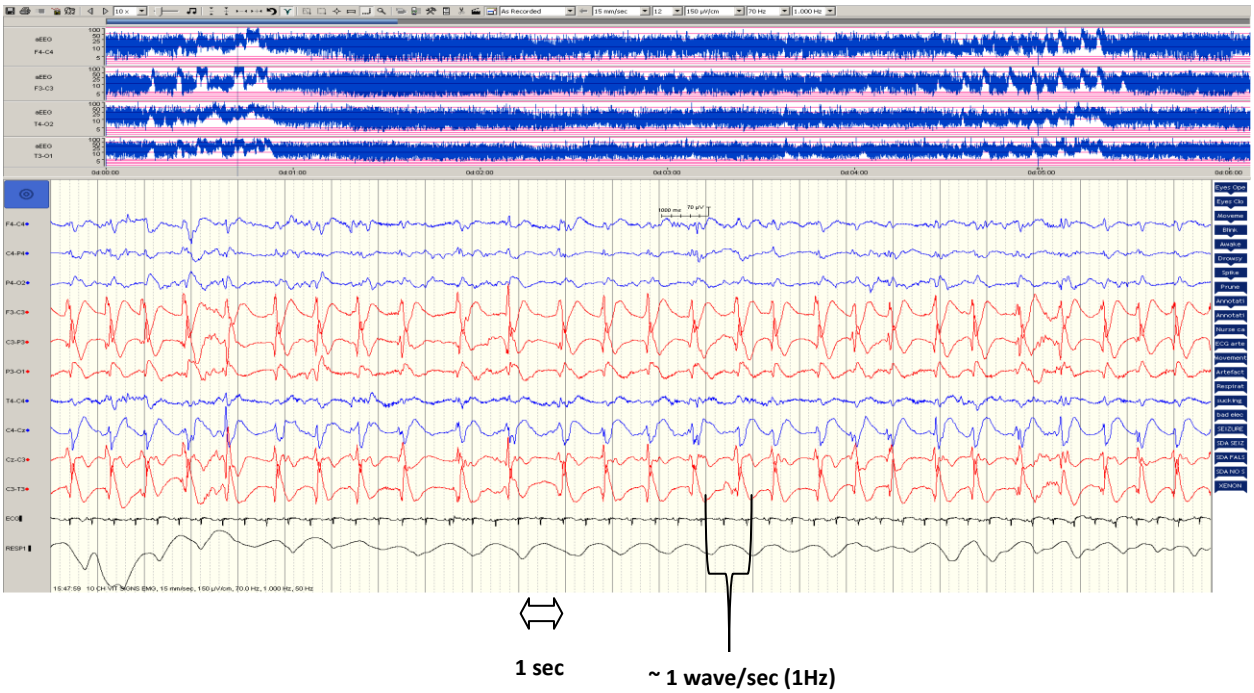
Frequency

Seizures often show changes in discharge frequency. Quite often faster frequencies are seen at the start, with progressive slowing particularly at the end of the seizure. Frequency can be estimated by counting the number of peaks (or troughs) occurring in a second.

Start of seizure



Middle of seizure



End of seizure

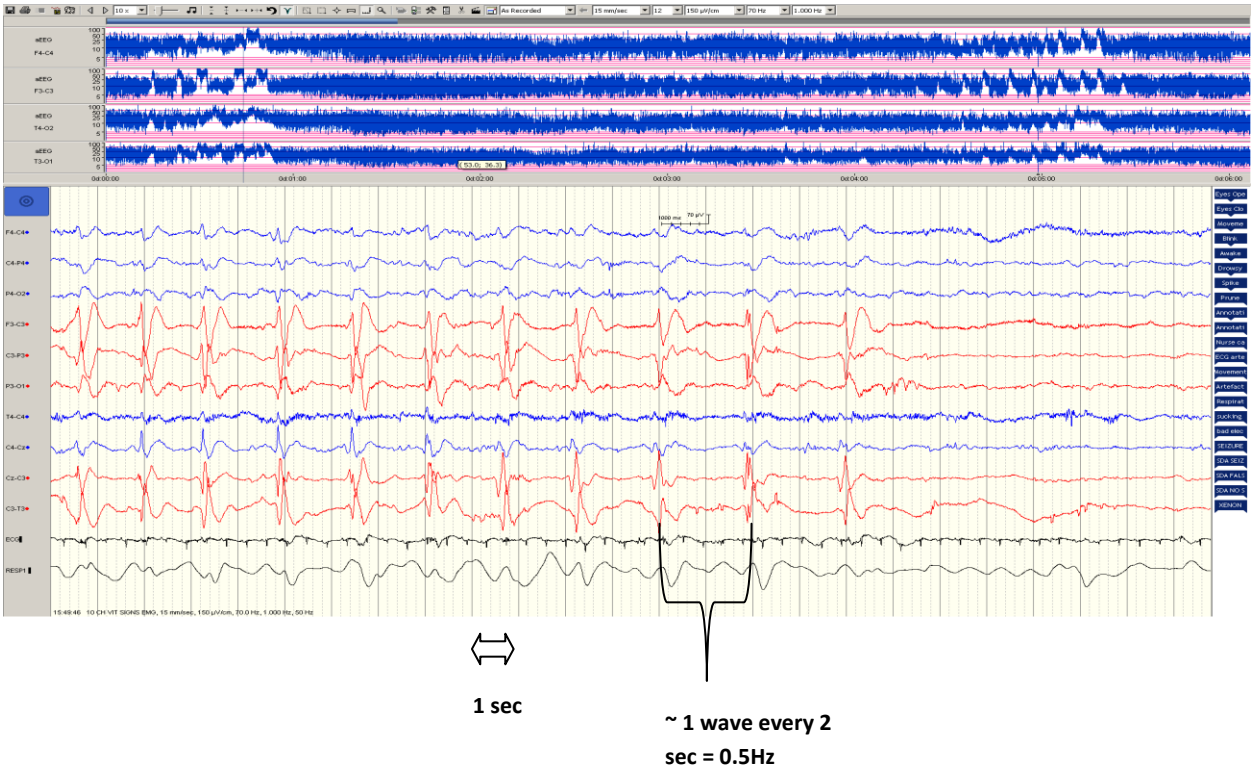


Fig 3.Frequency change during seizures.

Discharge morphology

The morphology of the epileptic discharges in neonatal seizures can vary from seizure to seizure and quite often the actual morphology of the discharge may vary within a seizure.Before we look at morphologies it is important to understand how brain potentials are displayed on the EEG.

EEG is usually displayed using 'bipolar' montages, i.e. each 'channel of EEG is the difference in electrical potential between 2 electrodes. The first electrode in the pair is designate lead 1 and the seconds is lead 2 and the EEG machine effectively subtracts the potential of lead 2 from lead 1. Negative potentials are always displayed as upward on the EEG. In bipolar montages EEG channels are displayed in chains with shared electrodes in subsequent EEG channels and any given electrode may appear in either lead 1 or lead 2 position in the pair. This can lead to inversion of the waveform on the display. For example, in fig 4 below, a negative potential on the head at electrode C4 will appear in EEG channel 2 as an upward deflection as it is the lead 1 position in the pair C4-P4. However in channel 1 C4 is the second electrode in the pair F4-C4 and the waveform will appear inverted. This is called a phase reversal and allows neurophysiologist to identify the site of onset of a focal seizure. **The only important thing to remember is that waveforms can appear inverted on adjacent EEG channels.**

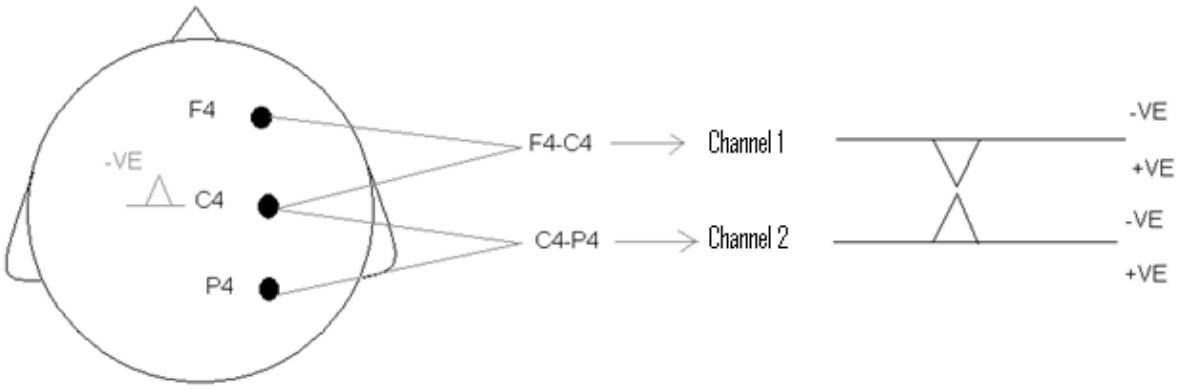


Fig 4.

Below (Fig 5) are some examples of typical seizure morphologies you are likely to see. The first is the **spike and wave complex**. The spike represents the abnormal concurrent firing of large groups of excitatory neurons. The slow wave represents the inhibitory response to that over-excitation. With some seizures the slow wave component is less apparent and the most prominent feature of the seizure is **repetitive spikes**. Conversely the **repetitive slow wave** may be the most prominent feature of the seizure and the spike component may be subtle or absent.

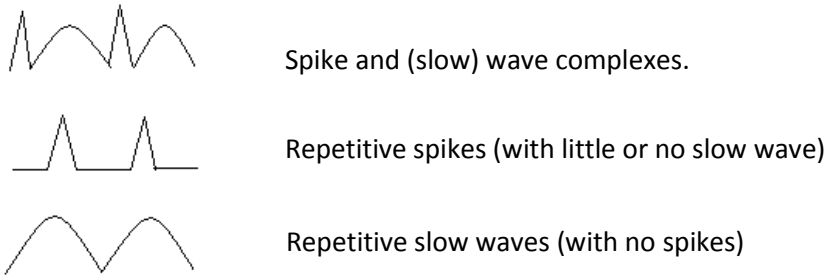


Fig 5.

However due to the nature of bipolar montages, as discussed above, these waveforms can appear inverted on some EEG channels and may appear as follows:

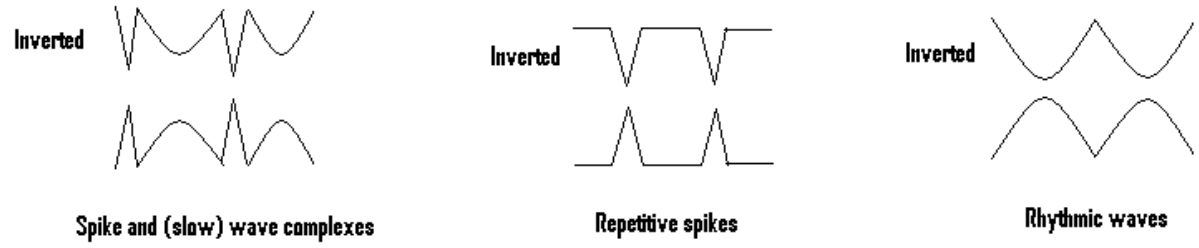
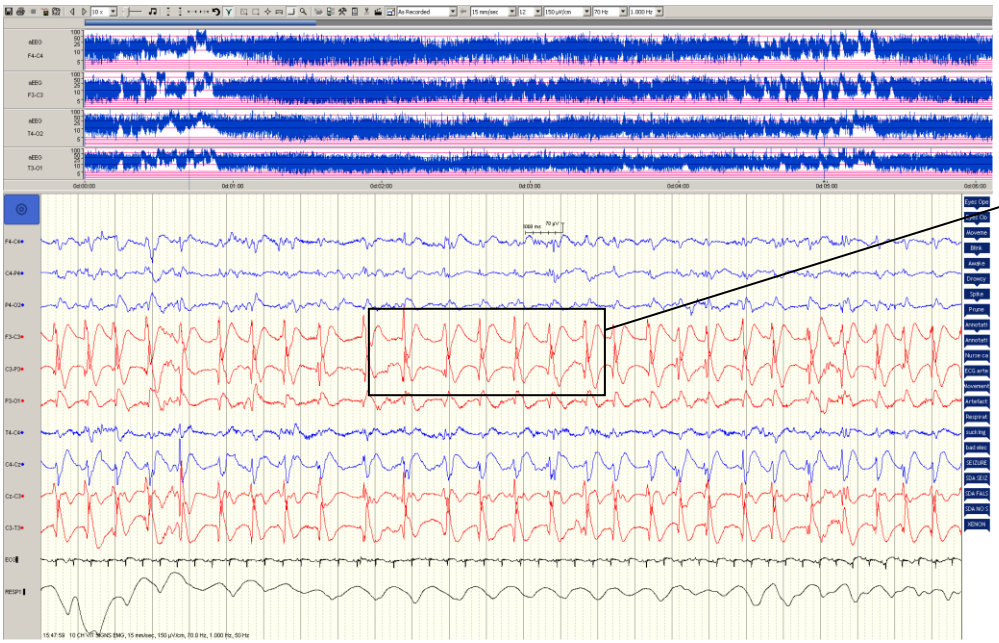


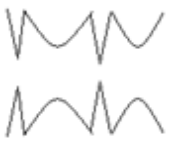
Fig 6.

Here are some examples of each.

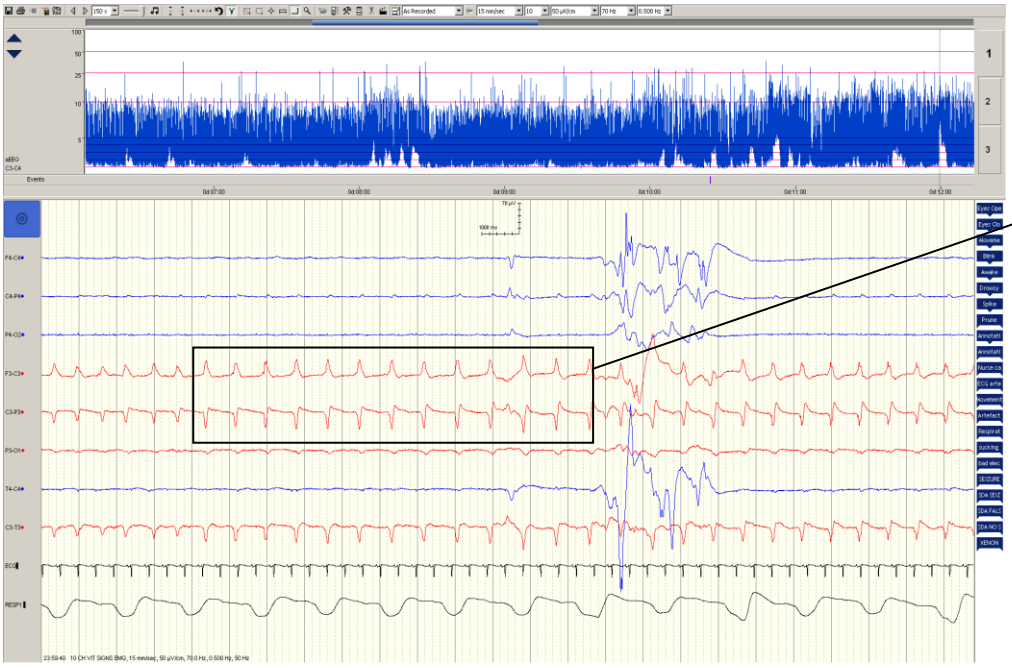
Spike and wave seizure



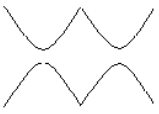
Note the phase reversing spike and wave



Rhythmic slow wave seizure



Note the phase reversing slow wave



Repetitive spike seizures

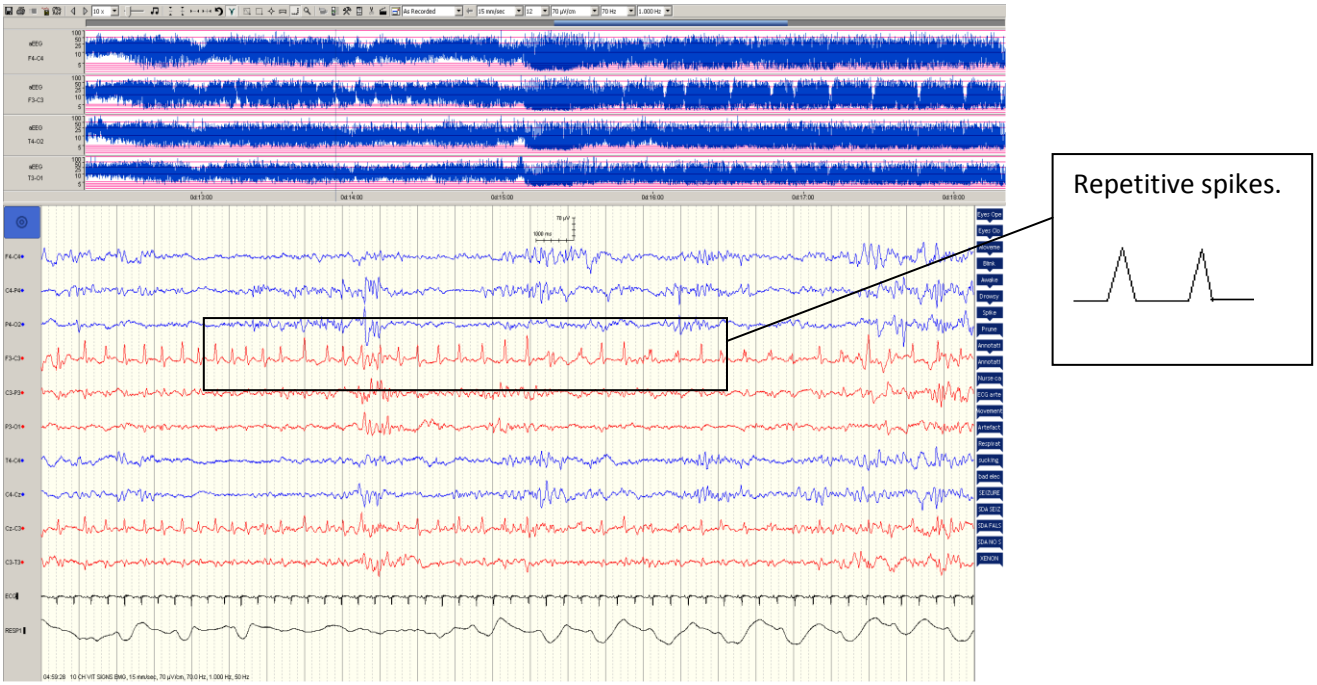
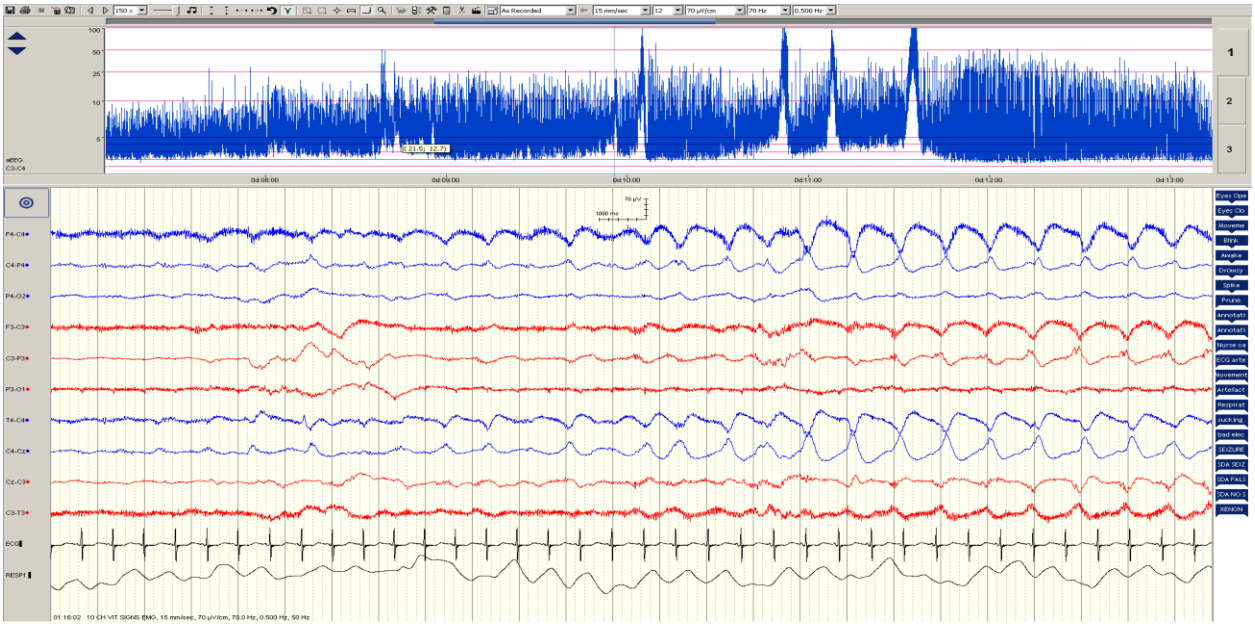


Fig 7. Common seizure morphologies.

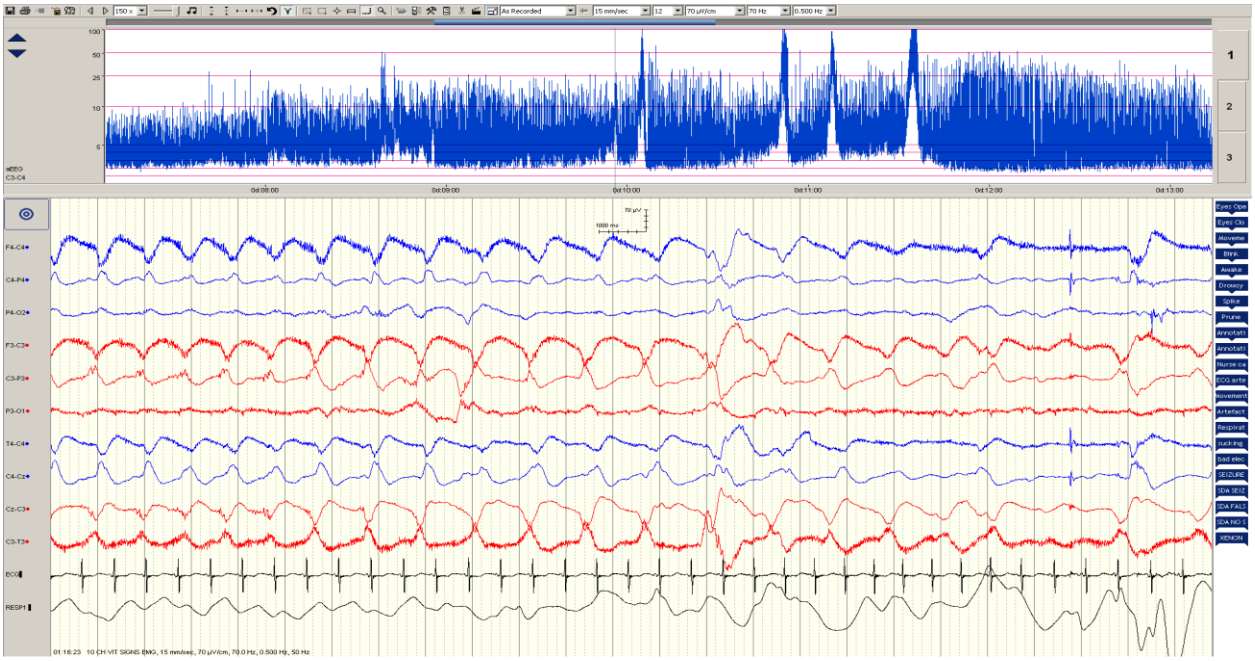
It is not uncommon for a seizure to change morphology during the seizure, for example the seizure in Fig 3 shows a rhythmic wave at the start of the seizure but by the middle it has developed a spike and wave morphology.

However seizures may maintain the same morphology as seen in fig 5 where rhythmic delta waves lacking spike components are the predominant waveform throughout.

Start of seizure



Middle of seizure



End of seizure

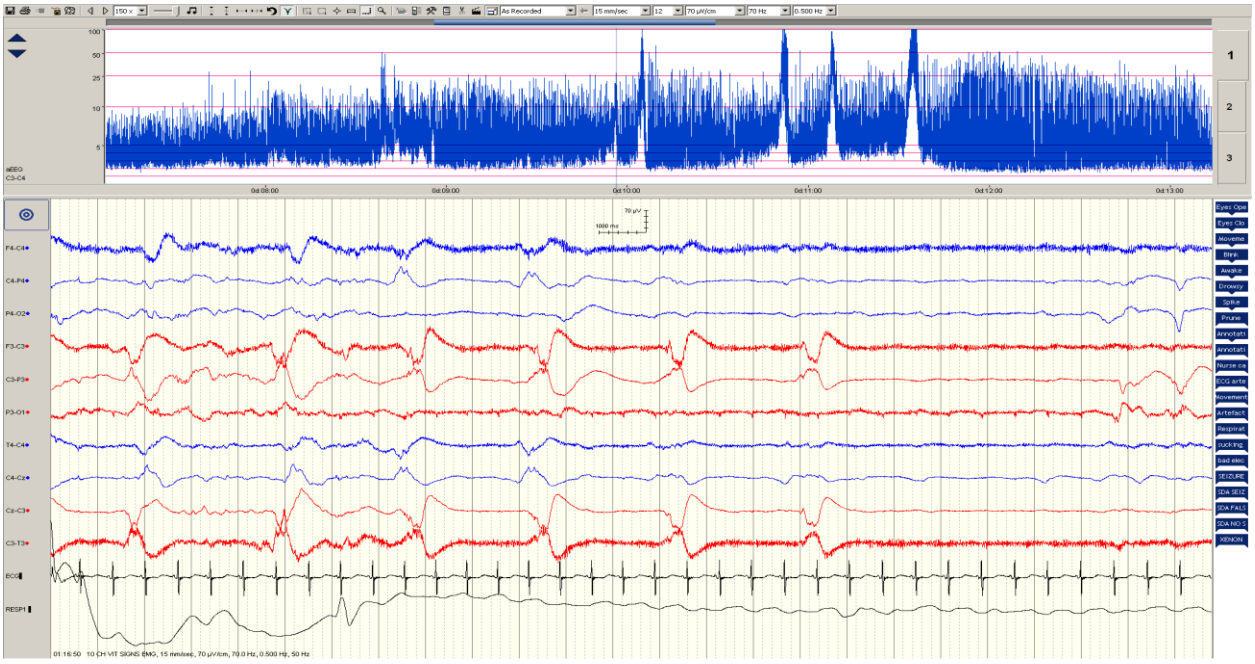


Fig 8. Seizure with slow wave morphology throughout.

False detections

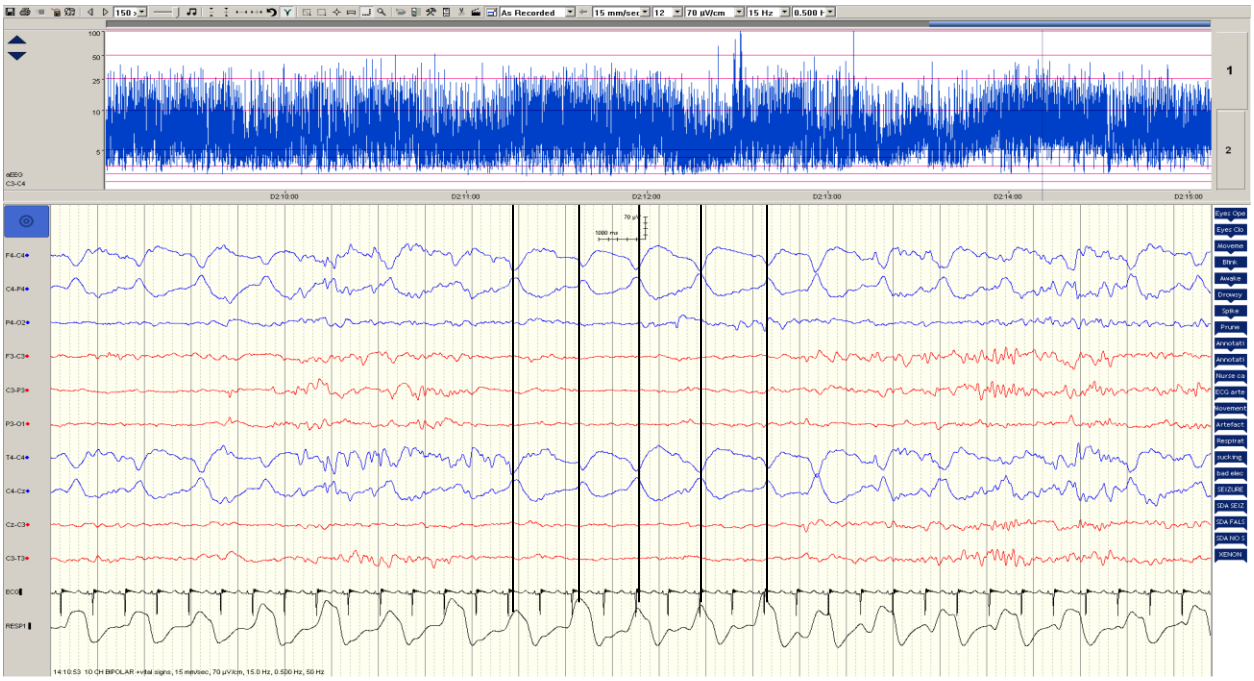
There are numerous sources of artefact on the neonatal EEG. Artefacts with a rhythmic nature can cause false detections on ANSeR and will be discussed first here.Some other artefacts will then be discussed that are unlikely to cause false detections but are useful for the EEG reviewer to be aware of.

The main causes of false detection are rhythmic artefacts including **respiration, pulsatile and sweat artefact and sometimes a poor electrode contact**. A highly **rhythmic background EEG** (not artefactual) may also cause false detections on occasion.

Respiratory artefact

Respiratory artefact is the most common cause of false detection. It is caused by the mechanical movement of the baby's breathing ,moving the head rhythmically relative to the cot and is often more pronounced over the electrodes on which the baby is lying (moving the baby's' head to the other side will cause the artefact to move to the other side also and is one method to identify the artefact). If the babies' breathing is supported by a ventilator, the artefact will tend to be very stereotyped and regular. If the baby is breathing on its own, the artefact will still be rhythmic but follow the baby's respiratory movements.

The simplest way to identify respiratory artefact is to record a separate respiratory trace on the EEG from the baby's abdomen. When this trace is available any suspect rhythm on the EEG can be compared against the respiration trace**. If it is a respiration artefact the waves on the EEG will be time-locked to the respiration trace** (although there may be a slight delay for the chest movement to be transferred to the head). This can be checked by using the vertical marker function on the EEG machine or a **ruler** or straight edge on the screen to see if the waveforms line up, as shown in the figures below. Several waveforms should be checked.



Placing vertical markers on the trace

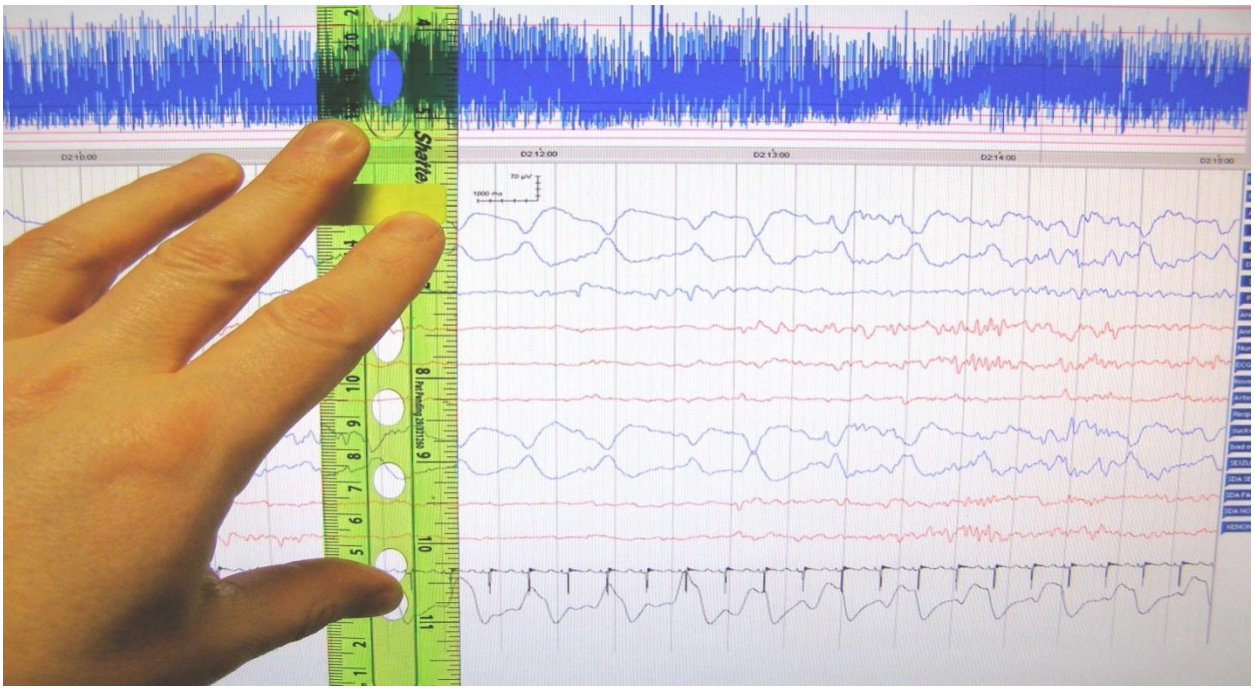


Fig 9. Identifying respiratory artefact with markers or a ruler.

Note how similar the morphology of this respiration artefact is to the seizure in Fig 8. The two are distinguishable firstly as the respiration artifact will be time-locked to the respiration trace and the

seizure will not, and secondly because seizures tend to show frequency change such as progressive slowing,whereas **the artefact has a fairly invariant frequency**.

If a baby is not ventilated there may be some variation in the respiration rate and the associated artefact but the two will still be time-locked (see below).

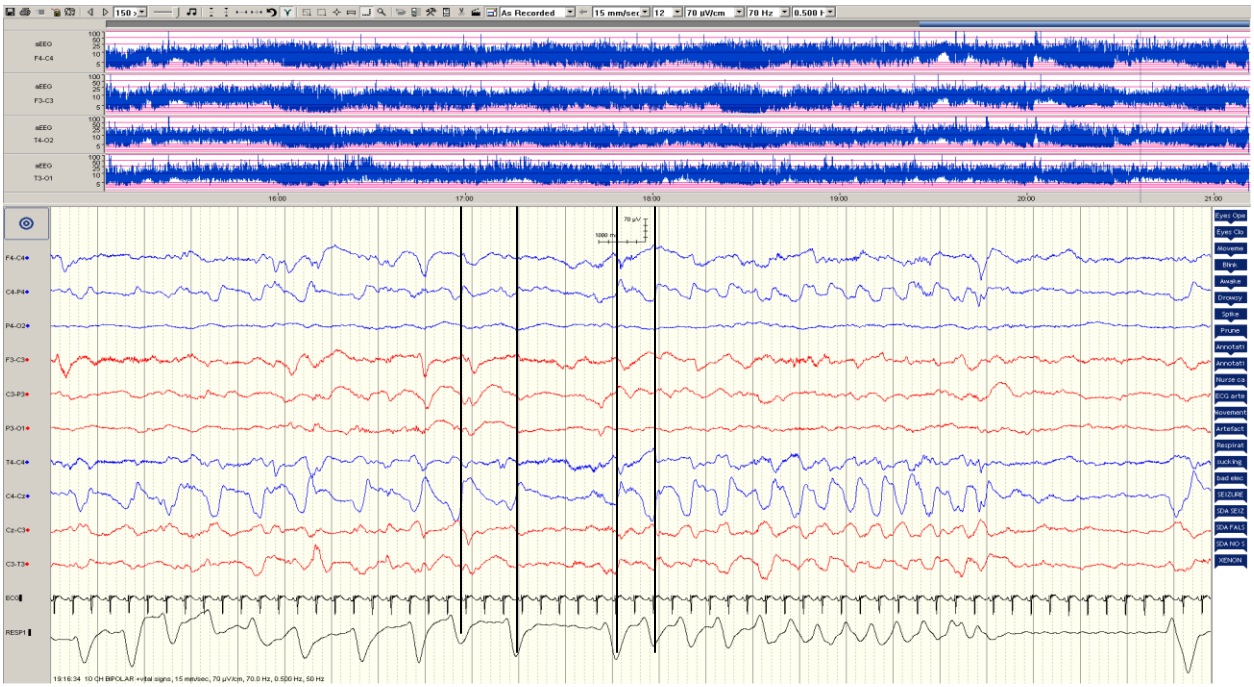


Fig 10. Respiration artefact in a non-ventilated baby with a variable respiration rate.

Pulsatile artefact

If an electrode is close to a pulsing blood vessel, a rhythmic artifact may appear on the EEG as shown in Fig 11. Similarly to the respiration artefact, pulse artefact will be time-locked to the ECG trace which is usually recorded from the shoulders. In a similar fashion, vertical markers or a ruler can be used to compare the EEG rhythm to the peaks on the ECG. **Again the artefact will be quite invariant and not show the frequency changes often seen in seizures.**

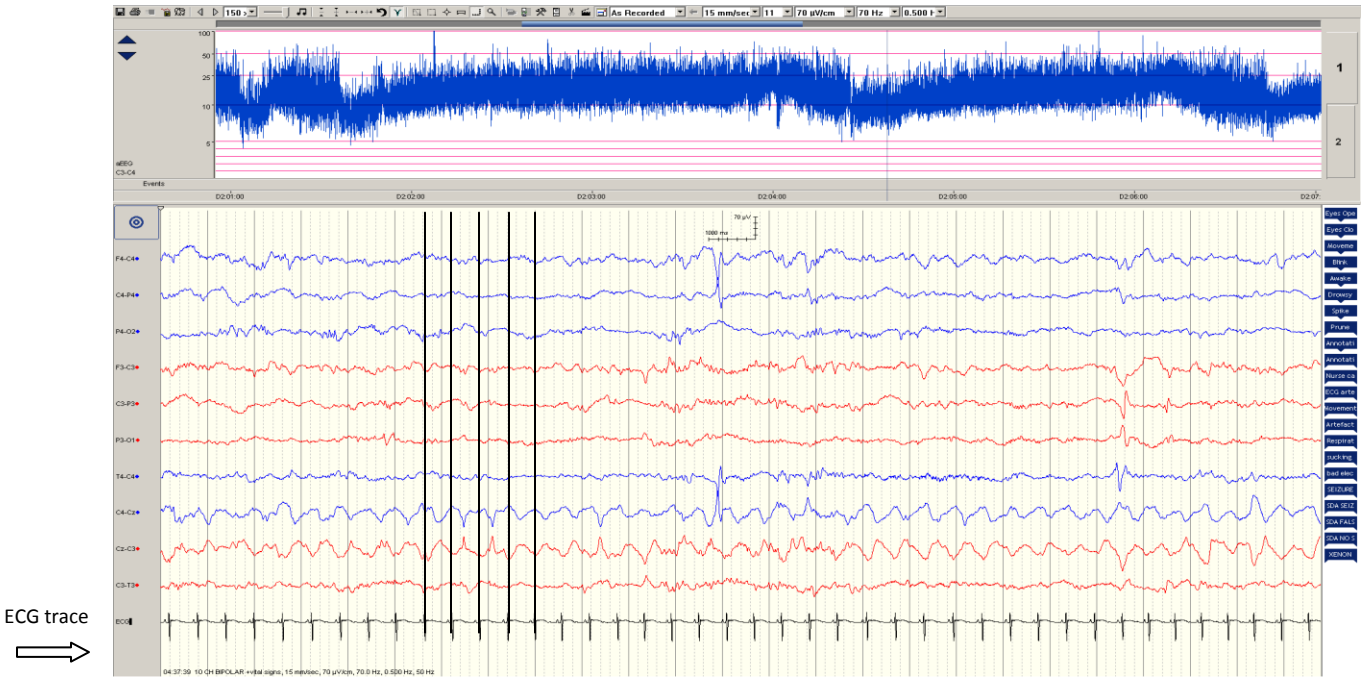


Fig 11. Identifying pulsatile artefact.

ECG artefact

The electrical potentials generated by the heart can also be picked up on the EEG recording and constitute an artefact. These sharp potentials can be identified as ECG as they will also be time-locked to the ECG trace. This form of artefact is quite common but does not often cause false detections on ANSeR.

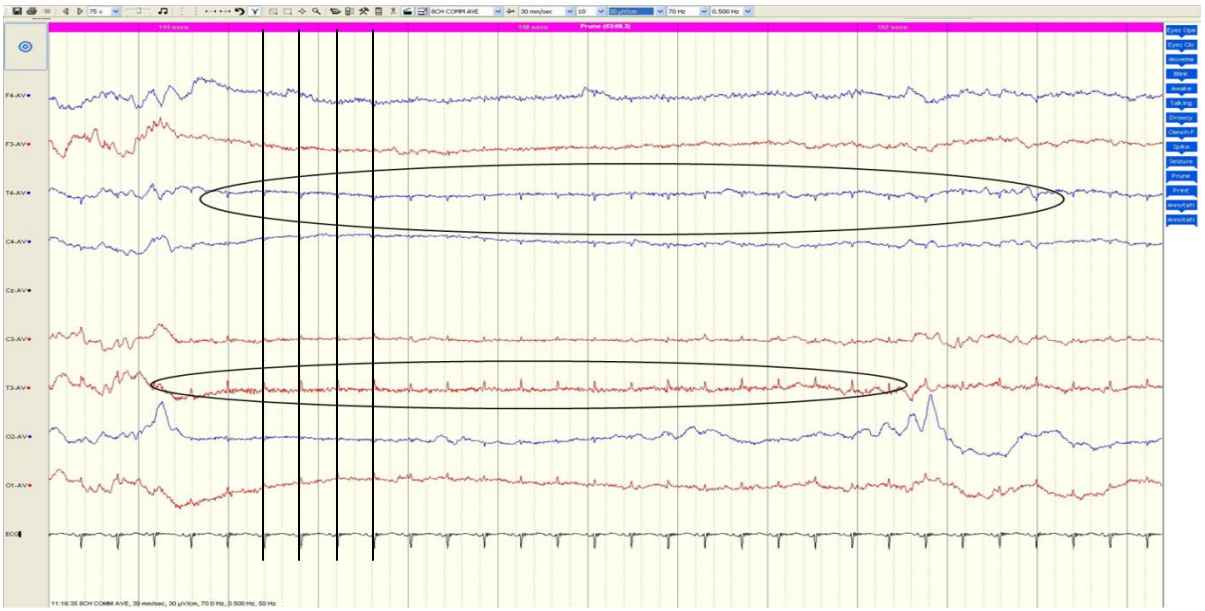


Fig 12. Identifying ECG artefact on the EEG.

Sweat artefact

If a baby's head is sweaty, the moisture can partially connect electrodes and cause a high amplitude, very slow, rolling, semi rhythmic artefact on the EEG. These slow wavesare very distinctive and can be distinguished from seizures as they tend to span several seconds, are only semi-rhythmic and may be intermittent.

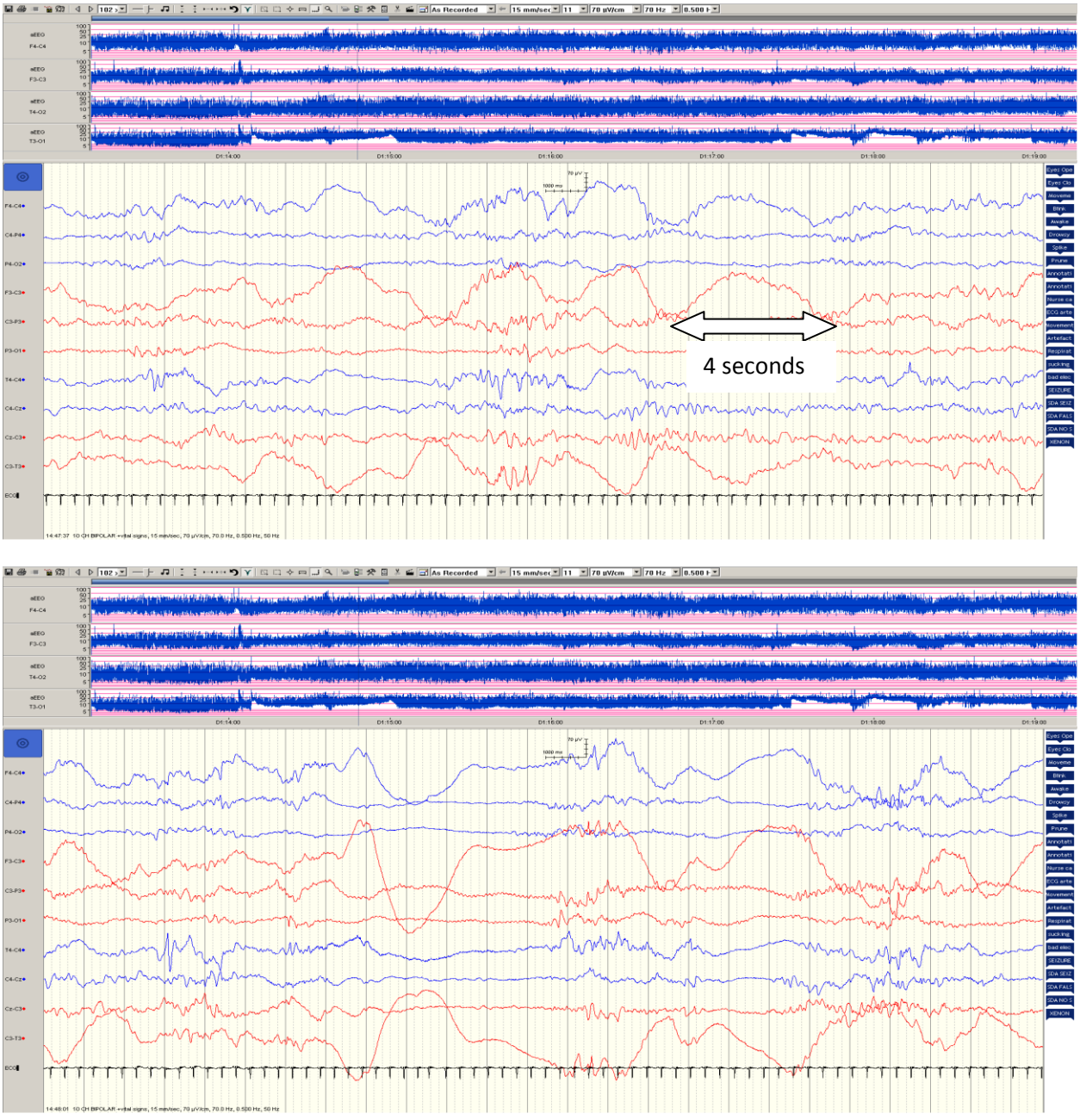
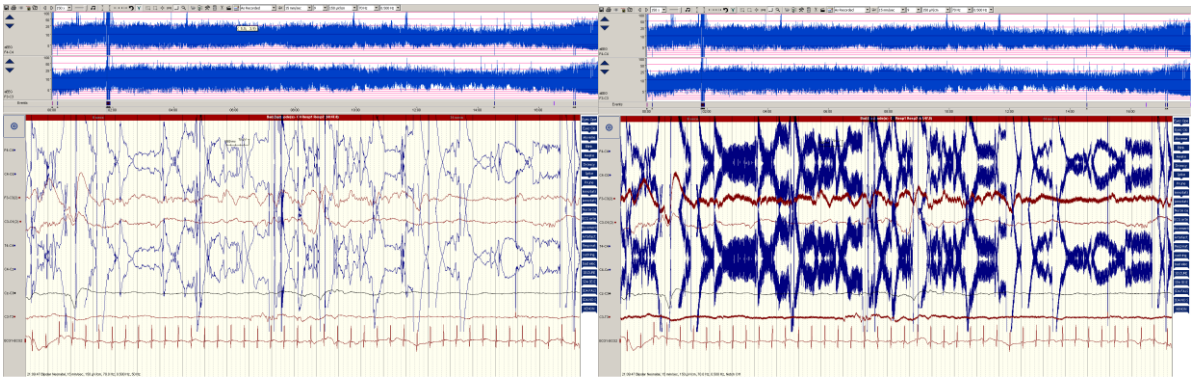


Fig 13. Examples of sweat artefact.

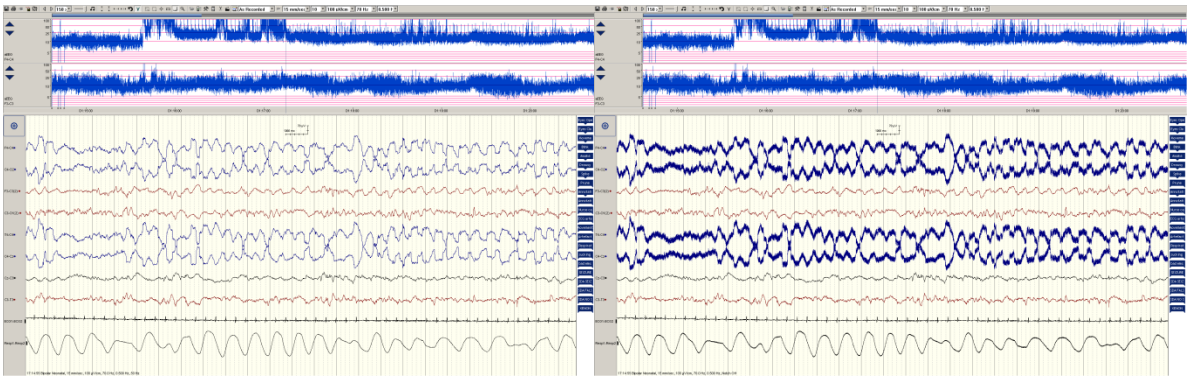
Bad electrode artefact

If an electrode is pulled or disrupted it can partially or fully lose contact with the baby's head. Often when this happens it leads to a high amplitude erratic artefact (fig 14a), but sometimes the artefact can be quite rhythmic and cause false detections (fig 14c). One way to determine if you have a bad contact is to turn off the Notch filter on the machine 

(the notch filter is a special filter that only takes out 50Hz mains frequency artefact on the EEG). A bad contact will have high impedance and tend to pick up mains interference (fig 14 b,d). Turning this filter off reveals the overlying fast artefact. Alternatively doing an impedance check will reveal a high impedance (Fig 15).



a)Bad electrode showing erratic artefact **b)**Same trace as a) but with notch filter off



c)Bad electrode showing rhythmic artefact **d)** Same trace as c) but with notch filter off

Fig 14. Erratic and rhythmic artefact caused by a bad electrode contact.

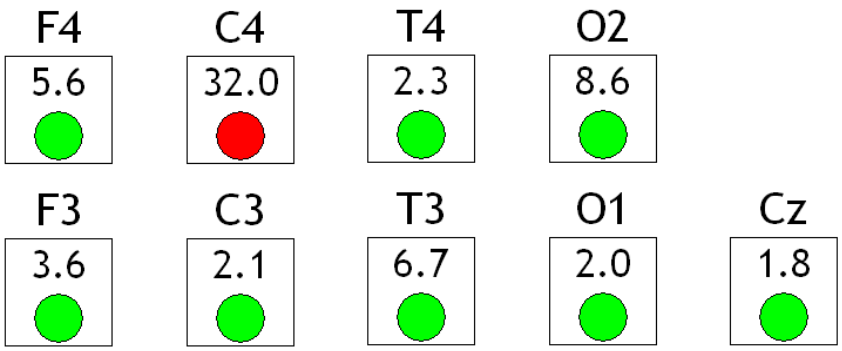
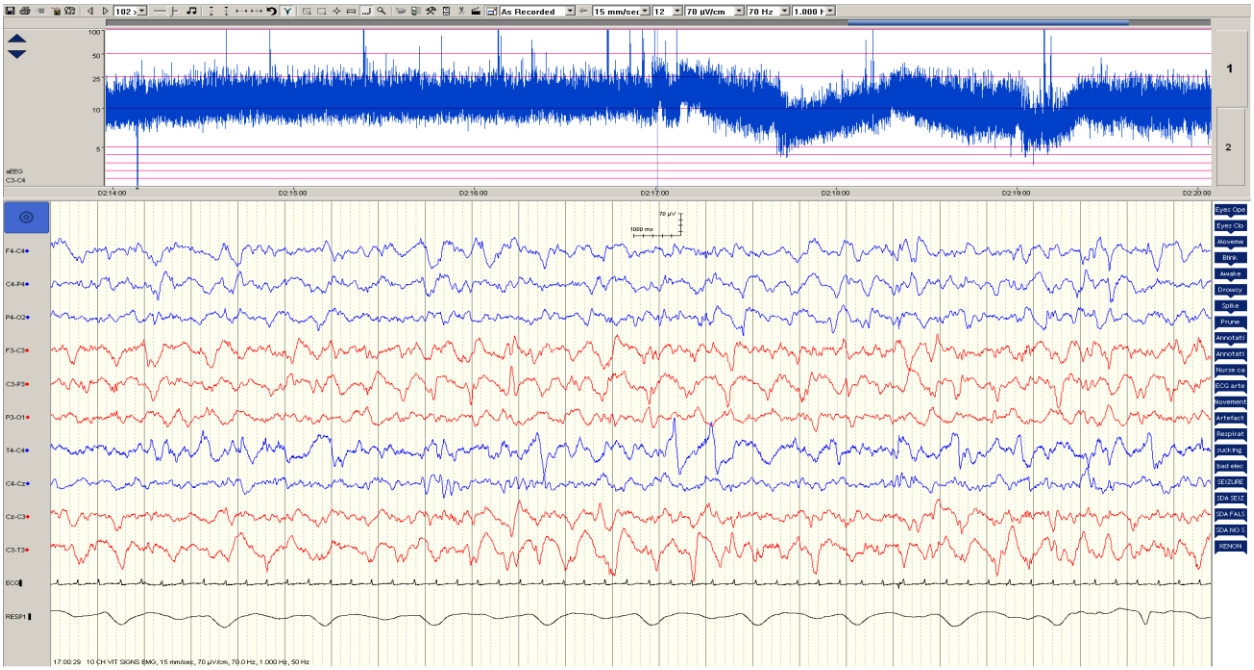


Fig 15. Impedance check with bad electrode (C4) showing high impedance.

False detections from a highly rhythmic background EEG pattern

In some patients the background EEG can show a large amount of semi-rhythmic slow (delta) activity, particularly in quiet sleep. Because of its rhythmicity, occasionally this type of activity can cause false detections. Generally this type of activity is only semi-rhythmic and not as rhythmic as seizures, the waveforms are not as regular and stereotyped as seizure waveforms and the activity does not tend to 'evolve' as seizures tend to. Three examples are shown in Fig 16 below.



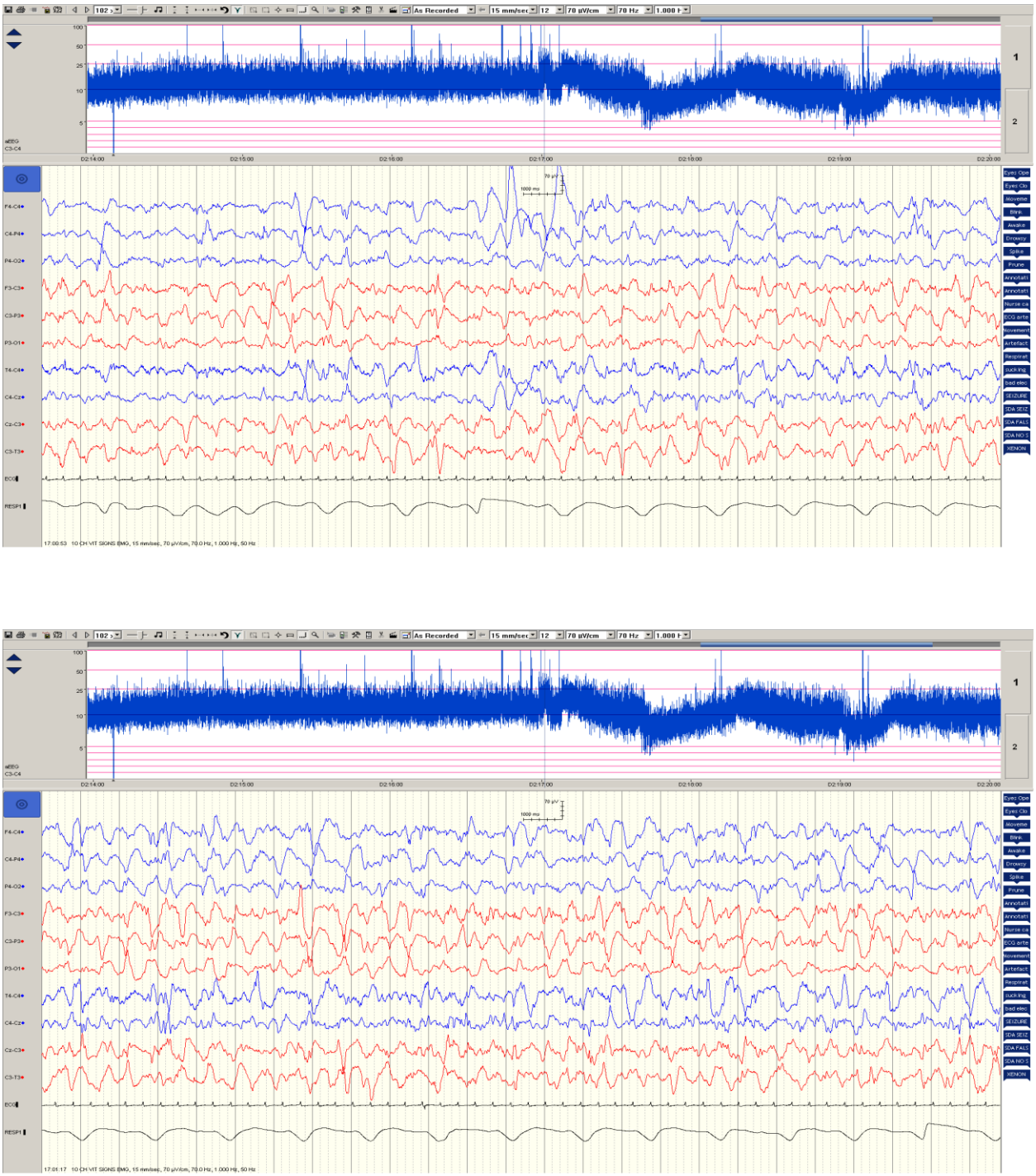


Fig 16. Examples of EEG showing increased background rhythmicity in the delta (slow) range.

Artefact from dummy sucking

If a baby is sucking a dummy, the rhythmic head movements may cause a rhythmic artefact on the EEG as in the example in Fig 17. There are two ways to identify this rhythm as an artefact. Firstly the intermittent activation of the jaw muscle causes short bursts of muscle artefact overlying the slow rhythm, often over the temporal electrodes (T3 and T4). Secondly the **video** can be used to identify the chewing/sucking movements. Unless this artefact is very pronounced and prolonged (it tends to be intermittent), it tends **not** to cause false detections but is worth knowing for EEG review purposes.

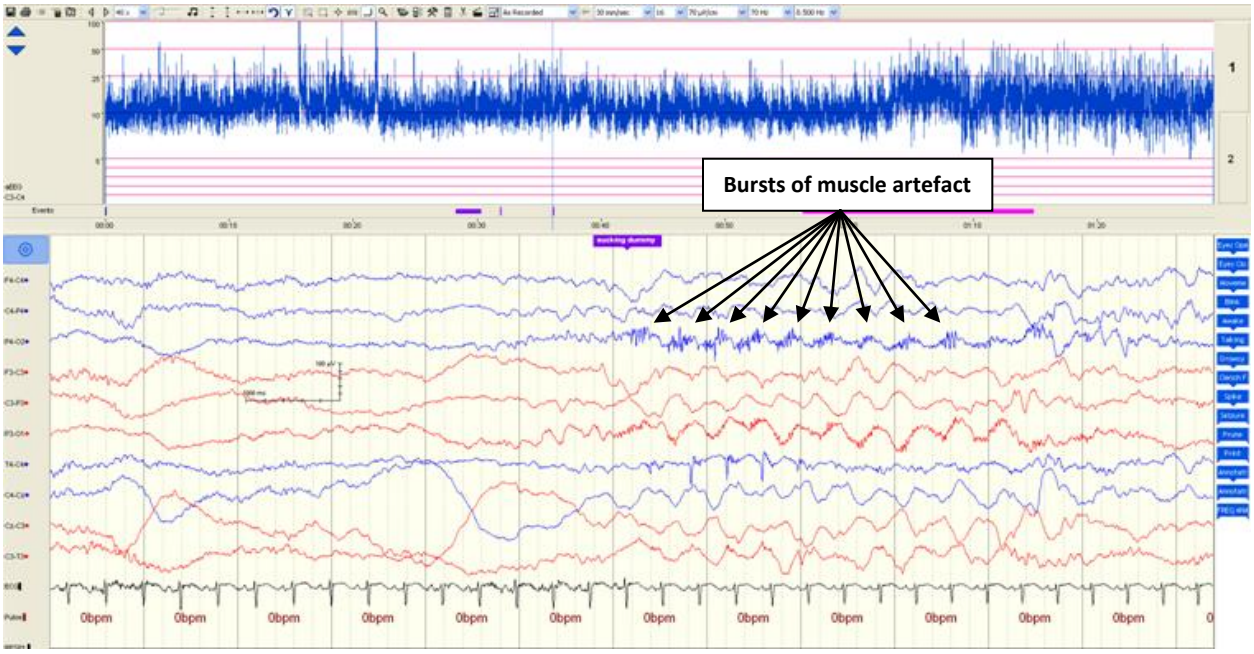


Fig 17. Dummy sucking artefact

Hiccups

Hiccups can cause a semi-periodic artefact on the EEG with slow waves from the ballistic movement of the head/body which can also be overlain with fast muscle movement from the jaw. The respiration trace will also show an abnormal wave coincident with the sharp inspiration of the chest. This artefact can also be determined by looking at the **video** recording.This form of artefact tends **not** to cause false detections as there are usually several seconds between hiccups, but again it is worth being able to identify this artefact for review purposes.

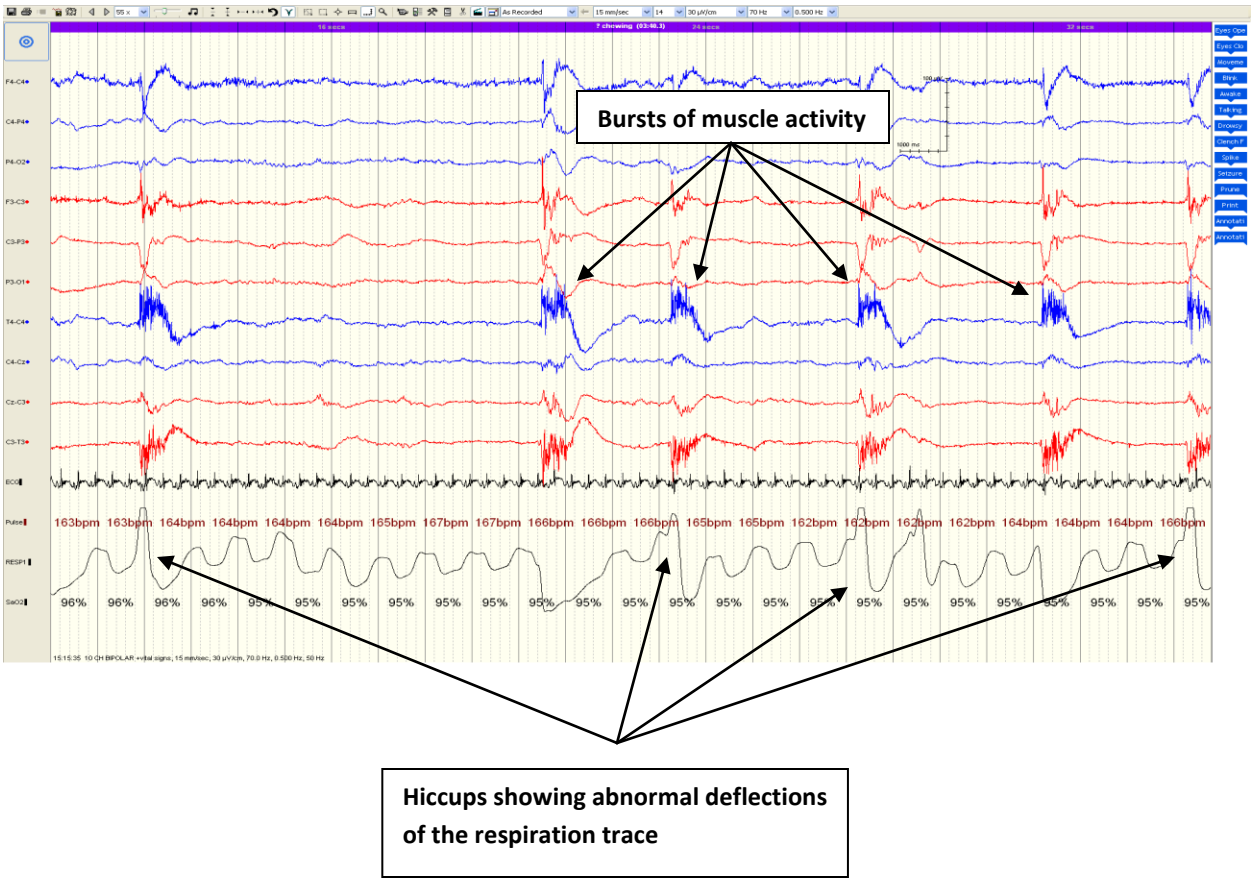


Fig 18. Periodic artefact caused by hiccups.

Patting/stroking artefact

If a baby is being patted, stroked or manipulated in a rhythmic way, it can cause a rhythmic artefact with variable morphology. Below is an example of an artefact caused by the nurse patting the baby (fig 19). The **video** is the best way to determine what was happening at the time and to differentiate artefact from seizure.

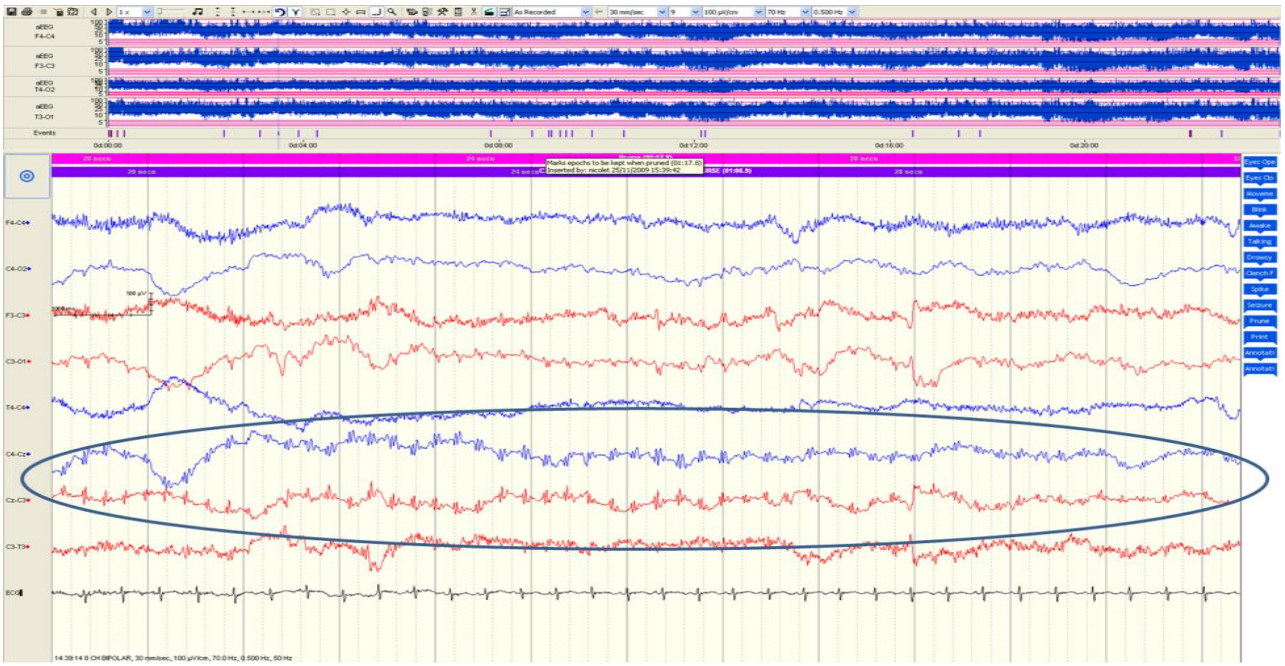


Fig 19. Rhythmic artefact caused by ‘patting’ the baby.

Oscillator artefact

If a baby is ventilated with an oscillator, the rhythmic vibration of the baby can cause an artefact on the EEG. The artefact tends to occur on the electrodes that the baby is lying on and will be at the same frequency as the oscillator (usually around 10Hz) and will be invariant. Oscillator frequencies are generally too fast to cause false detection on ANSeR (but can falsely elevate the aEEG baseline on a discontinuous EEG)

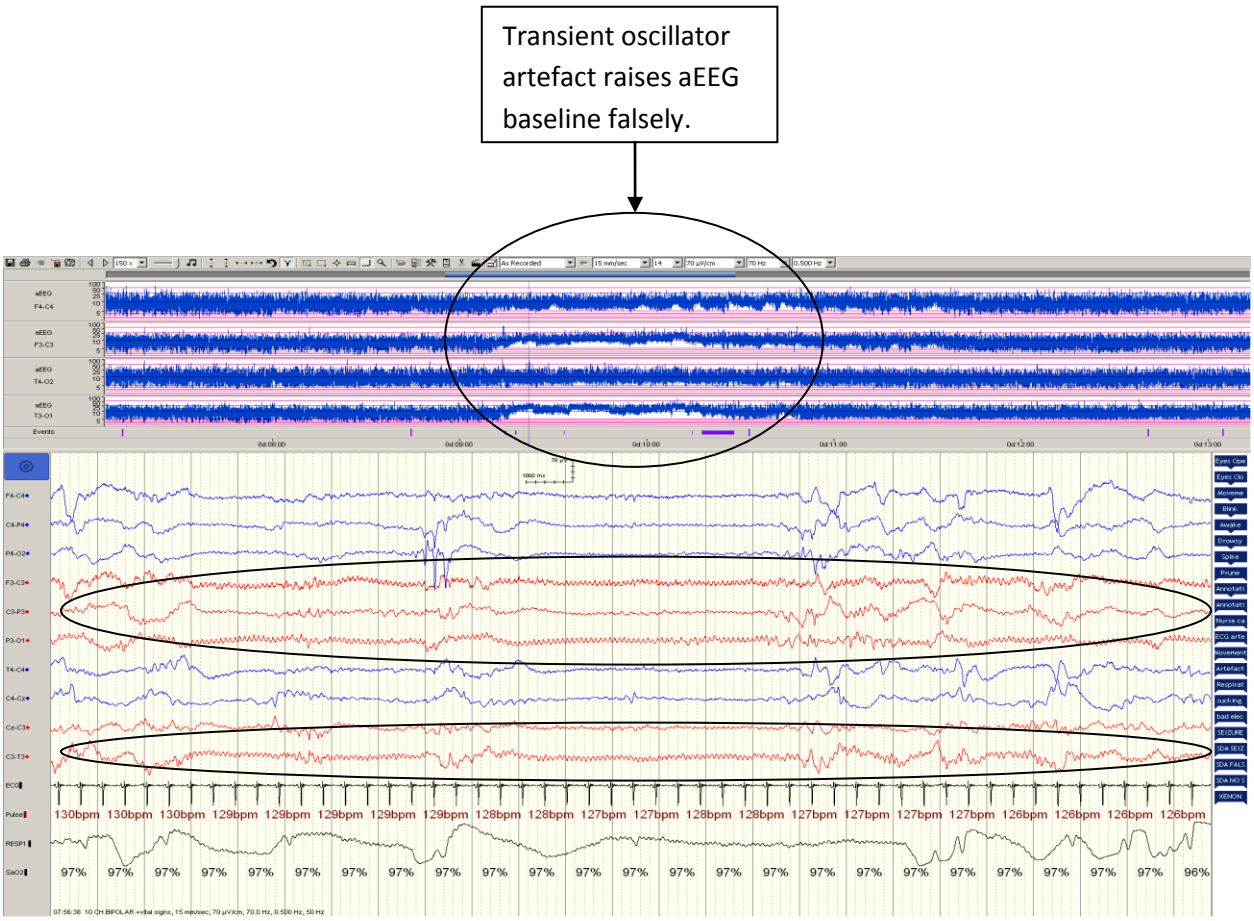


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Fig 20. Low amplitude rhythmic 10Hz oscillator artefact.

Muscle and movement artefact

Transient movement of the baby can cause high amplitude slow artefacts on the EEG. If the baby is crying, chewing on a dummy, biting on a ventilation tube or frowning, muscle activity will appear on the EEG as fast irregular low amplitude activity. Neither transient movement artefact nor muscle activity are likely to cause false detections on ANSeR.

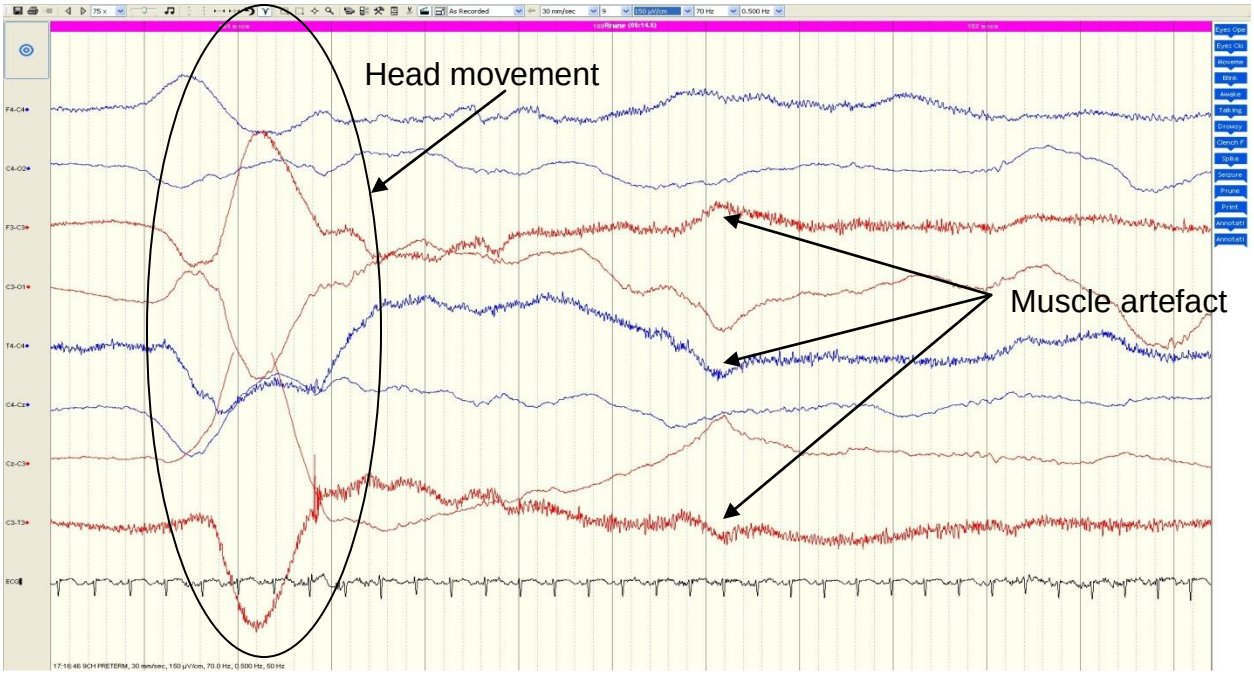


Fig 21. Transient movement and muscle artefact.

50Hz mains artefact

When there is a poor electrode contact at the head, the EEG channel tends to pick up a 50Hz artefact which appears as a thickening of the trace. This occurs as any equipment near the baby with a main 50Hz AC current running through it has an electromagnetic field at right angles to the current (fig 22) which can induce a small 50Hz signal in another wire close to it, such as an electrode wire. Usually the EEG amplifier cancels this artefact out but when there is a bad electrode contact it cannot. Fig 23 shows what this artefact look like normally and when the EEG is 'spread' out to reveal the 50Hz signal. This type of artefact on its own will not cause false detections as it is too fast a frequency but sometimes an unstable electrode may have a slower overlying frequency that may cause false detection (see fig 14). When this artefact is seen the electrode should be reapplied.

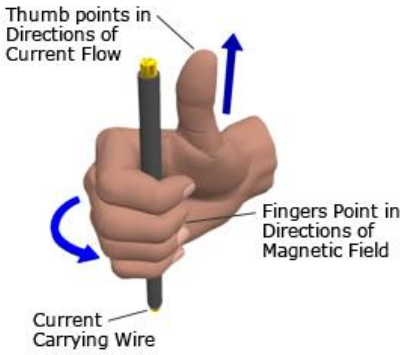
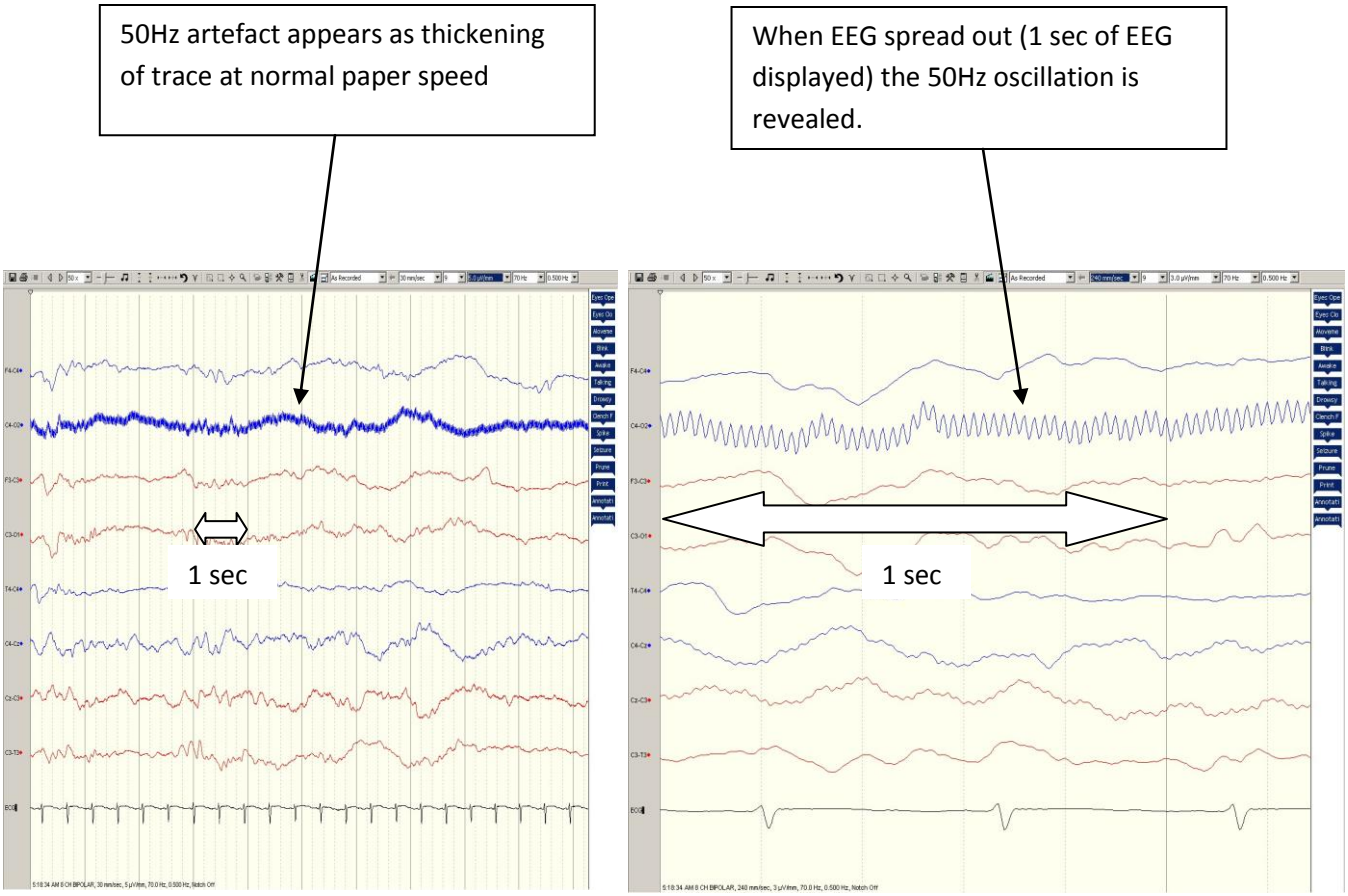


Fig 22. A current running in a wire has a magnetic field around it that can induce a current in another wire, eg. 50Hz mains AC can induce a 50Hz oscillation in the electrode wire.



a) b)

Fig 23. 50Hz mains artefact.a) Artefact at 'normal' paper speed. b) EEG spread out to reveal 50Hz oscillation.

Decision tree for differentiating true seizures from false detection

Suspect rhythm detected on EEG

Is it a false detection?

Is it a respiration artefact?

- Do the EEG waveformsline up with respiration trace?

Is it a pulsatile or ECG artefact?

- Do the waveforms line up with the ECG trace?

Is it sweat artefact?

- Are there intermittent high amplitude slow waves spanning several seconds?

Is it an artefact from a bad electrode?

- Is the trace erratic at times?
- Is the impedance high on the impedance check?
- Does 50Hz artefact appear on the trace when you switch off the Notch filter?

Is there anything happening to the baby on the video recording suggesting a rhythmic artifact?

- Is the baby sucking a dummy?
- Is anyone patting, stroking or performing any rhythmic action on the baby such as physiotherapy?

Is it a highly rhythmic background EEG?

- Is there increased amounts of semi-rhythmic background delta activity which does not tend to 'evolve'.

NO

Does the waveform 'behave' like a typical seizure?

Do any/all of the following apply to the waveform?

Does it evolve in amplitude?

Does it evolve in frequency?

- eg. Faster at the start and slower at the end

Does it spread to other electrodes?

Does it show typical seizure morphologies?

- Spike and slow wave
- Rhythmic slow waves
- Repetitive spikes

Does the waveform change/evolve in morphology?

- eg. Slow waves to spike and wave

Are there any obvious clinical signs of seizures?

- eg. Clonic limb jerking

YES

Probable false detection

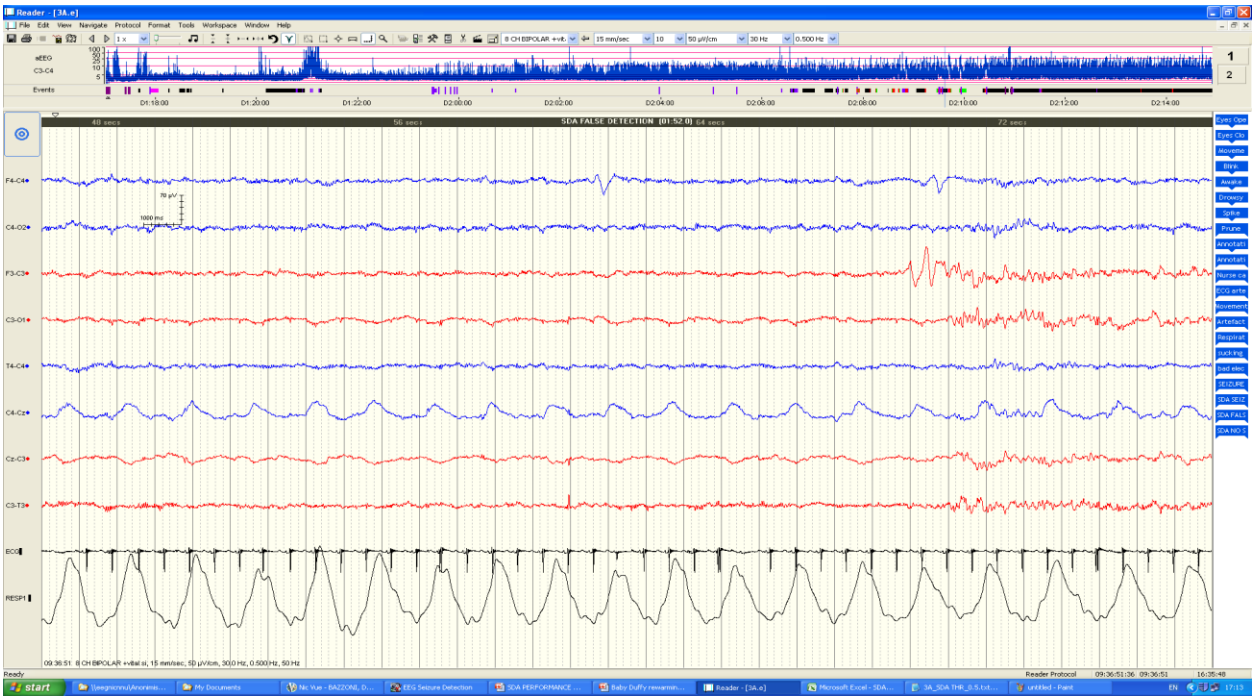
NO

Possible seizure, Seek further advice

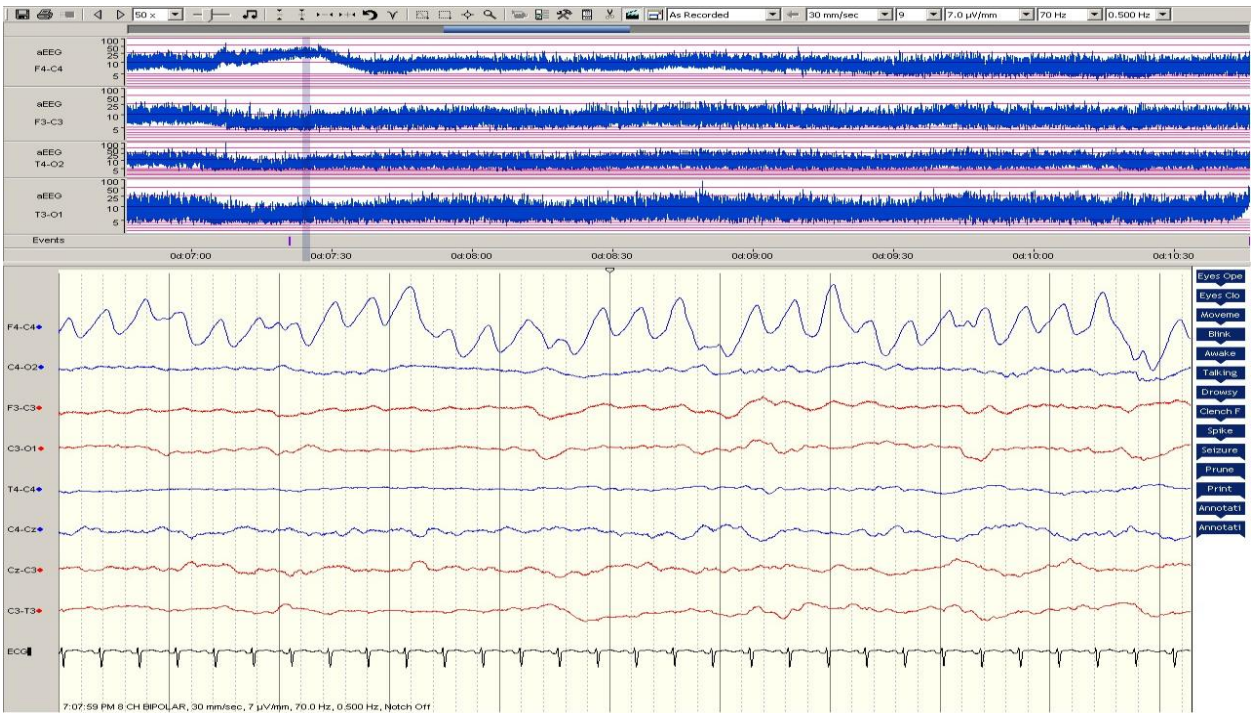
YES

Probable seizure

What's this? Example 1

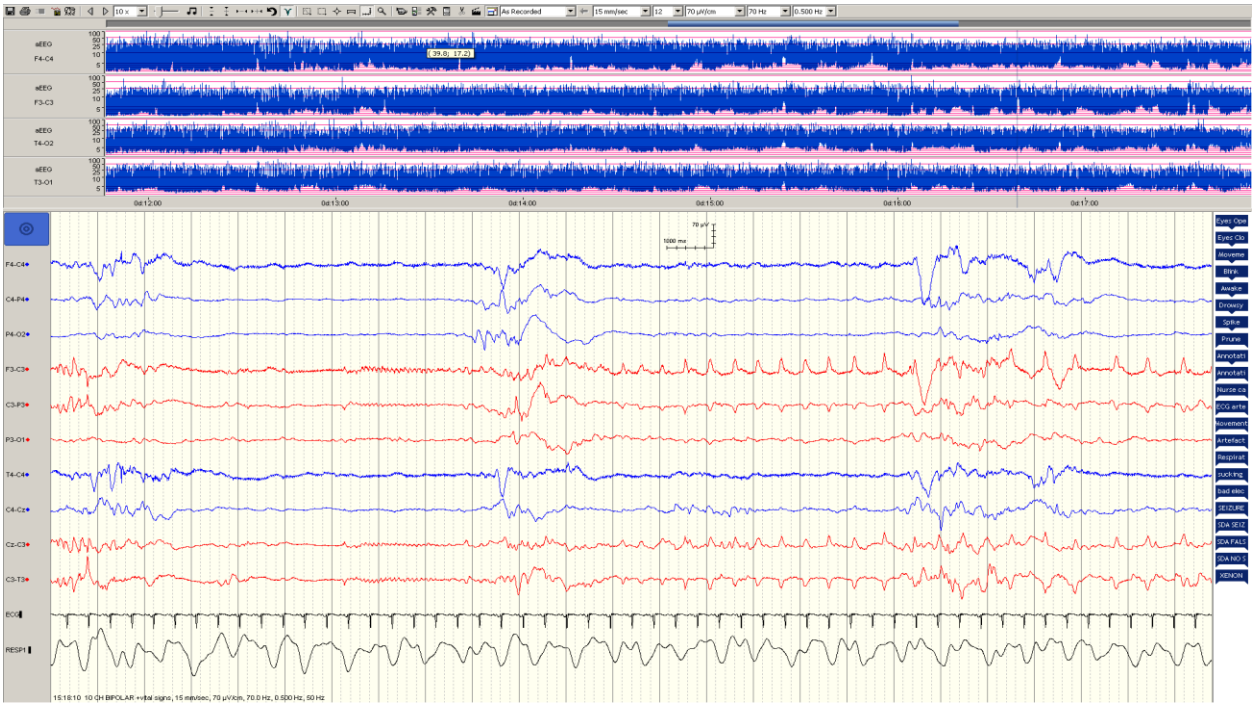


What's this? Example 2

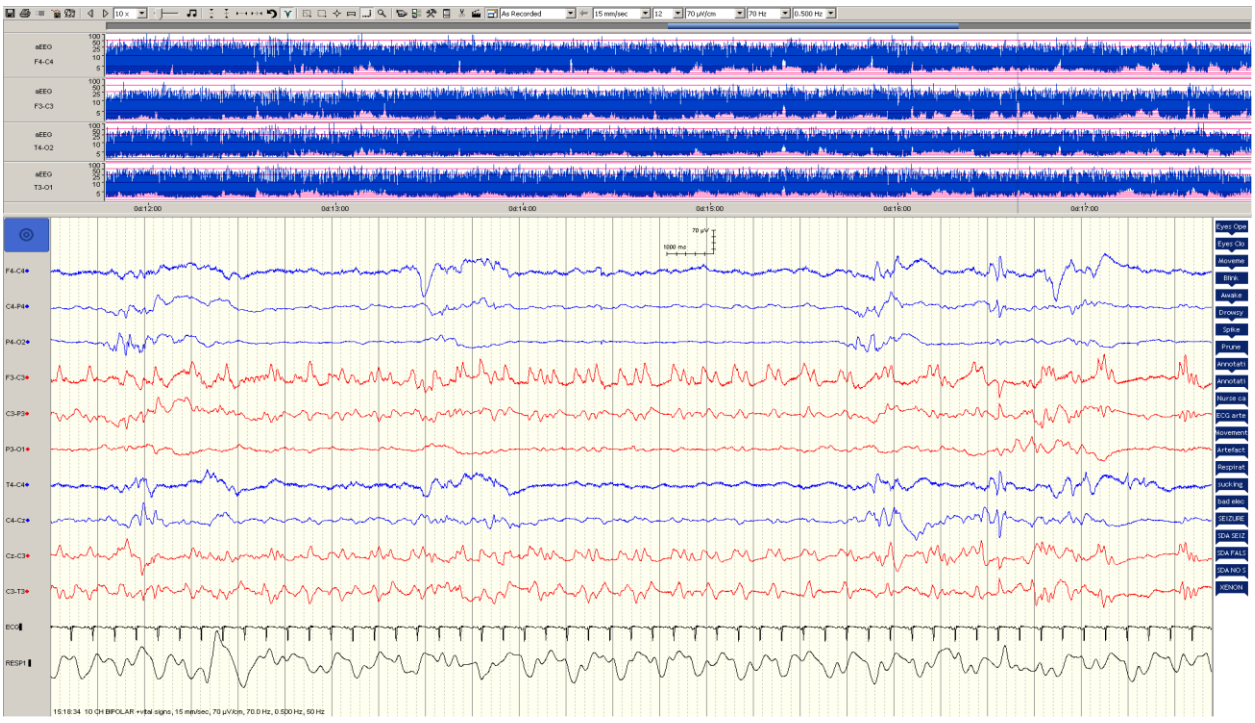


What's this? Example 3

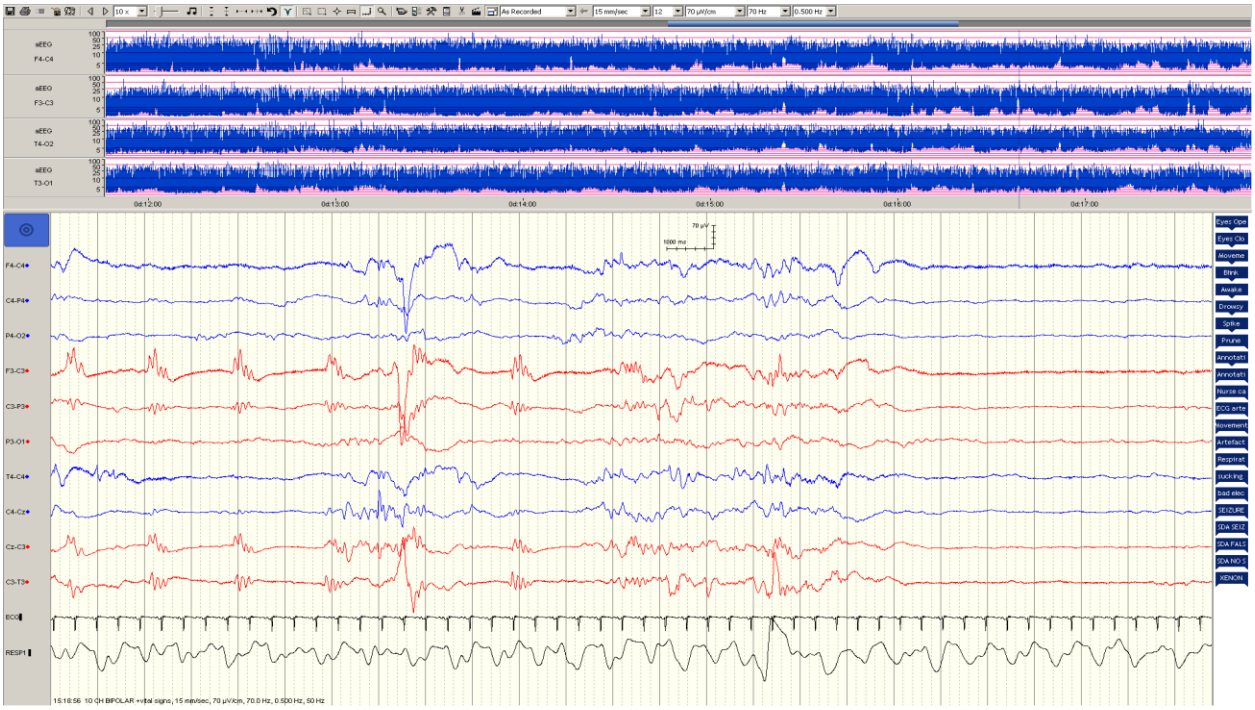
Start



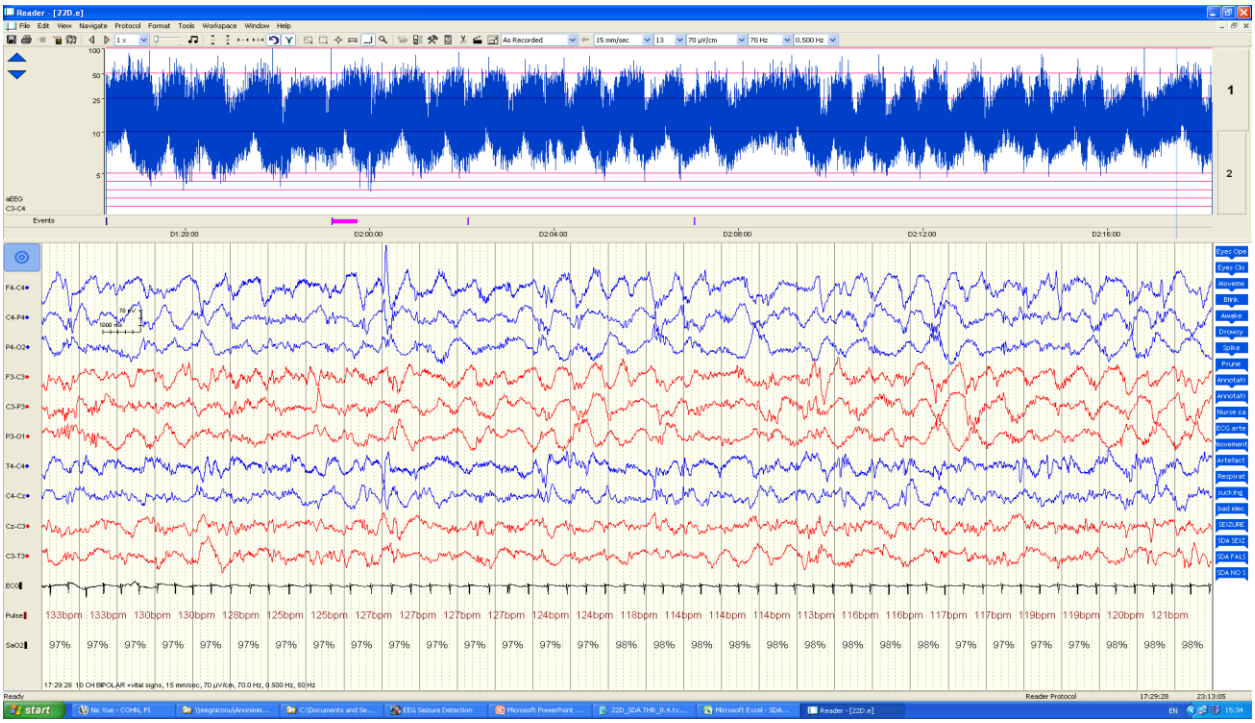
Middle



End



What's this? Example 4



What's this? Example 5

Reference List

(1) Clancy RR, Legido A. The exact ictal and interictal duration of electroencephalographic neonatal seizures. Epilepsia 1987 Sep;28(5):537-41.

(2) Rennie J M, Hagman C, Robertson N J. Neonatal Cerebral Investigation. 1st ed. Cambridge University Press; 2008.

(3) Bye AM, Flanagan D. Spatial and temporal characteristics of neonatal seizures. Epilepsia 1995 Oct;36(10):1009-16.

(4) Murray DM, Boylan GB, Ali I, Ryan CA, Murphy BP, Connolly S. Defining the gap between electrographic seizure burden, clinical expression and staff recognition of neonatal seizures. Arch Dis Child Fetal Neonatal Ed 2008 May;93(3):F187-F191.

(5) Rennie JM, Chorley G, Boylan GB, Pressler R, Nguyen Y, Hooper R. Non-expert use of the cerebral function monitor for neonatal seizure detection. Arch Dis Child Fetal Neonatal Ed 2004 Jan;89(1):F37-F40.