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The Importance of Epileptiform Activities in Breach Rhythms

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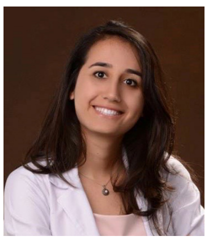

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Abstract

Objective: The breach rhythm is a benign activity variant that can be confused with epileptiform discharges. We aimed to investigate the relationship between breach rhythms and seizures, even though they are known as benign variants. In addition, to identify whether the seizure was related to seizures and which conditions should be considered by electroencephalographers.

Methods: Electroencephalograph records recorded between October 2017 and March 2021 were re-examined. Breach rhythms were classified for localization, frequency, morphology, and presence/absence of sporadic epileptiform discharges. The placement of skull defects, etiology of skull defects, presence of encephalomalacia, symptomatic seizures, and anti-seizure medication use were documented. Statistical analysis was performed using Statistical Package for Social Sciences software version 26.0.

Results: We included 71 recorded breach rhythm activities. All breach rhythms had a similar placement to skull defects. Twenty-three (32.4%) patients had an epileptiform abnormality with a breach rhythm in the same area. The presence of epileptiform abnormalities was associated with seizures more than 4.5 times [p=0.004, odds ratio (OR): 4.667]. The theta frequency was related to the presence of sporadic epileptiform activity exceeding 3.3 times (p=0.029, OR: 3.316).

Conclusion: Our study showed that breach rhythms are unrelated to seizure unless sporadic epileptiform activity is present. If the breach rhythm frequency is theta, the risk of sporadic epileptiform activity is higher than the alpha or beta frequency breach rhythm. According to our study results, the breach rhythm is a benign variant, unless accompanied by sporadic epileptiform discharges.

Keywords: Benign variants, breach effect, breach rhythm, epileptiform discharges, seizure

INTRODUCTION

The primary aim of all electroencephalographers is correct detection of epileptiform activities. Before we decide whether the activity is an epileptiform discharge, we consider whether there are artifacts, benign variants, or graph elements in the sleep. Breach rhythm or "breach effect" is classified as a benign variant, as described by Cobb et al.[1] in 1979. It is known to occur because of skull defects. The presence of bone prevents electrophysiological activity from the brain to the scalp.[1,2] The morphology of breach is typically sharply countered, with a higher amplitude, and generally 6-11 Hz but may have a faster or slower frequency.[1-4] Breach rhythms can be intermittent or continuous. If they are intermittent, this may lead to misdiagnosis as epileptiform activity. The irregular and sharp counter morphology can lead to misdiagnosis of epileptiform activity. On the other hand, the irregular morphology of breach rhythms may mask epileptiform activity in the same places. In addition, according to a three-case series, skull defects may also lead to the consideration of epileptiform discharges as artifacts on electrodes near defects.[5] Although breach rhythms are described and classified as a benign variant owing to skull defects, a few case reports have shown that the breach rhythm appears in patients with osteolytic skull involvement. In addition, breach rhythms may disappear due to seizures, recurrence, or enlargement of tumors.[6-9]

Identifying breach rhythms with/without sporadic epileptiform activity is essential in determining whether patients should be treated according to seizure risks. Our study aimed to investigate the relationship between breach rhythms and seizures, even though they are known as benign variants. In addition, to identify whether they were related to seizures and which conditions should be considered by electroencephalographers.

METHODS

Patients

The clinical data of patients were collected from the hospital archives. Demographic data, seizure history, places of cranium defects, presence of encephalomalacia, and use of anti-seizure medications (ASMs) were recorded.

The study was approved by the Dokuz Eylül University Local Ethics Committee (decision no: 2021/08-38, date: 08.03.2021).

Procedures and Definitions

Electroencephalography (EEG) records obtained between October 2017 and March 2021 from the epilepsy center of Dokuz Eylül University were re-examined, retrospectively. Datasets were re-analyzed if patients had a history of a skull defect or a "breach rhythm/effect" was reported. The investigators collected the data and re-analyzed all EEG records.

For the routine EEG records, the electrodes were placed according to the universal 10-20 system (Fp1, F3, F7, T3, T5, C3, P3, O1, Fz, Cz, Pz, Fp2, F4, T4, C4, P4, O2). The EEG device filters were LFF 0.3 Hz and HFF 70 Hz with a sensitivity of 100 V. The page sweep rate was 10 mm/s. All records considered at least three montages: monopolar, double banana, and transverse. If necessary, Laplacian and other montages were also used. Breach rhythms were described with higher amplitudes than those of the other electrodes and had an irregular sharp or sinusoidal morphology. The frequency, morphology, and continuity of activities were recorded.

The frequency was classified as theta, alpha, and beta. If there was a mixture of frequencies, we considered the lowest frequency for classification. The presence of sporadic epileptiform activity in the breach rhythm was noted. The instances in the EEG records are shown in Figures 1, 2.

All demographic data were documented. Skull defects were classified as frontal, temporal, parietal, or occipital. Additionally, encephalomalacia, the etiology of skull defects, symptomatic seizures, and ASM use were documented. The clinical course and neuroimaging findings of all included patients were re-analyzed.

Statistical Analysis

The statistical analysis was performed using IBM Statistical Package for Social Sciences software version 26.0.[10] The Kolmogorov-Smirnov test was performed for ages (p=0.2), and the histogram distribution was considered for normality tests. Missing data were assigned a missing value when statistical analyses were performed.

Descriptive statistics present the mean and standard deviation for age distribution as a normal variable. Fisher's exact test and the chi-square test were used for categorical variables. Bonferroni correction was used if the variables were more than two. Spearman's correlation analysis was used to determine which variables could be included in the regression analysis model. A binary logistic regression model was used to investigate independent risk factors. The 95% confidence intervals and $p<0.05$ were considered statistically significant.

MAIN POINTS

- Higher amplitude and sharply irregular morphology are the main structures to describe the breach rhythm, which could have any frequency.
- The breach rhythm is not associated with seizures unless it is accompanied by sporadic epileptiform discharges.
- The presence of the theta frequency is associated with a higher risk of sporadic epileptiform discharges in the breach rhythm.

RESULTS

Seventy-one recorded breach rhythm activities were obtained from different patients.

All breach rhythm activities recorded a similar placement as skull and bore hole defects regarding the area of the defects. The descriptive data are summarized in Table 1.

There was no statistical significance for age and sex in the seizure and seizure-free groups (Table 2).

Morphology of Breach Rhythm During Seizure

The breach rhythm morphology was categorized as theta, alpha, mu, and beta. Twenty-one (29.6%) patients had a beta-breach rhythm, 10 (14.1%) patients had an alpha-breach rhythm, eight (11.3%) patients had a mu-breach rhythm, 13 (18.3%) patients had a theta breach rhythm, and 19 (26.8%) patients had and theta and beta breach rhythms. There were no significant differences in the presence of seizures between the subgroups (Tables 1, 2).

Frequency of Breach Rhythm During Seizure

Breach rhythm frequencies were categorized as theta, alpha, and beta. We ranked frequencies according to the lowest frequency if there were more than two differences, such as alpha, theta with or without beta. There were no significant differences between the three frequency subgroups and according to the presence of seizures (p=0.929). Although we categorized the breach frequency in two subgroups, the theta and alpha or beta rhythm, there are no statistically significant differences (p=0.861) (Table 2).

Frequency of Breach Rhythms in Patients with Encephalomalacia

There were no significant difference between the frequency of breach rhythms and the presence of encephalomalacia (p=0.703).

Frequency of Breach Rhythm with Epileptiform Discharges

When breach frequency was divided into two subgroups, the theta and alpha or beta frequency was related to the presence of sporadic epileptiform activity >3.3 times [odds ratio (OR): 3.316, 95% confidence interval (CI): 1.133-9.699; p=0.029] (Tables 3, 4).

Figure 1. A) Breach rhythm with beta frequency, B) Breach rhythm with alfa frequency, C) Breach rhythm with mü morphology, D) Breach rhythm with theta frequency

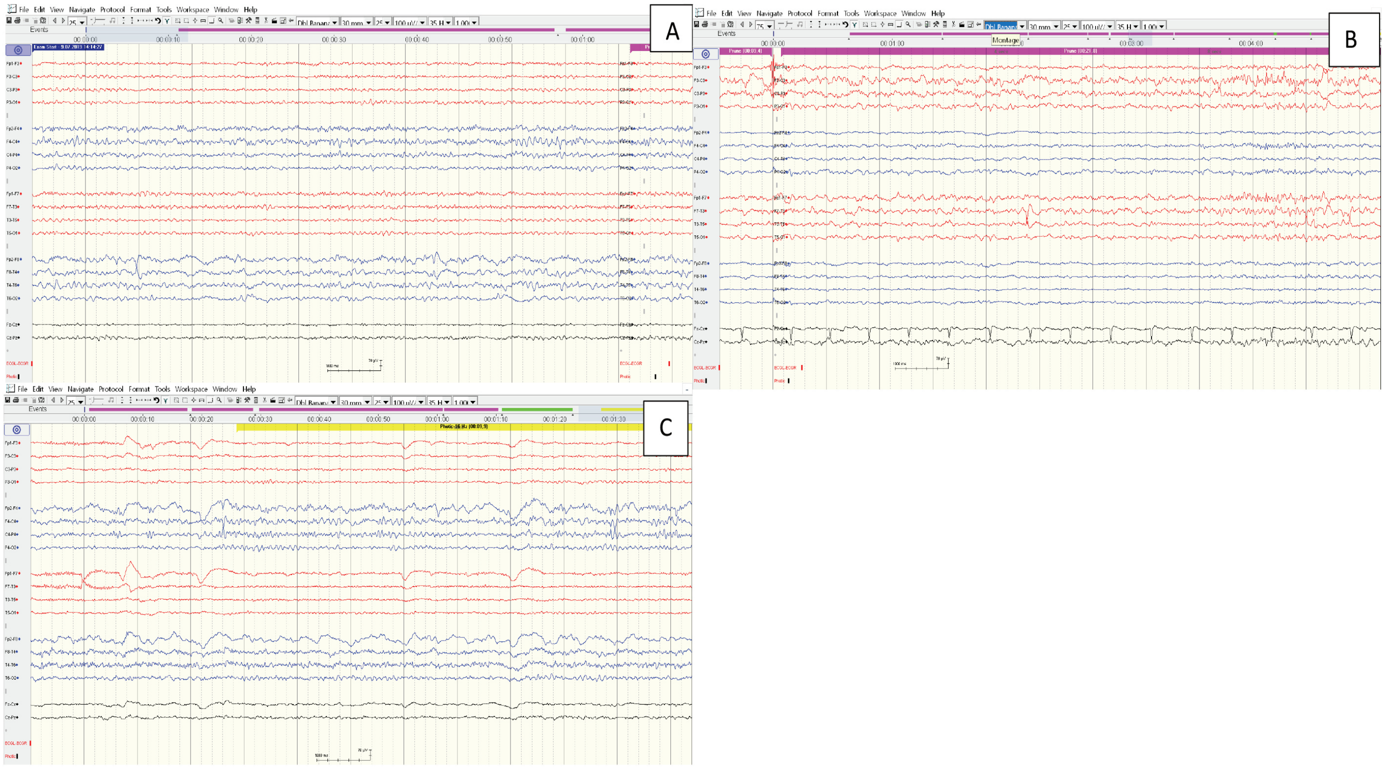

Figure 2. A-C) Breach rhythm with sporadic epileptiform abnormality

Table 1. Demographic and clinical data of patients with breach rhythm

Age, years (n=71)	Mean±SD 52.55±15.36 (21.00-87.00)	
Gender	**n**	**%**
Male	33	46.5
Female	38	53.5
Total	71	100.0
Seizure		
Yes	26	36.6
No	45	63.4
Total	71	100.0
ASMs		
Yes	63	88.7
No	8	11.3
Total	71	100.0
Breach morphology		
Theta	13	18.3
Theta-beta	19	26.8
Alpha	10	14.1
Mu	8	11.3
Beta	21	29.6
Total	71	100.0
Breach frequency		
4-7.99 Hz	21	29.6
8-12.99 Hz	18	25.4
>13 Hz	21	45.1
Total	71	100.0
Breach with epileptiform discharges		
Yes	23	32.4
No	48	67.6
Total	71	100.0
Localization of breach rhythm		
F3/4	13	18.3
F7/8	21	29.6
C3/4	10	14.1
T3/4	22	31.0
P3/4	4	5.6
O1/O2	1	1.4
Total	71	100.0
Encephalomalacia		
With encephalomalacia	58	88.1
Without encephalomalacia	8	11.9
Total	67	100.0
Missing	4	
Localization of cranium defect		
Frontal	30	44.8
Temporal	20	29.9
Parietal	15	22.4
Occipital	2	3.0
Total	67	100.0
Missing	4	
Etiology of skull defect		
Head trauma	7	10.1
Tumor surgery	37	53.6
Intracranial hemorrhage	19	27.5
Epilepsy surgery	6	8.7
Total	69	100.0
Missing	2	

ASMs: Anti-seizure medications, SD: Standard deviation

Breach Rhythms Associated with Epileptiform Activity and Seizures

The data were divided into two main groups according to breach rhythms with and without sporadic epileptiform activity (spike and/or sharp wave). Twenty-three (32.4%) patients had an epileptiform abnormality with breach rhythm in the same area, whereas 48 (67.6%) patients had only breach rhythm (Table 1). The presence of epileptiform abnormalities was associated with seizures more than 4.5 times (OR: 4.667, 95% CI: 1.613-13.498; p=0.004) (Table 5).

Localization of Breach Rhythm Associated with Epileptiform Activity

The localization of breach rhythm was categorized into temporal and extratemporal subgroups. There was no statistical significance regarding the localization of breach and the presence of sporadic epileptiform activity (OR: 2.832, 95% CI: 0.870-9.220; p=0.084) (Tables 3, 4).

DISCUSSION

Our study showed that breach rhythms were unrelated to seizures, except in cases with sporadic epileptiform activity. The presence of sporadic epileptiform discharges increases the independent risk of seizures by more than 4.6 times. In addition, lower frequency, as a theta breach rhythm, was associated with a 3.3-fold risk of sporadic epileptiform discharges with breach rhythm.

Identifying sporadic epileptiform discharges in the breach rhythm may be challenging for two reasons. One explanation is that irregular and sharp breach rhythms may mask epileptiform discharges. Second, artifacts in the same area may conceal sporadic epileptiform discharges that imitate natural phenomena. Mader et al.[5] highlighted the importance of using the 10-10 universal electrode system in patients with skull defects because artifacts can mask epileptiform activity. On the other hand, the breach effect appears in magnetoencephalography (MEG) less than EEG, so the authors suggested using MEG as an alternative.[11] The main requirement for evaluating sporadic epileptiform discharges is to follow the six rules in the International Federation of Clinical Neurophysiology glossary of terms.[12] In addition, sporadic epileptiform discharges have frequencies and amplitudes that differ from the breach rhythms.[4] Drowsiness and nonrapid eye movement sleep stages help evaluate physician-patient breach rhythms from sporadic epileptiform discharges.[13] Our study highlights these beneficial findings: breach rhythms with theta frequency have a higher risk of sporadic epileptiform discharges in the same area than other breach rhythms with higher frequencies.

The area of breach rhythm recording was the same as that of skull defects. Our study results are concordant with these findings. The cause of breach rhythms is known as skull defect. Lyudmilov et al.[9] suggested that breach rhythms might be affected by the functional state of brain tissue based on a case report; during electrographic seizures, breach rhythms did not register in a patient with a skull defect, but after electrographic seizures were treated, breach rhythm appeared. In other cases, there were reports of changes in breach rhythms according to the performance of serial EEGs, and it was observed that the differences might be related to tumor growth.[7]

Table 2. Statistical analysis of seizure and its variables

	With seizure (n,%)	Without seizures (n,%)	p value
Age (years)	49.96±14.73*	54.04±15.67*	0.284[a]
Sex (female)	11, 28.9	27, 71.1	0.150[b]
Encephalomalacia (with)	24, 40.7	35, 59.3	0.242[c]
Breach frequency			
Beta-alpha	15, 37.5	11, 35.5	0.861[b]
Theta	11, 35.5	20, 64.5	
Breach localization			
Centro-temporal	12, 42.9	16, 57.1	0.379[b]
Extra-temporal	14, 32.6	29, 67.4	
Epileptiform discharges			
With	14, 60.9	9, 39.1	**0.003[b]**
Without	12, 5.0	35, 75.0	

*Mean±standartd deviation, [a]Independent samples t-test, [b]chi-square, [c]Fisher's exact test, $p<0.05$

Table 3. Statistical analyses of epileptiform discharges and variables

	With ED (n, %)	Without ED (n, %)	p value
Breach morphology			
Beta	4, 19.0	17, 81.0	
Alpha	4, 40.0	6, 60.0	
Mu	0, 0.0	8, 100.0	
Theta	6, 46.2	7, 53.8	
Beta-theta	9, 47.3	10 52.6	**
Breach frequency			
Beta	4, 19.0	17, 81.0	
Alpha	4, 22.2	14, 77.8	
Theta	15, 46.9	17, 53.1	0.028[a]
Breach frequency			
Beta-alpha	8, 20.0	15, 48.4	
Theta	32, 80.0	16, 51.6	**0.011[b]**
Breach localization			
Centro-temporal	5, 17.9	23, 82.1	
Extra-temporal	18, 41.9	25, 58.1	0.035[b,#]

**Small sample size, achi-square, linear by linear association $p<0.016$, Bonferroni correction, bchi-square, Pearson $p<0.05$.
[b,#]Differences were disappeared with logistic regression analysis.
ED: Epileptiform discharges

Table 4. Binary logistic regression analysis to predict the presence of epileptiform discharge with breach rhythm

Model-1				**-2 Log-likelihood=79.771**	
Model variables	B	SE	p value	OR	95% CI for Exp (B)
Constant	-2.013	0.574	<0.000		
Breach localization	1.041	0.602	0.084	2.832	0.870-9.220
Breach frequency-theta	1.199	0.548	**0.029**	**3.316**	**1.133-9.699**

Extratemporal, alpha-beta frequency, Omnibus $p=0.008$.
Hosmer-Lemeshow $p=0.960$.
SE: Standard error, OR: Odds ratio, CI: Confidence interval

Table 5. Binary logistic regression analysis to predict seizure in patients with breach rhythm

Model-1				**-2 Log-likelihood=4.773**	
Model variables	B	SE	p value	OR	95% CI for Exp (B)
Constant	-1.099	0.333	0.001		
Epileptiform discharges (with)	1.54	0.542	**0.004**	**4.667**	**1.613-13.498**

Without epileptiform discharges, Omnibus p=0.004.
SE: Standard error, OR: Odds ratio, CI: Confidence interval

These observations suggest that the functional state of brain tissue may lead to a breach rhythm. Our study findings did not include serial EEG recordings of the same patients, although in our cohort encephalomalacia did not differ in the morphology and frequency of breach rhythms. However, our cohort did not include patients with electrographic seizures or untreated tumors. These two cases and our case series all had skull defects, confirming that the single source of breach rhythms is skull defects.[5] However, more longitudinal studies with these patient groups must be performed to discuss the pathophysiology of breach rhythms, whether their only source is skull defects, or whether functional brain mechanisms may involve breach rhythm appearance.

Breach location can be anywhere on the skull. The temporal region was the most frequent location in our cohort, followed by the frontotemporal region and central region. Our results showed no differences in morphology and frequency according to location. In addition, no differences were observed among patients with signs of seizure or the presence of sporadic epileptiform activity in our cohort. However, the most critical limitations of this study are the not equal, even not similar, distributions of the subgroups. In addition, the temporal breach rhythm was the most frequent region of breach localization. Electroencephalographers should evaluate benign epileptiform variants more carefully because they can be localized more temporally than other locations, which can cause misdiagnosed wicket spikes.[5,14]

Study Limitations

Our study has several limitations. First, it included retrospective data, which led to missing values and a heterogeneous distribution of subgroups. Second, we did not perform a follow-up EEG, which might have allowed us to comment that the pathophysiologic source of the breach rhythms was skull defects alone. However, only a few studies have been conducted on this topic, which renders the results of these studies valuable.

CONCLUSION

In conclusion, our study showed that breach rhythms are unrelated to seizures unless sporadic epileptiform activity is present. If the breach rhythm frequency is theta, the risk of sporadic epileptiform activity is higher than that of alpha or beta frequency breach rhythms.

Ethics

Ethics Committee Approval: The study was approved by the Dokuz Eylül University Local Ethics Committee (decision no: 2021/08-38, date: 08.03.2021).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Medical Practices: D.M.D., İ.Ö., B.B., Concept: D.M.D., İ.Ö., B.B., Design: D.M.D., İ.Ö., B.B., Data Collection or Processing: D.M.D., Analysis or Interpretation: D.M.D., İ.Ö., B.B., Literature Search: D.M.D., İ.Ö., B.B., Writing: D.M.D., İ.Ö., B.B.

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