An Electroencephalographic Classification for Coma

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ABSTRACT: ***Background:*** The assessment of thalamocortical function in comatose patients in the intensive care unit (ICU) can be difficult to determine. Since the electroencephalogram (EEG) affords such assessment, we have developed an EEG classification for comatose patients in our general ICU. ***Methods:*** One hundred EEGs were classified in a blinded fashion by two EEGers, using our method and that of Synek. Interobserver agreement was assessed using kappa score determination. ***Results***: Kappa scores were 0.90 for our system and 0.75 for the Synek system. (The Kappa score represents the inter-rater agreement that is beyond chance; 0.90 is almost perfect agreement, while 0.75 is substantial agreement). ***Conclusion:*** Our system for classifying EEGs in comatose patients has a higher interobserver reliability than one that was previously published. This EEG classification scheme should be useful in clinical electrophysiological research involving ICU patients, allowing for internal consistency and comparisons among centres.

RÉSUMÉ: Une classification électroencéphalographique du coma. ***Introduction:*** Il peut être difficile d'évaluer la fonction thalamocorticale chez les patients comateux à l'unité de soins intensifs (USI). Comme cette évaluation peut être faite au moyen de l'électroencéphalogramme, nous avons développé une classification EEG pour les patients comateux à notre USI générale. ***Méthodes:*** Deux électeoencéphalographistes ont classifié cent EEGs à l'aveugle, en utilisant notre méthode et celle de Synek. La concordance interobservateur a été évaluée au moyen de la cote kappa. ***Résultats:*** Les cotes kappa étaient de 0.90 pour notre système et de 0.75 pour le système Synek. (La cote kappa représente la concordance interobservateur au-delà de la chance; 0.90 est une concordance presque parfaite, alors que 0.75 est une bonne concordance). ***Conclusion:*** Notre système de classification des EEGs chez les patients comateux a une plus grande fiabilité interobservateur qu'une autre classification déjà publiée. Cette méthode de classification EEG devrait être utile en recherche clinique électrophysiologique chez des patients de l'USI, en tenant compte de la concordance interne et de la comparaison intercentres.

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Neurological disease in the setting of the intensive care unit (ICU) has a variable prognosis from full recovery to death. More than 10% of patients in general ICUs suffer serious central nervous system complications that add to their morbidity and mortality.[1] Assessment of illness severity is an important component of the management of such cases. There are a number of standardized assessment scales for measuring the severity of illness, which is related to outcome: APACHE (Acute Physiology and Chronic Health Evaluation), APACHE II or APACHE III, the Sepsis Severity Score, Simplified Acute Physiology Score II (SAPS II) and the Mortality Prediction Model (MPM).[2-6] The APACHE scales use the Glasgow Coma Scale as part of the acute physiology evaluation while other scales incorporate clinical neurological variables.[7,8] None, however, has included neurophysiological variables despite the predictive value of certain EEG patterns in certain conditions such as anoxic-ischemic encephalopathy.[9-12]

Electroencephalography serves as a sensitive tool for assessing cerebral cortical function of comatose or paralyzed patients, for whom clinical neurological evaluation is of limited value and the Glasgow Coma Score cannot be accurately applied.[13-15] In this paper, our objective was to establish a classification system for the EEG in coma that has high inter-observer reliability. A reliable classification system will allow for better identification of trends in the course of EEG findings. This should also provide the necessary consistency for clinical research in critical illness and foster collaboration among centres for outcome studies combining EEG and clinical-physiological scales.

Methods

One hundred consecutive electroencephalograms (EEGs) on 92 comatose patients (86 had 1, 5 had 2, one had 4 recordings) in the general ICU at Victoria Hospital, London, Ontario, were classified separately, in a blinded fashion, by two of the authors, GBY and RSMcL, first with the Synek system (Table 1) and then using our revised system (Table 2).[16] We had used the Synek system for about a year before the new system was developed; the EEGers were equally familiar with both systems.

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Interobserver agreement was assessed using kappa score determination, equal to the actual agreement beyond chance divided by the potential agreement beyond chance.[17]

Table 1: Synek (1988) Classification System

Grade	Subgrade	Subsubgrade
I (regular alpha, some theta – reactive		
II (predominant theta)	(a) normal voltage, reactive (b) low voltage, unreactive	
III (delta/spindles)	(a) predominant delta, widespread, rhythmic, reactive (b) spindle coma (c) predominant delta, low voltage, irregular, nonreactive (d) predominant delta, medium voltage, usually nonreactive	
IV (Burst-suppression/alpha coma/theta coma/low voltate delta)	(a) burst-suppression	(i) epileptiform activity (ii) no epileptiform activity
	(b) alpha pattern coma	(i) some reactivity (ii) no reactivity
	(c) theta pattern coma (d) < 20 μV delta	
V (Suppression)	Electrocerebral silence (< 2 μV)	

Table 2: EEG Classification

Category	Subcategory
I Delta/theta > 50% of record (not theta coma)	A. Reactivity B. No reactivity
II Triphasic waves	
III Burst-suppression	A. With epileptiform activity B. Without epileptiform activity
IV Alpha/theta/spindle coma (unreactive)	
V Epileptiform activity (not in burst-suppression pattern)	A. Generalized B. Focal or multifocal
VI Suppression	A. < 20 μV, but > 10 μV B. ≤ 10 μV

Guidelines

1. Burst-suppression pattern should have generalized flattening at standard sensitivity for ≥ 1 second at least every 20 seconds.
2. Suppression: for this category, voltage criteria should be met for the entire record; there should be no reactivity.
3. When > 1 category applies, select the most critical:
   - suppression is the most serious category
   - burst-suppression is more important than the category of triphasic waves which is more significant than dysrhythmia or delta
   - alpha pattern coma is more important than focal spikes, triphasic waves, dysrhythmia or delta categories.

The EEGs, usually done between 24-72 hours of coma onset, were performed in the Critical Care/Trauma Centre at Victoria Hospital, London, Ontario, between 1982 to 1992. All patients were over 16 years of age. We used 16 or 18 channel Grass Model 8 machines with paper-based recordings of greater than 20 minutes duration and a paper speed of 30 mm per second. Standard bipolar front-to-back, coronal bipolar and referential montages were used. Tin disk electrodes (interelectrode impedences 2,000-5,000Ωs) were secured with collodion and filled with saline jelly and applied using the ten-twenty system of electrode placement.[18] We tested for reactivity to stimulation during the recording using somatosensory (squeezing nail beds) and auditory (shouting the patient's first name in the ear) stimulation and passive eye opening. Electrographic reactivity to stimuli was separately assessed and tabulated. If any EEG response was noted to any of the three types of stimuli, reactivity was said to be present.

Results

The results of the agreement between electroencephalographers using the Synek and new systems is shown in Table 3.[16] This is shown in graphic form in Figure 1. With the Synek system the observed agreement was 77%, with expected agreement of 7.4%. This left an actual agreement beyond chance of 69.6% and a kappa score of 0.75, which is a *substantial* agreement. With the new classification system, the agreement was 91% with an expected agreement of 11.3%. This left an actual agreement beyond chance of 79.7% and a kappa score of 0.90, considerably better than the Synek system.

With the Synek classification, disagreements were principally between: "alpha coma with reactivity" and poorly sustained alpha with variability and reactivity; various slow frequency classifications. The lack of a triphasic wave classification caused some difficulty in placement in several records. This led to a best estimate of the next best classification on the part of both electroencephalographers.

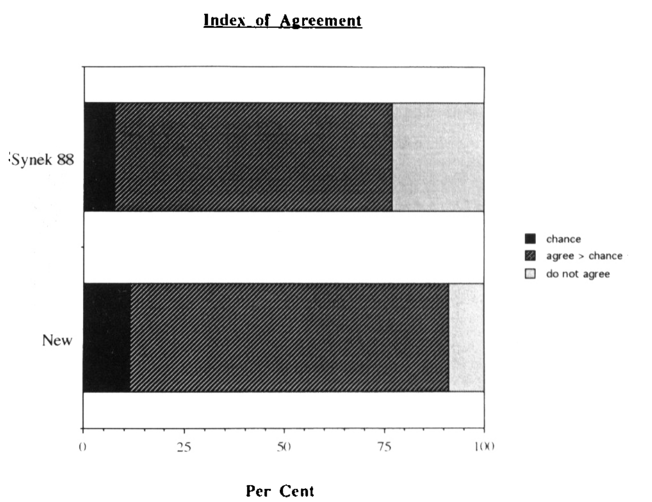

Figure 1: The index of agreement using our classification system of Synek (1988) our new classification system. The description is in the text.

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Table 3: Synek EEG Classification System

EEGer A (columns); EEGer B (rows)

	I	IIa	IIb	IIIa	IIIb	IIIc	IIId	IVai	IVaii	IVbi	IVbii	IVc	IVd	V
I	5													
IIa		3												
IIb		5	8								1			
IIIa				3										
IIIb					6									
IIIc						8						1		
IIId				2			3							
IVai								10						
IVaii									9			1		
IVbi	4			2						3				
IVbii				2	1			1			2		3	
IVc												4		
IVd													3	
V														10

NEW CLASSIFICATION SYSTEM

EEGer A (columns); EEGer B (rows)

	IA	IB	II	IIIA	IIIB	IV	VA	VB	VIA	VIB
IA	12	3								
IB	2	7								
II			9		4					
IIIA				7						
IIIB					7					
IV						15				
VA							15			
VB								5		
VIA									4	
VIB										10

With the new classification, the disagreements involved: presence or absence of reactivity and triphasic waves vs. burst-suppression pattern without reactivity. All the recordings could be classified without difficulty on first reading.

Figures 2-8 show examples of EEGs.

Discussion

Synek developed one of the first EEG classification systems for comatose patients.[16] Because of difficulties we encountered with this system, we developed a simpler model that proved to be comprehensive (applicable to all cases) and less ambiguous, with higher rate of inter-observer agreement than one that was previously published.

Some of the ambiguities in the Synek system were eliminated by: omitting assessment for reactivity in alpha pattern coma, in which it should be absent or essentially absent in any

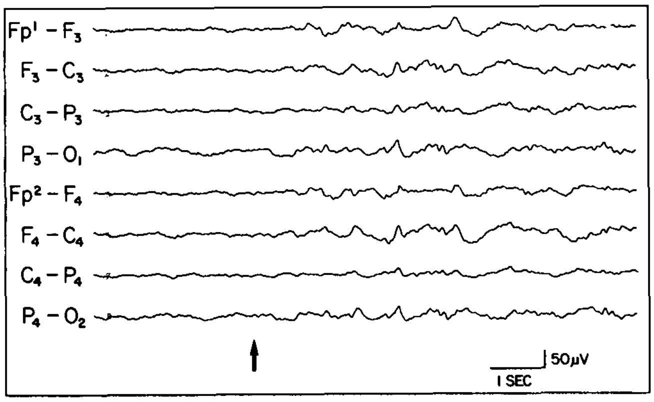

__Figure 2:__ A burst of slow frequency waves is evidence of reactivity to sound of a loud clap near the ear (arrow) in this patient with a toxic encephalopathy who survived.

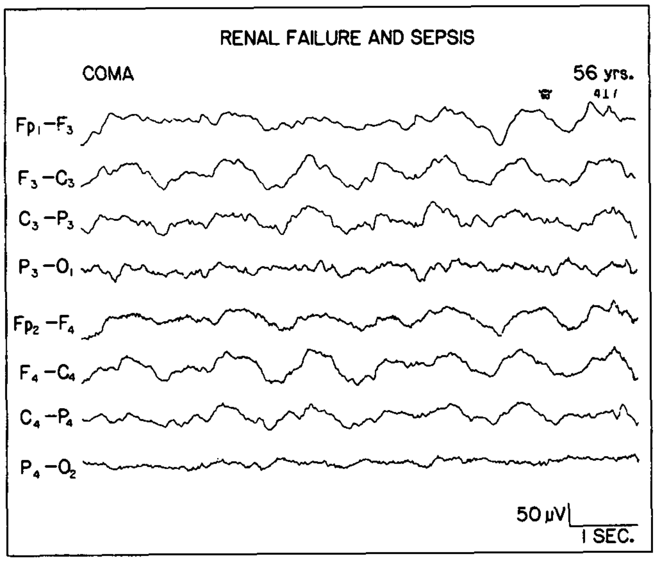

__Figure 3:__ Delta (≤ 4Hz) rhythm is the predominant frequency in this patient with renal failure and sepsis (New category I - see Table 2). Faster frequencies are reduced in the right side (lower 4 channels) due to a previous ischemic cerebral infarction. The patient recovered conscious awareness.

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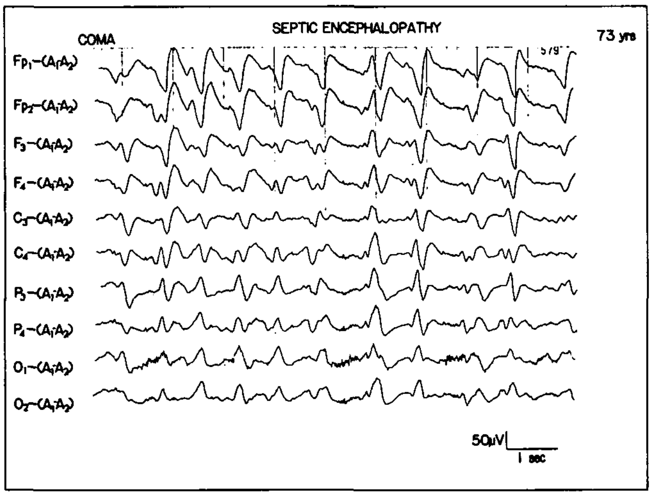

Figure 4: Triphasic waves (Category II) are present in this patient in coma with septic encephalopathy who later died of multiorgan failure.

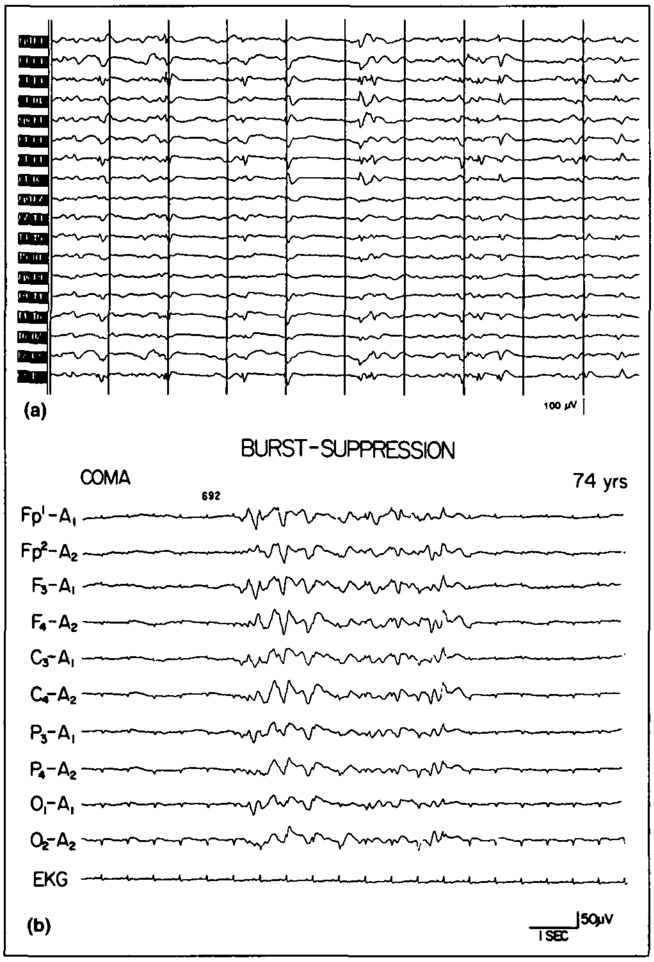

***Figure 5a and b:** A burst-suppression pattern consists of generalized bursts containing various frequencies with (a) (Category III A) and without (b) (Category IIIb) generalized epileptiform activity alternating with periods of generalized flattening or attenuation. In both cases the patient died from hypoxic-ischemic encephalopathy secondary to earlier cardiac arrest.*

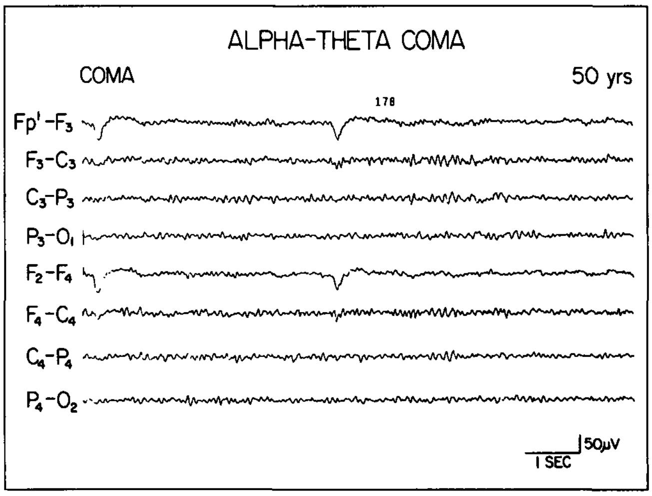

Figure 6: Alpha-theta pattern coma (Category IV) consists of frequencies between 5 and 13 Hz with widespread distribution and no reactivity in this patient with anoxic-ischemic encephalopathy from cardiac arrest. He died later without recovery of consciousness.

adding a classification for triphasic waves; combining categories which have been shown to be similar in character, e.g., alpha, theta and spindle coma; and by adding guidelines that allow prioritization when two or more classifications apply to the same case.[11]

It is important to test for reactivity, as illustrated in Figure 2. Patients with EEG reactivity have a lower mortality than those without EEG response.[19] Appropriately, this is reflected in the EEG classification for coma. For example, had reactivity not been tested in the Patient whose EEG is shown in Figure 2, the EEG would have been classified as showing suppression (Category VI. A). However, such reactivity, with augmented voltage, changed the classification to Class I. The patient did recover after exposure to profound hypoxemia with exposure to hydrogen sulfide gas. This favorable outcome would be less likely with sustained EEG suppression.

The future role of EEG in the ICU includes trending, detection of treatable conditions, such as seizures and potentially reversible ischemia from vasospasm, monitoring the effect of treatment and assessment of prognosis.[13,20] Jordan found continuous EEG monitoring altered management decisions in 82% of patients.[13] Prognostication needs to be linked to clinical variables, such as etiology and age.[21-23] Some EEG factors, e.g., generalized suppression, burst-suppression and generalized epileptiform activity, have previously been associated with a poor prognosis in anoxic-ischemic encephalopathy.[24,25] Conversely, serial EEG and clinical neurological findings have relatively low predictive value for mortality in systemic infection and metabolic disturbances other than anoxia.[26] In these potentially reversible encephalopathies, the EEG may not be sufficient to predict a poor prognosis, regardless of the pattern. Certain EEG patterns favor survival and allow some optimism, e.g., EEG reactivity, generalized dysrhythmias with spontaneous variability and focal rather than generalized epileptiform discharges,[27,28] in determining trends in the course of encephalopathy or its treatment.

The EEG has limitations in the ICU. Since the EEG signal represents summated post-synaptic potentials from the cerebral

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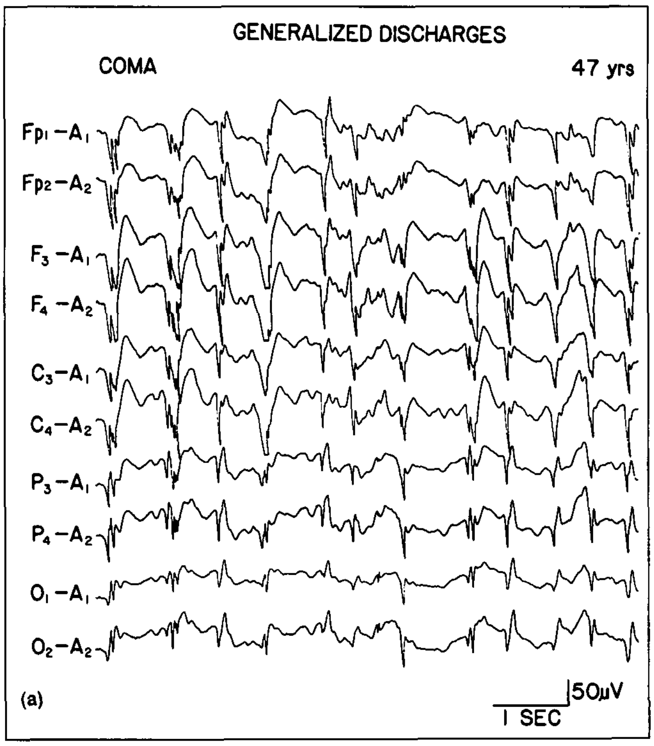

Figure 7a: This 47-year-old man suffered a cardiac arrest 4 days before this recording. Generalized epileptiform discharges (Category VA) are present against a suppressed background. He was in a deep coma with only flexor response to noxious stimuli. He had generalized myoclonus when not on muscle relaxants. He died shortly afterwards without recovery of consciousness.

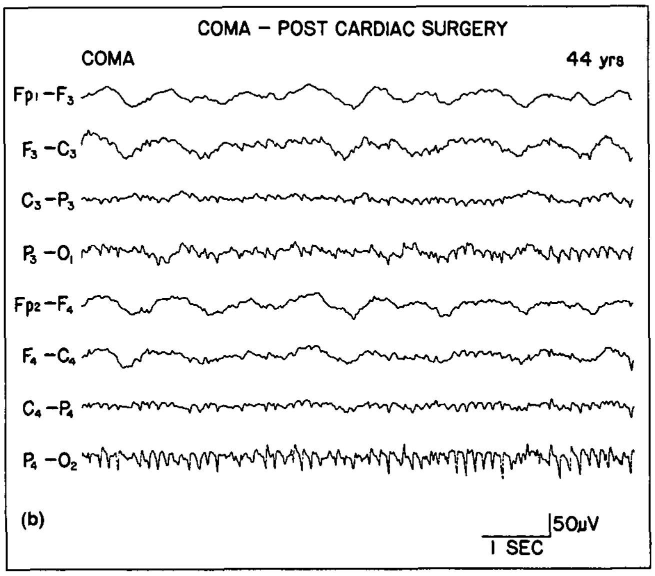

Figure 7b: This 44-year-old man had seizures associated with horizontal nystagmoid eye movements while in coma after open heart surgery. A seizure consisting of augmenting focal epileptiform discharges (Category VB) begins on the right occipital region (last channel) and spreads to the left side (4th channel). The patient ultimately completely recovered neurologically.

cortex only, it cannot be used to directly examine the impairment of brainstem function.[29] Hence, in the overall assessment

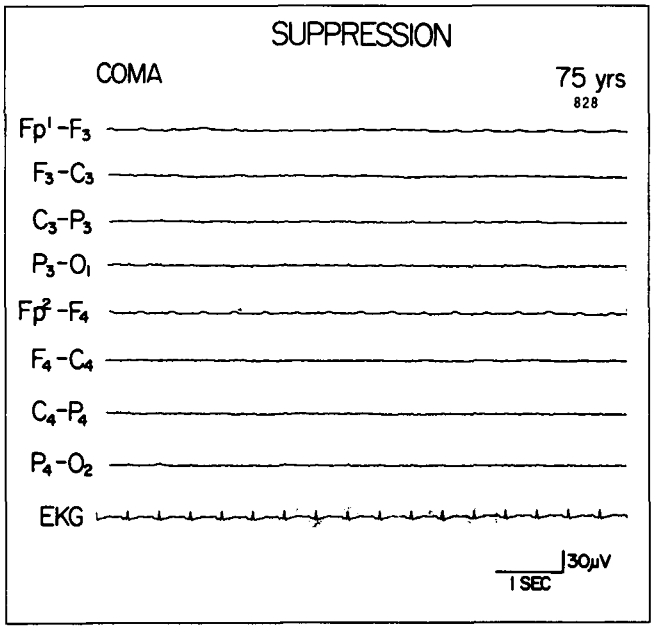

Figure 8: Generalized suppression (Category VI) followed cardiac arrest and severe anoxic-ischemic encephalopathy. The patient died without recovery of consciousness.

of brain dysfunction and prognosis, EEG findings should be combined with a clinical assessment of brainstem function.[30] The effects of a focal cerebral lesion may be overshadowed by a severe generalized disturbance, such as septic encephalopathy.[31]

Our paper represents initial steps in the development of a reliable EEG classification system for coma. This will be essential for the creation of a predictive model in the general ICU that incorporates both clinical neurological and neurophysiological predictors.[32] The use of other promising electrophysiological techniques, including continuous EEG monitoring and serial sensory evoked response testing, should also be assessed.[33-35]

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