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Rhythmic Coma in Children

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Abstract

We describe a syndrome of rhythmic coma in children that consists of an invariant, nonreactive, diffuse cortical activity of a specific frequency, such as alpha, beta, spindle, or theta, recorded from a comatose child. We report 11 cases of children who were found to be in rhythmic coma during their acute illnesses. Their ages ranged from 2 to 15 years, and their diagnoses included encephalitis, head trauma, seizures, near drowning, brain tumors, stroke, and metabolic derangements. The specific frequency of the electroencephalographic pattern, ie, alpha, beta, spindle, or theta, did not influence the outcome. The clinical outcome appeared to depend on the primary disease process rather than the electroencephalographic finding. The prognosis of alpha-frequency rhythmic coma as well as of rhythmic coma in general was better in children than in adults. The pathophysiology in children may be similar, ie, the interruption of reticulothalamocortical pathways by metabolic or structural abnormalities, but the expression of this deafferentation may be more varied in the developing brain. Thus, we propose the term rhythmic coma as a unified concept for alpha, beta, spindle, and theta coma in children. (*J Child Neurol* 1990;5:242-247).

The etiology and pathophysiology of alpha coma in adults has been well described.¹ Primary etiologies include cardiopulmonary arrest and brain-stem strokes, though more recently it has been reported in sedative overdose, respiratory arrest, and disturbances of glucose metabolism.² Disruption of reticulothalamocortical connections is the accepted mechanism for this syndrome; the disruption may be on a structural or metabolic basis.¹ As originally described in cases of cardiopulmonary arrest and brain-stem stroke, the prognosis of alpha coma is quite poor for survival.¹ However, the outcome may actually be more dependent on the etiology of the coma than on the electroencephalographic (EEG) findings.²

Only rare and scattered cases of alpha coma have been reported in the pediatric population.^{1,3-9} Etiologies included hypoxic-ischemic encephalopathy (cardiac arrest), hypoxia (strangulation and near drowning), metabolic and toxic derangements (Reye's syndrome and barbituate overdose), and

head trauma (Table 1). Outcome in reported cases was varied; three survived and were normal neurologically, three survived with significant neurologic deficit, and three died. Neurologically normal survivors were those after drug intoxication and strangulation. Death was the outcome in a drowning victim, a child with Reye's syndrome, and a child with cardiac arrest.

We present six children with alpha coma, as well as five other patients in coma that manifested persistent, diffuse, unreactive cortical activity of other frequencies, including beta, spindle, and theta. We propose that these all may be included under the description of rhythmic coma, as the pathophysiology may be similar in all 11 cases. The prognosis of patients in rhythmic coma is discussed.

Materials and Methods

Previously reported cases of alpha coma in children are summarized in Table 1. This includes all reported cases to our knowledge.

From February 1988 to February 1989, 11 acutely ill, comatose children with rhythmic coma on EEG were studied at Children's Hospital of Los Angeles. Electroencephalograms were performed using a 21-channel Nihon Koden machine. Electrode placement was according to the International 10-20 system, and gold electrodes were applied with paste. The EEGs were evaluated by W.D.G. and/or E.J.H. A record was described as rhythmic coma when the background was invariant, nonreactive, diffuse EEG activity of a specific frequency, such as alpha, spindle, beta, or

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TABLE 1
Reported Cases of Alpha Coma in Children

Source	Age, Yr	Diagnosis	EEG	Outcome
Westmoreland et al ¹	14	Cardiac arrest	Alpha coma	Death
Collins & Chatrian ³	1½	Strangulation	Alpha coma	Normal
Lersch & Kaplan ⁴	3	Barbiturate OD	Alpha coma	Normal
Molofsky ⁵	15	MVA, head trauma, cardiac arrest	Alpha coma	Seizures, vegetative
	12	Cardiac arrest	Alpha coma	Ataxia, LD, dysarthria
Yamada et al ⁶	2	Reye's syndrome	Alpha coma	Death
Homan & Jones ⁷	¾	Drowning	Alpha coma	Death
Sorensen et al ⁸	16	Cardiac arrest	Alpha coma	Impaired memory, inattentive
Pulst & Lombroso ⁹	13	Imipramine OD	Alpha coma	Normal

EEG = electroencephalogram; OD = overdose; MVA = motor vehicle accident; LD = learning disability

theta. Follow-up recordings were obtained when possible. Evoked potentials were performed on a limited number of patients with a Tracor Northern Nomad machine.

Results

Of the eleven children with rhythmic coma (Table 2), two survived without deficit, two survived with unchanged neurologic examinations, three survived impaired, and four died (one was a cardiac death). Therefore, four of 11 (36%) survived without new deficits. Etiologies of coma in these cases included encephalitis, head trauma from a motor vehicle accident, stroke with sepsis, and stroke alone. Of those that survived with new deficits, two had head trauma from motor vehicle accidents, one had a brain tumor, and one had both a stroke and hypernatremia. In the category of patients who died acutely, two were drowning victims, one sustained motor vehicle accident-related head trauma, and one had a thalamic tumor. If the groups of patients that survived with new deficits and those that died acutely are considered together, there are a total of seven patients with poor outcome. In this group, three suffered head trauma in motor vehicle accidents, two were drowning victims, and two had brain tumors. In comparison, the four survivors without deficits included only one head trauma from a motor vehicle accident, no drowning victims, and no brain tumors. Thus, patients with rhythmic coma from these three causes may have poor prognoses.

All frequencies of rhythmic coma were represented: six alpha, three spindle, and one each of

theta and beta frequencies. Figures 1 and 2 provide examples of rhythmic coma EEGs. Of the patients with rhythmic coma of alpha frequency, two survived intact (one normal and one with unchanged preexisting deficits) and four died, one a cardiac death. Thus, 33% of patients with alpha-frequency rhythmic coma survived intact. In the remaining five patients representing rhythmic coma of spindle, theta, or beta frequencies, all five survived, with two of these intact (40%). Survival rates without new deficits are comparable among those with alpha-frequency rhythmic coma (33%), other-frequency rhythmic coma (40%), and rhythmic coma overall (36%).

In patients 2, 5, 6, 7, and 8 (Table 2), repeat EEG recordings were obtained during the acute illness. Patients 5 and 8 demonstrated a persistence of rhythmic coma with poor outcomes. The other three patients, 2, 6, and 7, demonstrated resolution of rhythmic coma with poor outcome in one and no change from baseline in the other two. This suggests two important points: (1) rhythmic coma of various frequencies may be an acute phenomenon and may last for only 4 to 11 days, and (2) persistence of rhythmic coma of any frequency during an acute illness may suggest a poor prognosis.

Evoked potentials were tested in patients 1, 5, and 8 during their acute illnesses (Table 3). Each demonstrated abnormalities suggesting dysfunction of auditory and/or somatosensory pathways. Auditory-evoked potentials in patient 8, who suffered head trauma and a posterior fossa hematoma with mass effect, were initially abnor-

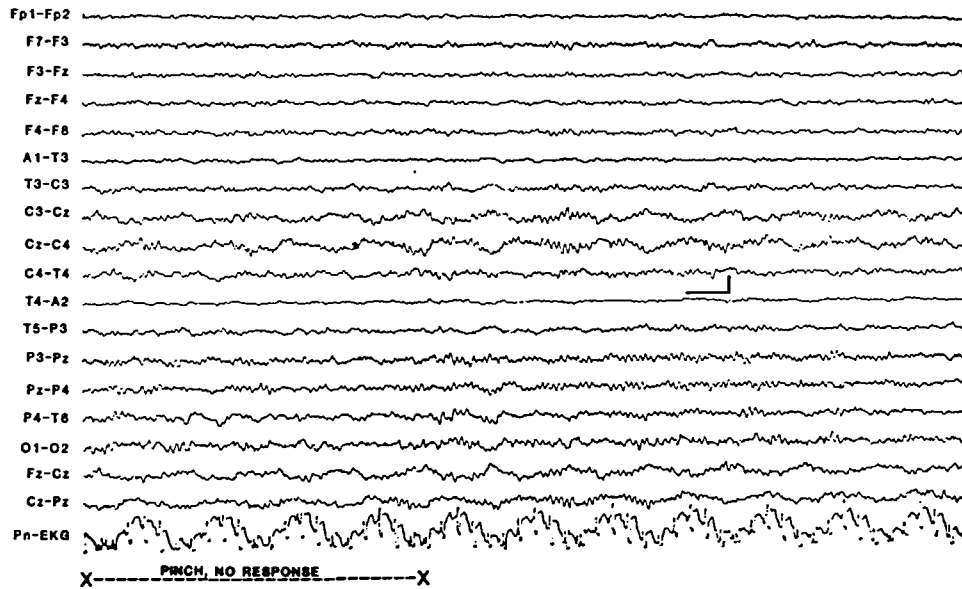


FIGURE 1
Initial EEG from patient 2, a 2-year-old girl, after head trauma. The record demonstrates invariant, unreactive, diffuse 8-Hz activity representative of alpha frequency rhythmic coma. The EEG settings included high-frequency filter of 70 Hz, time constant of 0.1 s, sensitivity of 7 mV/mm, and paper speed of 30 mm/s. Calibration bar equals 50 mV and 1 s. Pn-EKG = cardiopneumograph.

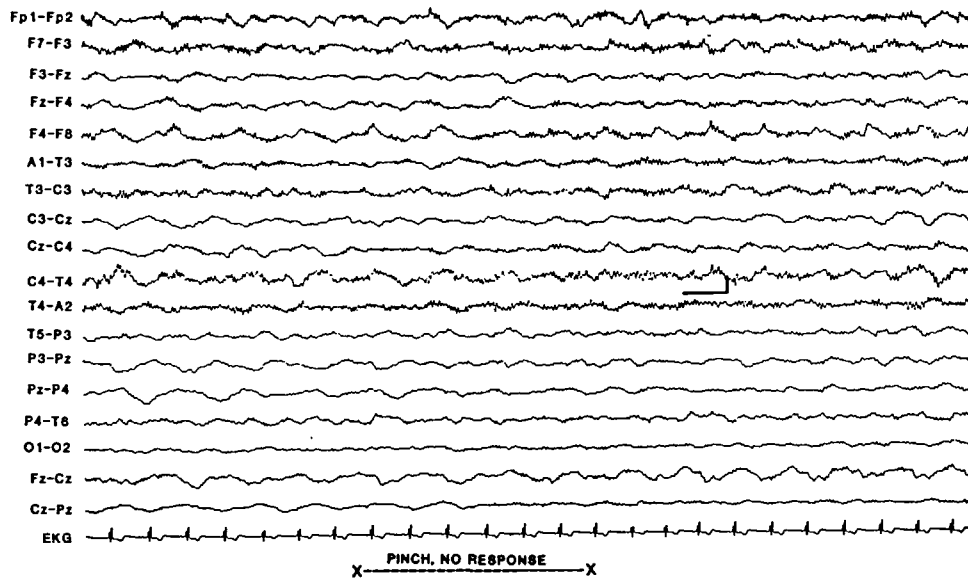


FIGURE 2
EEG from patient 11, a 15-year-old boy, after head trauma. The record is representative of spindle frequency rhythmic coma. The EEG settings included high-frequency filter of 70 Hz, time constant of 0.1 s, sensitivity of 5 mV/mm, and paper speed of 30 mm/s. Calibration bar equals 50 mV and 1 s.

Rhythmic Coma

TABLE 2
Cases of Rhythmic Coma

Patient No.	Age, Yr	Sex	Diagnosis	Day of Illness	EEG Frequency	Drugs (Serum Level)	CT Scan	Outcome
1	2	M	Drowning	2	Alpha	None	None	Death, day 4
2	2	F	MVA, head trauma, seizure	1 8	Alpha Theta, delta	Phet (NA), narcotics	None	Death, MI, day 11
3	2	M	Drowning	4	Alpha	None Pheb (NA), pancuronium	None	Death, day 5
4	4	M	Viral encephalitis, seizure	2 4 mo	Alpha Normal	Pheb (48*), phet (2.6*) None	Normal	Survived, normal
5	8	M	Thalamic tumor	5 11	Alpha Spindle	Pheb (20*) None	Abn	Death
6	12	F	SCD, NF, seizure, stroke	1 7	Alpha Theta slowing, disorganized	Carb (9.7†) Carb (NA), valium	Abn	Baseline, demented, bedridden
7	11	M	MR, CP, seizure, status epilepticus	1 5	Spindle Theta slowing	Pheb (48*), phet (36*) Pheb (NA), phet (NA)	Normal	Baseline
8	12	F	MVA, head trauma	1 12	Spindle Theta	Phet (13*), narcotics Phet (10*), valium	Abn	Retarded, hemiparesis
9	13	F	Suprasellar tumor, hypernatremia, stroke	1	Spindle right, attenuation left	Pheb (<5*)	Abn	Quadriplegia
10	3	M	MVA, head trauma	21 2.5mo	Theta Slow, sharp	Chl hyd None	Abn	Spastic quadriplegia, seizure, hydrocephalus
11	15	M	MVA, head trauma	1	Beta	Chl hyd, albuterol	Abn	Alert, spinal cord dysfunction

*µg/mL.

†µg/dL.

EEG = electroencephalogram; CT = computed tomographic; MVA = motor vehicle accident; phet = phenytoin; NA = not available; MI = myocardial infarction; phebo = phenobarbital; Abn = abnormal; SCD = sickle cell disease; NF = neurofibromatosis; carb = carbamazepine; MR = mental retardation; CP = cerebral palsy; chl hyd = chloral hydrate.

mal but improved to near normal after surgical evacuation of the hematoma.

Discussion

We define rhythmic coma as a diffuse, invariant, nonreactive EEG frequency of alpha, beta, theta, or spindles present in a comatose child. The pathophysiology of rhythmic coma in children may be the same as alpha coma in adults, ie, the interruption of reticulothalamocortical pathways by structural or metabolic derangements. The manifestation of this deafferentation may be more varied in children (alpha, beta, theta, or spindle frequencies), possibly because of the difference in the response of the immature brain to such deafferentation. The more in-

clusive term of rhythmic coma is proposed for this age group.

Comparison of our patients with alpha-frequency rhythmic coma (Table 2, cases 1 through 6) to previously reported cases of alpha-frequency rhythmic coma in children (Table 1) initially suggests differences in coma etiology between the two groups. However, a physiologic approach lessens these differences. Each case from the two groups could be described as coma secondary to hypoxic-ischemic encephalopathy (cardiac arrest, strangulation, drowning), structural abnormalities (head trauma, brain tumor, stroke), or metabolic derangements (drug overdoses, Reye's syndrome, encephalitis, status epilepticus, hypernatremia). Adult cases of alpha coma fit into these categories as well: hypoxic-

TABLE 3
Evoked Potentials and Rhythmic Coma

Patient No.	Age, Yr	Diagnosis	Frequency	Evoked Potential Result
1	2	Drowning	Alpha	SEPm: absence of N20 bilaterally
5	8	Thalamic tumor	Alpha, spindle	BAEP: flattening of waves III and V. SEPm: asymmetry with flattening and delay of N13 and N20 on right stimulation
8	12	MVA, head trauma	Spindle, theta	BAEP: no wave forms on left ear stimulation and flattening and delay of wave V on left stimulation

MVA = motor vehicle accident; SEPm = somatosensory evoked potential after stimulation of median nerve; BAEP = brain-stem auditory-evoked potential.

ischemic encephalopathy (cardiac arrest) and structural abnormalities (stroke) as discussed by Westmoreland et al¹ and metabolic derangements (drug overdoses, hypoglycemia, or hyperglycemia) as discussed by Austin et al² and Pulst and Lombroso.⁹

The 8-year-old patient with a thalamic tumor (patient 5) is intriguing, considering the accepted pathophysiology of alpha-frequency rhythmic coma, ie, the interruption of reticulothalamocortical pathways. Autopsies of all four patients who died were performed, but examination of the brain was allowed only in patient 5 in whom we already knew of the structural deafferentation, ie, thalamic tumor. Nonetheless, abnormal evoked potential studies in patients 1, 5, and 8 (Table 3) suggest dysfunction of related pathways. These three patients manifested alpha-, theta-, and spindle-frequency rhythmic coma and so suggest that the pathophysiology of deafferentation as described in adult alpha coma after brain-stem stroke and cardiac arrest¹ may also be operative in children with rhythmic coma.

Barbiturates and other central nervous system-active medications administered to these patients may influence the manifested frequency slightly, but could not be solely responsible for the patients clinical status or EEG findings.^{4,9-11} Certainly, drug overdose alone is a known cause of rhythmic coma of various frequencies, but each of our patients had suffered significant hypoxic-ischemic, structural, or metabolic insults as well.

Austin et al² and Iragui and McCutchen¹² suggested that if all etiologies of alpha coma in adults were considered, the outcomes might be less dismal than if victims of cardiac arrest and stroke were considered alone, suggesting that outcome was dependent on coma etiology rather than on EEG findings. Perhaps because of the more varied scenarios in which alpha coma is found in childhood (Tables 1 and 2), outcome of alpha coma in children is not as bleak as in adults after arrests or stroke, an idea mentioned by Iragui et al.¹² In our patients with

rhythmic coma, outcome did depend on etiology of coma; near-drowning victims, followed by brain tumor patients and those suffering from head trauma in motor vehicle accidents had the poorest prognosis. There was no clear association between the etiology of coma and EEG frequency, nor any relationship of EEG frequency to outcome.

Our data suggest that children with rhythmic coma of all frequencies have a 33% to 40% survival rate without new deficits. Compared to cases of alpha coma in adults with cardiac arrest and brain-stem stroke, this is a much better survival rate.^{1,13,14}

The outcome of children with rhythmic coma may be no worse than in children in coma without rhythmic EEG activity. Previous studies of children with prolonged, nontraumatic coma (encephalitis, anoxia, and Reye's syndrome)¹⁵ and with head trauma¹⁶ report that approximately one third of these patients survived without deficits. A separate study concerning near-drowning victims reports that only 14% have a good prognosis.¹⁷ Both of our near-drowning patients died.

According to our data, rhythmic coma may be an acute phenomenon lasting from 4 to 11 days. However, continual monitoring was not done, thus limiting this inference. Persistence of rhythmic coma, even of a frequency other than that originally recorded, may be a poor prognostic sign. This is similar to suggestions by Iragui et al¹² that immediate and brief alpha coma has a better prognosis than later and persistent alpha coma in adults.

Previously, only scattered reports of alpha coma in children existed in the literature (nine patients), suggesting that it was a rare phenomenon.^{1,3-9} In 1 year's time, we identified six patients with alpha coma and five patients with rhythmic coma of other frequencies at one institution, suggesting that this is not a rare occurrence.

Other-frequency rhythmic coma has been reported, including spindle frequency (secondary to hypoxic-ischemic encephalopathy, stroke, encephali-

tis, and drug overdose),^{9,10,18-22} beta frequency (secondary to stroke, hypoxic-ischemic encephalopathy, and drug overdose),^{11,21,23} theta frequency (hypoxic-ischemic encephalopathy),²² and coexisting frequencies over the course of an acute illness (secondary to hypoxic-ischemic encephalopathy and drug overdose).^{9,11,21,22} Synek and Synek in 1984 and 1987 proposed an entity of theta coma and suggested its similarity to alpha coma.^{24,25} However, the description of their EEG findings in theta coma suggests a variant of a burst-suppression pattern at times with reactivity, rather than invariant, nonreactive, diffuse activity of a distinct frequency that qualifies as alpha- or other-frequency rhythmic coma. Moreover, their population dealt only with adults with cardiopulmonary arrest or motor vehicle accident victims with head trauma, both of which fit into poor prognostic groups from the adult literature^{1,2} and as suggested by our data. We submit that theta coma as they report is fundamentally different from the syndrome of rhythmic coma that we describe.

In summary, we propose a syndrome of rhythmic coma in children, defined as diffuse, invariant, nonreactive activity of alpha, spindle, beta, or theta frequencies recorded in a comatose child. Rhythmic coma may have the same pathophysiology as adult alpha coma but may be variably expressed by the immature or previously abnormal brain. The frequency does not affect the prognosis, but the etiology of the coma itself does. Persistence of rhythmic coma may carry a poor prognosis. Recognition of this relatively frequent syndrome in children is important for prognosis and management of these patients, who have a 33% to 40% chance of survival without deficits, in contradistinction to a far worse prognosis for alpha coma in adults. Prognostic inferences should be based on the etiology of coma and not solely on the EEG.

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