HOT TOPIC

SHOULD WE USE PROCESSED EEG MORE OFTEN IN PAEDIATRIC ANAESTHESIA?

SUMMARY OF KEY POINTS:

- Use of processed EEG (pEEG) in paediatrics is increasing but is not yet used as frequently as in adult practice
- pEEG patterns are different in paediatric patients compared to adults but there are recognisable patterns in 3 broad age groups (neonates, infants and children) which can be used to guide titration of anaesthesia
- With TIVA use increasing, we encourage paediatric anaesthetists to consider use of pEEG in cases where neuromuscular blockers are used, IV access cannot be monitored or during long anaesthetic cases.

REVIEW OF EVIDENCE

Background

Processed EEG is now used in adult anaesthetic practice for depth of anaesthesia monitoring in numerous situations, however its use in paediatric anaesthesia is lagging behind. Possible reasons for this could include lack of familiarity of paediatric anaesthetists with interpretation in the paediatric population and the fact that current pEEG depth of anaesthesia (DOA) monitors are based on algorithms tested on adult populations. With the use of TIVA in paediatrics increasing, it is important to consider that the pEEG may have a valuable role to play in DOA monitoring and titration of anaesthesia. Studies have indicated that traditional dosing methods based on patient movement or heamodynamic changes can result in imprecise dosing, particularly in younger infants who may also experience more adverse events (1). Current AABGI guidelines for use of TIVA recommend use of pEEG in all cases with NMB however the current limitations of its use in children under 1 are recognised (2)

Arguments for use of pEEG

Studies on use of pEEG in paediatrics are increasing and further large-scale studies are needed to demonstrate clear reproducible benefits. Studies to date have shown that pEEG guided anaesthesia titration reduces time to emergence, time to discharge, incidence of emergence delirium, propofol consumption and sevoflurance dosage (1,3, 4).

Although awareness is difficult to study in the paediatric population it is reasonable to deduce that use of pEEG monitoring can help to reduce risk of awareness. NAP 5 demonstrated only a small number of cases of AAGA in children (8 of 141 cases identified in 2.8 million cohort) but found that 18% cases involved TIVA and 3/4 of cases were avoidable. In situations where TIVA is used with NMB or IV access cannot be reliably seen during anaesthesia, use of pEEG was recommended (5).

Despite current DOA algorithms being based on adult populations, interpretation of the paediatric EEG under anaesthesia shows recognisable patterns which can be used to titrate anaesthesia. In children over the age of 1, patterns start to become similar to that seen in adults. Some current DOA monitors

have age adjusted algorithms which enable more accurate numerical correlation with depth of anaesthesia particularly in children over 1.

Titration of anaesthesia based on traditional markers such as those mentioned above have been shown to be unreliable indicators of depth of anaesthesia and do not correlate well to an equivalent end tidal concentration of sevoflurane or clinical endpoints of loss of consciousness/awake (6).

Arguments against use of pEEG

Current available pEEG devices use algorithms based on data from adult populations. Therefore, as the EEG changes with brain development, their ability to monitor DOA in paediatric patients can vary with age, making the index number less reliable in younger patients particularly under 1 year old (7,8)

1) Fourier transformation of EEG in infants and neonates is less reliable and more research is needed before it's use is recommended in this age group. Age-related changes in the EEG, which mirror the synaptogenesis and myelination during the first year of life, also diminish the total DSA power and its representativeness of the depth of hypnosis in infants to the point that the devices currently in use cannot be deemed accurate and reliable in this group in paediatric patients less than 6 months of age (7) .
2) Interpretation may be difficult in children with co-morbidities particularly neurological diseases as lower bispectral index (BIS) and a greater tendency to burst suppression at comparable doses of anaesthetic has been described in these patients (7).

Current available monitors have age limits of recommended use from the manufacturer with the majority recommending index values used over the age of 1 or 2 years old and some stating that Density Spectral Array (DSA) can be used for over 6 month olds (7).

<u>Our suggested approach to use of pEEG in paediatric anaesthesia</u>

When to use?

Any cases where NMB used.

TIVA cases where IV access cannot be reliably monitored during case (risk of inadvertent disconnection may not be recognised).

TIVA cases which are prolonged to avoid over/underdosing.

How to use?

There are a small number of pEEG monitors currently available for use. A review of their merits are outwith the scope of this article. In our hospital we prefer to use Narcotrend monitoring as it has an age

adjusted algorithm, allows easy viewing of all relevant information and electrodes can be easily placed on children. TIVA is used routinely for paediatric cases in our hospital and we use the following principles to guide titration of anaesthesia.

Use raw EEG, Spectral Edge Frequency (SEF) and DSA to titrate depth of anaesthesia

Whilst some models have age adjusted numerical index values, rather than relying solely on this, we use the raw EEG, SEF and DSA to recognise common age-related patterns. Some or all these features are available on the commonly used DOA monitors.

Raw EEG

The ability to recognise normal waveform pattern by age range helps to analyse the EEG and depth of anaesthesia (figure 1). In all age ranges burst suppression or iso-electric EEG indicates overdosing.

Generally analysis of raw EEG can be divided into 3 age groups:

1. Neonates

Under anaesthesia neonates are delta dominant, with reduced power and SEF. This means that current DOA algorithms may not be able to interpret the waveforms and may display numerical index values that do not correlate with level of anaesthesia. In this age range, the monitor will recognize undifferentiated EEG or burst suppression. Anaesthesia should be titrated to avoid burst suppression and other clinical parameters, such as heart rate, blood pressure, and clinical signs of responsiveness used to guide dosing (1).

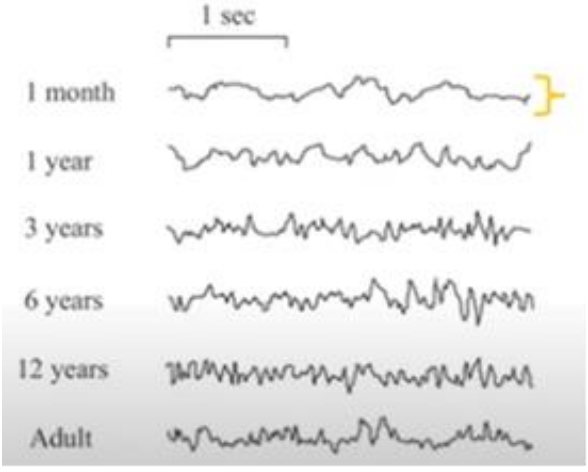

Figure 1. Awake pEEG Waveforms by Age. Neonate trace shows slow waves of high amplitude. Amplitude diminishes and frequency increases with age (9).

2. Infants

From 4-6 months old, theta and alpha bands develop and can be seen as distinct bands on DSA and SEF (figure 2). They can also show an initial paradoxical increase in power after induction of anaesthesia which then drops. Some studies have shown good correlation with index values in this age range to sufficient depth of anaesthesia (6)

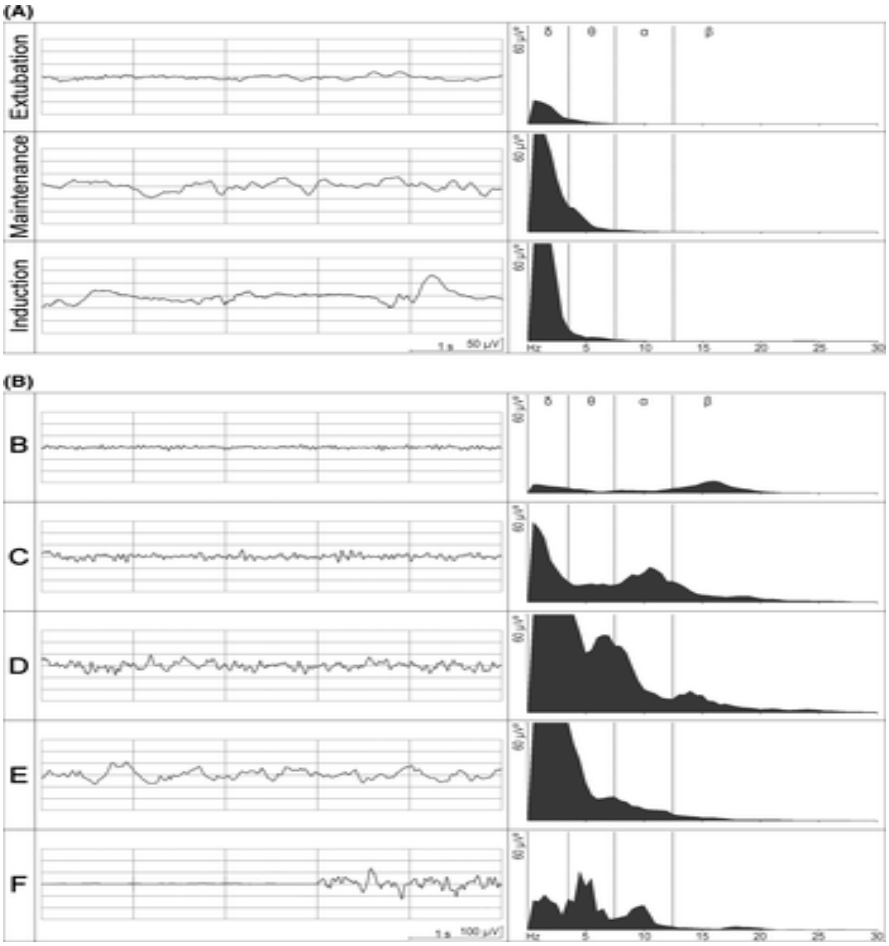

Figure 2. pEEG and SEF in (A) 3 month old and (B) 6 month old under anaesthesia. Notice more distinct waveforms and frequencies at 6m with changes in pEEG and SEF from light to deep anaesthesia B-F

3. Children aged 1-16

By 1 year old the pEEG pattern starts to show the more typical alpha-delta activity we associate with appropriate depth of anaesthesia which can be seen clearly on the raw EEG. By 10-14 years old the EEG resembles that of an adult. Therefore, the numerical indices given by the DOA monitor become more reliable with increasing age and can be used to titrate anaesthesia alongside the DSA/SEF.

<u>SEF 95 (frequency below which 95% of activity is taking place)</u>

Paradoxical changes in neonates/infants are seen with initial increase in SEF after induction which then decreases. After this initial perioid, a trend in SEF to lower frequency range indicates increased depth of anaesthesia while SEF in higher frequencies indicates light anaesthesia/emergence. The SEF95 is often used together with the DSA to assess hypnotic depth. Whereas the DSA provides a graphical representation of EEG frequency and power over time, the SEF95 provides a numerical index of EEG frequency and power at any given time (1).

<u>DSA</u>

In anaesthetized children over 1, the spectogram shows a classical ‘tram-line’ appearance, with higher power in alpha-delta frequency. Aim to maintain this pattern during maintenance of anaesthesia. If alpha starts to reduce and delta becomes stronger, it may indicate too deep anaesthesia/ burst

suppression. Increase in alpha activity is noticed when lighter anaesthesia/emergence. Again, in neonates and infants different patterns are seen, with mainly delta activity in neonates, then theta appearing around 4-6 months and more alpha predominance from 7 months (10).

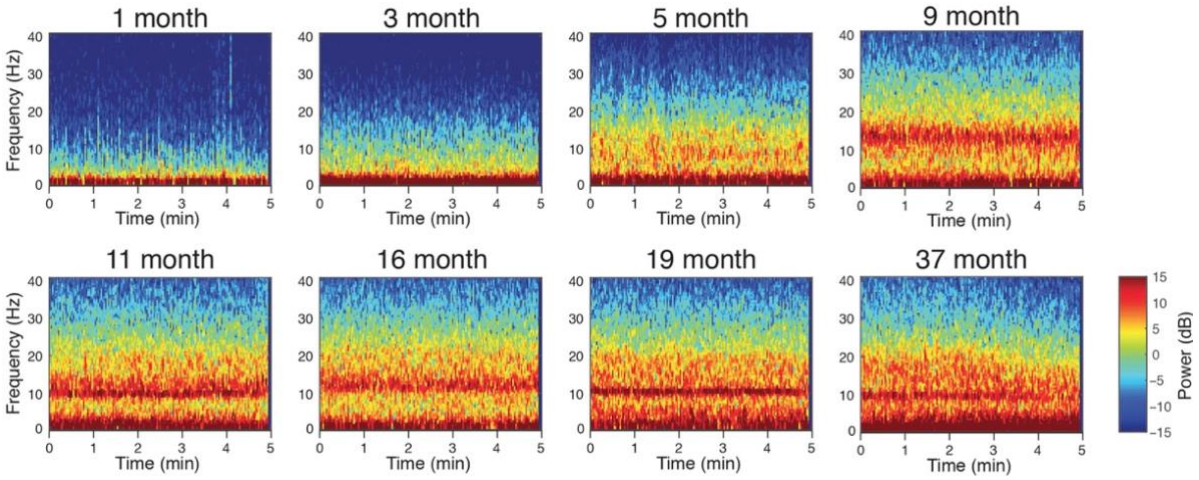

Figure 3. Changes in DSA with age under GA. Initially delta dominant then theta and alpha appearing (10).

Recognise common drug patterns and how this may affect EEG and DSA interpretation

Propofol and sevoflurane produce similar recognisable patterns with a strong alpha-delta signal and 'fill in with sevoflurane'. However, when other drugs are used in addition to these agents, the EEG will be affected and may be incorrectly interpreted by the DOA monitor giving incorrect numerical readings. Therefore, recognising these patterns on DSA and the EEG can aid clinical interpretation and titration of anaesthesia in these scenarios.

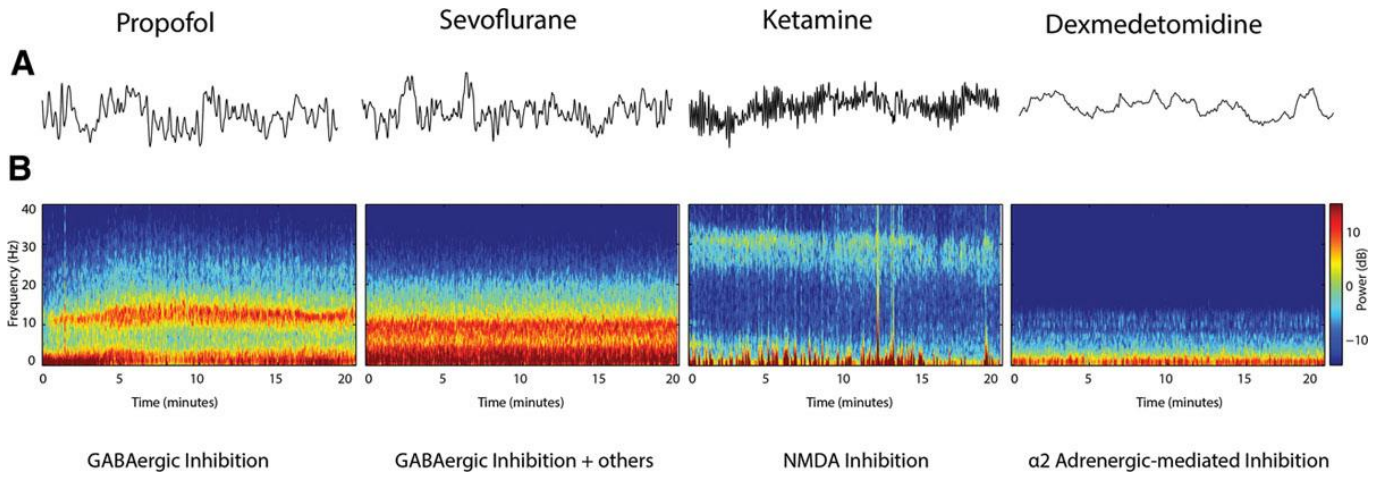

Figure 4. EEG waveforms(A) and DSA patterns (B) with different anaesthetic agents (11).

Conclusion

Whilst acknowledging the current limitations of pEEG in the paediatric population, particularly those under 1 year of age, we believe that it is a useful adjunct in depth of anaesthesia monitoring for TIVA cases and can potentially help reduce unwanted effects of overdosing/underdosing anaesthetic drugs.

Recognising the normal wavelengths that should be present for age and use of raw EEG, SEF and DSA can aid titration of anaesthesia but further research is needed to establish the role of pEEG DOA monitoring in infants and neonates.

REFERENCES:

1. Yuan I, Bong C, Chao J. Intraoperative pediatric electroencephalography monitoring - an updated review. Korean J Anesthesiol. 2024 Jan 17. doi: 10.4097/kja.23843 [Epub ahead of print]
2. Nimmo, A.F., Absalom, A.R., Bagshaw, O., Biswas, A., Cook, T.M., Costello, A., Grimes, S., Mulvey, D., Shinde, S., Whitehouse, T. and Wiles, M.D. (2019), Guidelines for the safe practice of total intravenous anaesthesia (TIVA). Anaesthesia, 74: 211-224. https://doi.org/10.1111/anae.14428
3. Han Y, Miao M, Li P, Yang Y, Zhang H, Zhang B, Sun M, Zhang J. EEG-Parameter-Guided Anesthesia for Prevention of Emergence Delirium in Children. *Brain Sciences*. 2022; 12(9):1195. https://doi.org/10.3390/brainsci12091195
4. Yuan, I., Chao, J.Y., Kurth, C.D. *et al.* Intraoperative EEG Monitoring in Pediatric Anesthesia.*Curr Anesthesiol Rep* 13, 135–142 (2023). https://doi.org/10.1007/s40140-023-00562-4
5. 5th National Audit Project of the Royal College of Anaethetists and the Assocation of Anaesthetists of Great Britain and Ireland. Accidental Awareness during General Anaesthesia in the United Kingdom and Ireland. Report and Findings. Sept 2014.
6. Dennhardt N, Arndt S, Beck C, et al. Effect of age on Narcotrend Index monitoring during sevoflurane anesthesia in children below 2 years of age. *Pediatr Anesth*. 2018; 28: 112–119. https://doi.org/10.1111/pan.13306
7. Grasso C, Marchesini V, Disma N. Applications and Limitations of Neuro-Monitoring in Paediatric Anaesthesia and Intravenous Anaesthesia: A Narrative Review. *Journal of Clinical Medicine*. 2021; 10(12):2639. https://doi.org/10.3390/jcm10122639
8. Gao Z, Zhang J, Zhang X, Wang L, Huang Y, Yu J. A retrospective study of the patient state index during general anesthesia in infants and young children. Clin Pediatr (Phila) 2023. Advance Access published on Apr 11, 2023. doi:10.1177/00099228231168475.
9. Constant, I. and Sabourdin, N. (2012), The EEG signal: a window on the cortical brain activity. Pediatric Anesthesia, 22: 539-552. https://doi.org/10.1111/j.1460-9592.2012.03883.x
10. Cornelissen L, Kim SE, Lee JM, Brown EN, Purdon PL, Berde CB. Electroencephalographic markers of brain development during sevoflurane anaesthesia in children up to 3 years old. Br J Anaesth 2018; 120: 1274-86.
11. Patrick L. Purdon, Aaron Sampson, Kara J. Pavone, Emery N. Brown; Clinical Electroencephalography for Anesthesiologists: Part I: Background and Basic Signatures. ANESTHESIOLOGY 2015; 123:937–960 doi: https://doi.org/10.1097/ALN.0000000000000841

AUTHORS:

Dr Lisa Dewar, specialist registrar, South East Scotland School of Anaesthesia

Dr Su Ying Ong, consultant, Royal Hospital for Children and Young People Edinburgh