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Timing of Seizure Recurrence in Adult Epileptic Patients: A Statistical Analysis

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Summary: Seizure diaries were maintained prospectively in 24 epileptic patients (19 with partial complex, three with partial simple, and three with primary generalized seizures) who were selected consecutively, had stable seizure patterns, were reliable historians, and were known to be compliant with medications. Diaries were maintained for an average of 237 days (range, 61–365), and an average of 18 seizures were recorded per patient (range, 5–76). Seizure patterns were analyzed by using the methods appropriate for a time series of events (point process). Two patients had a decreasing trend in seizure frequency. For 12 patients, seizure occurrence was indistinguishable from that of a Poisson process. The remaining 10 patients had an exponential distribution of seizure intervals, but did not fit other criteria for a Poisson process; 3 of these showed evidence for seizure clustering; none showed evidence for a seizure cycle. It is concluded that the pattern of seizure occurrence in most epileptic people is random, but in approximately 50%, it is not occurring according to a Poisson process. These observations indicate that seizure cycling and/or clustering are not common in epileptic patients, but do not exclude the possibility that seizures have been precipitated by some randomly occurring event, such as sleep deprivation or increased stress. Key Words: Epilepsy—Seizures—Periodicity—Activity cycles—Mathematics—Point process.

The timing and circumstances of seizure recurrence are a source of apprehension for the patient and a mystery for the neurologist. In some patients, seizures appear to recur regularly (Griffiths and Fox, 1938; Almqvist, 1955; Halberg, 1978). In others, there are fairly long seizure-free intervals and then, within a few days, there is a "burst" of seizure activity, referred to as clustering (Rodin, 1968). An example of a seizure diary in which both seizure cycles and clusters appear to occur is shown in Fig. 1. The occurrence of seizure cycles may point to underlying physiological (Newmark and Penry, 1980) or meteorological cycles (Ruhenstroth-Bauer et al., 1984), but lunar and seasonal cycles have not been observed (Pastrnak, 1967). Seizure clusters may arise because the occurrence of one seizure increases the likelihood of a second occurring (Hopkins et al., 1985) and may indicate a poor prognosis for seizure control (Rodin, 1968).

Past studies on the timing of seizure recurrence have focused on patient groups in whom the occurrence of seizure cycles and/or clusters was strongly suspected on clinical grounds (Griffiths and Fox, 1938; Almqvist 1955; Newmark and Penry, 1980; Bowman et al., 1984). Undoubtedly, there are epileptic patients who have seizure cycles and clusters. However, in our experience, there are also many patients who do not report these phenomena. There is surprisingly little known about the timing of seizure recurrence in the general population of patients with epilepsy.

The purpose of this article is to examine seizure occurrence in a consecutively selected group of outpatients who were asked to maintain seizure diaries. The statistical analysis of a time series of events (point process) has been described extensively (Cox and Lewis, 1966; Lewis, 1965, 1966, 1972; Karr, 1986) and used in the neurological literature for the analysis of neural spike trains (Van der

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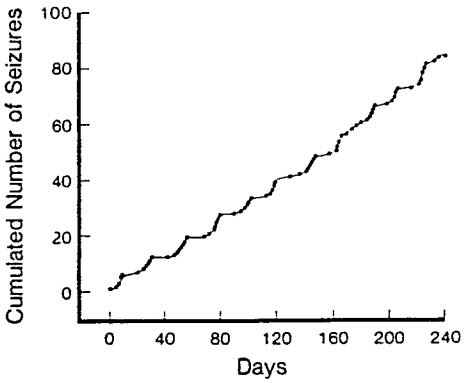

FIG. 1. Example of a seizure diary in a man with partial complex epilepsy thought clinically to have seizure cycles and clustering. The data are plotted as cumulated number of seizures versus time to facilitate visualization of these trends. This patient was not included in the analysis in this paper.

Kloot et al., 1975). However, to our knowledge, these methods have not been applied to analysis of seizure recurrences. We illustrate these methods and show that for most of these patients, the pattern of seizure recurrence is random. These results suggest that the proportion of patients with seizure cycles and/or clusters in the general population of patients may be quite small. However, these observations do not exclude the possibility that the seizures have been induced to occur by some randomly occurring factor, such as increased stress, missed night of sleep, etc.

METHODS

Patients

Patients (Table 1) who were followed in the neurology office practice of one of us (G.M.R.) were asked to record the occurrence of their seizures on a pocket calendar (5 cm × 10 cm). This method of recording seizures had been suggested by one of these patients. All patients were aware of the occurrence of their seizures and had seizure patterns that had not changed for several years. Patients were excluded if they were unable to maintain their own diary (e.g., mental retardation), if the description of their episodes was not clearly epileptic in nature, or if there had been problems with drug compliance, as suggested by an overt lack of motivation and large fluctuations in serum and antiepileptic drug blood levels. There was no history of mental illness in this group of patients. They were not aware that the purpose of this data collection was to look for rhythmicity and were otherwise unselected. Patients satisfying these criteria and who were willing to maintain seizure diaries were admitted consecutively into this study. Seizure diaries were initiated during 1982, collected at the beginning of 1983, and covered an average period of 237 days (males plus females in Table 1).

TABLE 1. *Clinical characteristics of patients*

	Women	Men
Number of patients	17	8
Age		
Mean	43	30
Range	15–68	22–56
Length of seizure diary (days)		
Mean	247	217
Range	92–365	61–365
Number of seizures		
Mean	22	11
Range	5–76	5–29
Seizure diagnosis[a]		
Generalized	4	3
Partial		
Simple	4	2
Complex	12	6
Treatment		
Surgery	3	1
Number anticonvulsants		
0	1	1
1	4	4
2	10	2
3	2	1

[a] Some patients had more than one seizure diagnosis. For male patients, two with partial complex seizures and one with partial simple seizures also had generalized seizures. For female patients who had partial complex seizures, two also had generalized seizures and one partial simple seizures.

Thirty-one seizure diaries were obtained, and 24 of them were analyzed. We excluded 6 diaries as they were uninterpretable and excluded one patient who had 3 changes in medication over 9 months because we were interested in determining the recurrence of seizures when antiepileptic medication regimens were stable. The analysis included three patients who did not have further seizures following a change in medication.

Statistical Methods

Figure 2 shows seizure occurrence as a function of time for one of the patients. Patients were initially asked to indicate if their seizures occurred with (major) or without (minor) loss of consciousness. Since the mode of onset was similar for both major and minor attacks, we combined seizure types and identified them only by the day of their occurrence.

Five parameters were used to describe the occurrence of seizures (Fig. 2): (1) seizure frequency, (2) the number of days with 0, 1, 2, 3 . . . seizures, (3) the interseizure interval (I in Fig. 2), (4) the number of days to the occurrence of a seizure (t in Fig. 2), and (5) the differences between successive interseizure intervals (ΔI in Fig. 2).

The statistical methods used in this study are

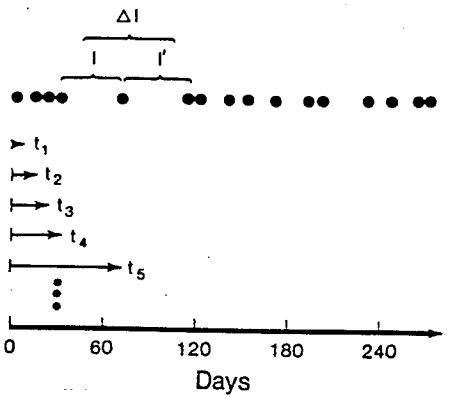

FIG. 2. Example of a seizure diary illustrating the parameters that are used to describe seizure occurrence (●). Day 0 is the day on which the diary was begun. The number of days to the occurrence of a seizure is given by the values of *t*; we have shown the values of *t* for the first five seizures. The number of days between successive seizures is given by *I*, for example, *I* and *I'*. Differences between successive interseizure intervals are given by $\Delta I = I' - I$.

valid only when seizure frequency, i.e., the number of seizures per day, is constant (Cox and Lewis, 1966; Van der Kloot et al., 1975; Karr, 1986). Seizure frequency is equal to the slope of a plot of the cumulated number of seizures versus time, and a constant seizure frequency is indicated by a linear relationship (Fig. 3). We tested linearity in two ways. First, a least-squares linear regression analysis was used to compute the slope (Sokal and Rohlf, 1969), and the fit was tested with an analysis of variance employing *F* statistics. In addition, we calculated the value of R^2, which is equal to the ratio of the regression sum of squares to the total sum of squares. Then, two tests were used to determine whether or not there was a systematic

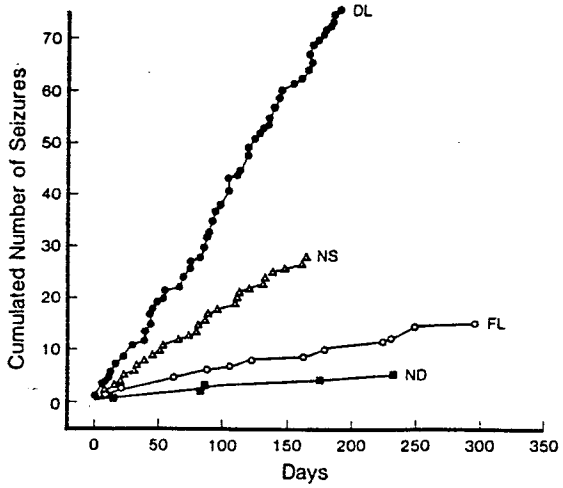

FIG. 3. Plot of the cumulated number of seizures versus days for four patients. The patients were chosen to illustrate the range of seizure frequencies observed. The seizure frequency for each patient is equal to the slope of a straight line fitted through the points.

trend in the occurrence of seizures. (1) The run test, in which each day is converted into a yes/no variable with respect to seizure occurrence, was used to determine whether or not there were significant nonrandom trends (Sokal and Rohlf, 1969). (2) The trend statistic, *U*, was used to test for progressively increasing or decreasing trends in seizure occurrence (Lewis, 1965, 1966, 1972; Cox and Lewis, 1966; Van der Kloot et al., 1975). It should be noted that when seizure frequency is constant, this method of calculating the mean seizure frequency is equivalent to dividing the total number of seizures recorded by the total number of days the seizure diary was kept; however, this cannot be assumed a priori. These tests are sufficiently sensitive to detect seizure cycling and/or clustering of the type shown in Fig. 1, but are not sensitive enough to exclude the possibility of more subtle seizure patterns.

Seizure clustering can be defined as an increase in the number of days with two or more seizures (Hopkins et al., 1985) and/or an increase in the number of short interseizure intervals (to account for clustering of the type shown in Fig. 1). *The number of days with 0, 1, 2, 3 seizures* was compared to the number expected by a simple random process, i.e., the Poisson process. The expected number of days with 0, 1, 2, 3 . . . seizures, E_n, for a Poisson process is equal to

$$E_n = \frac{D_T f^n}{n!} \exp(-f) \qquad (1)$$

where D_T is the length in days of the seizure diary, f is the mean seizure frequency as determined above, and n is equal to 0, 1, 2, 3. . . . The expected and observed number of days with 0, 1, 2, 3 . . . seizures were compared by using a log maximum likelihood ratio test (Sokal and Rohlf, 1969).

The interseizure interval is the number of days between successive seizures. To test whether or not the distribution of interseizure intervals was given by a Poisson process, we plotted the logarithm of the proportion of interseizure intervals longer than a certain value *I*, $\ln R(I)$, versus *I* (Fig. 4). Linearity of this plot is consistent with a Poisson process (Cox and Lewis, 1966; Van der Kloot et al., 1975). A least-squares linear regression analysis was used to fit a straight line to these data, and the fit was determined by an analysis of variance using *F* statistics.

Two additional statistical tests were included to determine how closely seizure occurrence was described by the Poisson process. The differences between successive interseizure intervals were com-

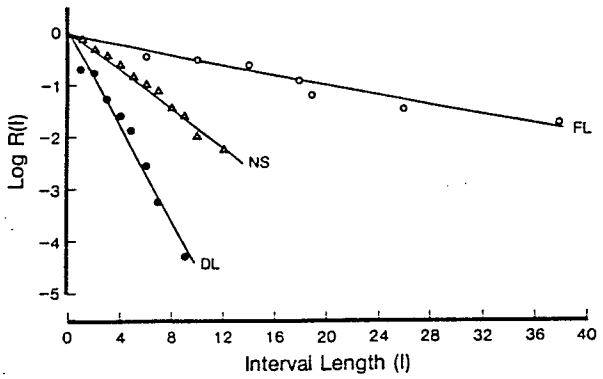

FIG. 4. Plot of the logarithm of the proportion of interseizure intervals (l) longer than l, in $R(l)$, versus the length of the interseizure interval. Data are for three of the patients shown in Fig. 3. The linearity of these plots indicates that the distribution of the interseizure intervals is exponential.

pared to those expected for a Poisson process, as described previously (Cox and Lewis, 1966; Lewis, 1965, 1966, 1972). This test is based on Durbin's modification of the uniform conditional test. We ordered the interseizure intervals, I_i, from smallest to largest, to obtain the order statistics, X_i, and then calculated the statistic, T_i, as

$$T_i = \frac{1}{D_T}(X_1 + X_2 + \cdots + X_{N-1} + (N + 2 - i)X_i) \quad (2)$$

where $i = 1, 2, 3, \ldots N$, and N is the total number of ordered interseizure intervals. Kolmogorov-Smirnov statistics were used to test for goodness of fit, as described previously (Lewis, 1966). *The number of days till the occurrence of a seizure* was calculated for each seizure beginning on the day the first seizure was observed. These values were compared to those expected for a Poisson process by calculating the statistic, WE_0, where

$$WE_0 = \frac{\sum_{i=1}^{m} t_i^2 - \frac{\left(\sum_{i=1}^{m} t_i\right)^2}{m}}{\left(\sum_{i=1}^{m} t_i\right)^2} \quad (3)$$

where $i = 1, 2, 3, \ldots m$, and m is the total number of observed values of t_i (Hahn and Shapiro, 1967). Tables of the values of WE_0 have been published previously (Hahn and Shapiro, 1967).

As will be shown in Results, seizure occurrences were random for most of the patients. Therefore, a formal test for *seizure cycles* is not necessary. However, we confirmed this observation by calculating autocorrelation functions according to the methods of Cox and Lewis (1966).

RESULTS

Figure 3 shows typical plots of the cumulated number of seizures versus days for four patients, and Table 2 summarizes the results. For 23 of 24 patients, there is a linear increase in seizures with time ($R^2 > 0.85$, F-test with probability <0.001). However, in 1 of these patients and the remaining patient, there was a decreasing trend in seizure occurrence. Therefore, it was concluded that seizure frequency was constant in 22/24 patients (see Methods section). These results should be compared to the seizure diary of a patient known to have seizure clustering and cycling (shown in Fig. 1) in which seizure frequency is clearly changing. He came to our attention after data collection for this study was completed: he is therefore not part of our group of subjects. The two patients with a decreasing trend in seizure frequency were excluded from further analysis.

We then examined four parameters that describe seizure occurrence and compared them to that expected on the basis of the Poisson process: (1) the number of days with 0, 1, 2, 3 . . . seizures [E_n; see Eq. (1)]; (2) the number of days between successive seizures, i.e., the interseizure interval (I in Fig. 2); (3) the number of days to the occurrence of a seizure from the beginning of the seizure diary (t_1 in Fig. 2); and (4) the differences between successive interseizure intervals (ΔI in Fig. 2). The results are summarized in Table 3.

For 22 of 22 patients, the distribution of interseizure intervals was Poisson, and for 19 of 22, the number of days with two or more seizures did not differ significantly from that expected by a Poisson process. As seizure clustering would be reflected by changes in the distribution of interseizure intervals and/or the number of days with two or more

TABLE 2. *Seizure frequency for 24 patients*

Sex	Seizure frequency[a] (seizures/day)	Linearity $R^2 > 0.85$[b]	Significant trends: Run test[c]	Significant trends: U test
Female	0.12 (0.03–0.41)	15/16	2/14	2/16
Male	0.07 (0.02–0.13)	8/8	0/5	0/8

[a] Seizure frequency is determined from the slope of a plot of the cumulative number of seizures versus time (days). Values are expressed as mean (minimum–maximum)

[b] In all cases with $R^2 > 0.85$, F-test gave $p < 0.001$.

[c] Five patients had ≤6 seizures, and run test could not be done.

TABLE 3. *Summary of seizure occurrence in 22 patients*

Patient	Age (yr)	Diagnosis	Parameters describing seizure occurrence[a]			
			E_n	I	t_i	ΔI
Poisson		3 Generalized[c]				
7 F	15–68	3 Partial simple	P	P	P	P
5 M		9 Partial complex				
Non-Poisson						
Male						
A.C.	56	"Eating epilepsy"	NP	P	NP	NP
G.S.	26	Partial complex; generalized	P	P	NP	NP
Female						
R.B.	59	Partial complex	P	P	NP	NP
M.Be.	30	Partial complex	NP	P	NP	NP
M.Ba.	55	Partial simple	P	P	P	NP
L.L.	44	Partial complex; generalized	P	P	NP	NP
D.L.	21	Partial complex	P	P	NP	NP
E.L.	60	Partial simple/complex	NP	P	NP	NP
L.M.	61	Generalized	P	P	NP	NP
N.S.	24	Partial complex	P	P	NP	NP

[a] E_n is the number of days with 0, 1, 2, 3, . . . seizures; I is the interseizure interval; t_i is the days till seizure occurrence; ΔI is the difference between interseizure intervals; *P* denotes not significantly different from a Poisson process, and NP denotes significant from a Poisson process at the 5% probability level.

[b] In all cases, $R^2 > 0.80$ and $p < 0.001$.

[c] Three patients with partial complex seizures had more than one diagnosis: two patients also had generalized seizures and one had partial simple seizures.

seizures, these results indicate that only three of 22 patients showed evidence of seizure clustering.

The observations that seizure frequency is constant (Table 2) and that there is an exponential distribution of interseizure intervals effectively excludes the possibility of simple seizure cycles (i.e., cycles of the type of a seizure every 28 days). This prediction was confirmed by calculating autocorrelation functions (Cox and Lewis, 1966; Lewis, 1966, 1972) for those 15 patients who had more than 20 seizures. No significant correlations were found (data not shown).

For 12 of 22 patients, none of the parameters differed from that expected from a Poisson process (Table 3). In the remaining 10 of 22 seizure diaries, 9 patients departed from a Poisson process with respect to the days to seizure occurrence and 10 patients with respect to the differences between successive interseizure intervals. Statistical tests based on these latter two parameters are more sensitive in detecting departures from a Poisson process (Lewis, 1972; Van der Kloot et al., 1975). The types of seizures as well as the relative proportion of each seizure type were similar in the groups of patients with Poisson and non-Poisson seizure occurrence (Table 3). The fact that departures from a Poisson process are observed for both men and postmenopausal women suggests that this does not simply arise because of the influence of the menses on seizure occurrence. Finally, it was noted that as a group, the patients who showed departures from a Poisson process had more seizures [average 28.7, range 5–76, compared to 11.4 (5–37)] and higher seizure frequencies [0.12 (0.015–0.404) seizures/day compared to 0.07 (0.016–0.148) seizures/day]. We cannot exclude the possibility that had more seizures been recorded, all diaries would eventually show departures from a Poisson process.

DISCUSSION

We have prospectively recorded seizure occurrence in patients followed in an outpatient neurology practice. Each of these patients was aware of the occurrence of their seizures, was thought to be compliant to medications, and to be a reliable historian. In 22 of 24, there was a constant rate of seizure recurrence. Two patients had a decreasing trend in seizure frequency and were not analyzed further. In 19 of 22 patients, we were unable to detect seizure cycling and/or clustering.

Are seizures occurring randomly in this group of patients? The Poisson process is considered to be the simplest, but not the only, example of a random process. The connection between the Poisson process and randomness arises because the Poisson process can be generated by randomly distributing independent events on a time interval according to a uniform probability distribution, i.e., in such a manner that there is equal probability for all possible outcomes (Cox and Lewis, 1966; Van der Kloot et al., 1975; Karr, 1986). An infinite number

of different random processes can be formed by changing either the condition that seizures occur independently and/or the requirement of a uniform probability distribution. Thus, rejecting the Poisson process does not mean that seizures are occurring in a nonrandom manner.

In our study, for 10 of 22 patients, seizure recurrence was non-Poisson. One explanation may be that seizure recurrences are not always independent events, but that the occurrence of one seizure can influence the occurrence of the next (see Temkin and Davis, 1984; Hopkins et al., 1985). Alternately, it is possible that any one of an infinite number of stochastic models is valid, in which instead of a uniform probability distribution, a different one is chosen. We have considered the obvious alternatives of seizure cycles and clustering and found little evidence to support these possibilities. We conclude that seizures are occurring randomly in our patients, but in half, are not occurring according to the Poisson process.

It is important not to interpret the observation that the time series for seizure occurrence is random in our patients as evidence excluding the possibility that the occurrence of a seizure has been determined by some underlying physiological or psychological event, such as increased stress (Temkin and Davis, 1984), missed medication or nights of sleep, or alcohol consumption. In other words, randomness in seizure occurrence may reflect randomness in an underlying parameter to which seizure occurrence is strongly correlated. Our primary interest was to identify patients with seizure cycles or clustering, and we did not pursue these possibilities further.

There are a number of problems that necessarily underlie studies of seizure occurrence. First, it is uncertain whether or not multiple seizures occurring on 1 day should be counted separately, as we have done, or as a single event (Griffiths and Fox, 1938; Hopkins et al., 1985). This problem is further compounded by the observation that even random processes can lead to days on which more than one seizure occurs (see Eq. 1). Secondly, it is unclear what time unit should be used to express seizure frequency, i.e., the hour, the day, the week, etc. Determination of the appropriate time unit is important because the choice can affect the decision as to the presence of seizure clustering or cycles. We have used the day as the time unit as 60–80% of patients are known to have a circadian variation in seizure occurrence (Langdon-Down and Brain, 1929; Patry, 1931; Griffiths and Fox, 1938; Halberg, 1978), suggesting that the day is in some sense a "natural" time unit. On the other hand, in patients having large numbers of seizures per day, it may be necessary to consider the time unit as equal to 90–100 min, as analysis of spike frequency in electroencephalograms (EEGs) has suggested the presence of a rhythm with this period (Stevens et al., 1972; Kellaway et al., 1980). Our observations indicate that in addition to processes that regulate the most probable time of day for seizure occurrence, there must be other randomly occurring events involved in determining on which day a seizure actually occurs.

A final problem concerns the adequacy of statistical tests for describing seizure occurrence when only a few seizures are recorded. Failure to reject the Poisson hypothesis does not necessarily imply that seizure occurrence is Poisson. Moreover, statistical tests based on small numbers of observations are not as reliable as those based on large numbers. Determination of the power, i.e., probability of rejection, of the statistical tests used in the analysis of point processes is notoriously difficult (Karr, 1986). However, for 22 of 24 patients, the seizure diaries closely resembled the examples shown in Fig. 2 and 3. We think that it is quite unlikely that larger numbers of seizures would alter our impression that there are no clinically significant cycles and/or clusters in such patients.

The difficulty in interpreting the significance of time series has become greatly confounded by the recent realization that even simple deterministic mathematical models for biological rhythms can exhibit a rich variety of dynamics ranging through varying periodicities to "noise-like" dynamics even in the complete absence of environmental noise as certain control parameters are varied (May, 1976; Mackey and Glass, 1977; Glass and Mackey, 1979; Lasota and Mackey, 1986; Mackey and Milton, 1987). In particular, it has been recently shown that the time series of any random process, including the Poisson process, can be mimicked precisely by an appropriately constructed deterministic model (Lasota and Mackey, 1986). The fact that the dynamics of biological rhythms can change from periodic to random as certain critical control parameters are altered may be particularly relevant to patients with seizure cycles. Griffiths and Fox (1938) described a number of patients with cyclic seizures in whom treatment led to irregular seizure occurrences, and in some cases, an increase in seizure frequency. Thus, it is possible that our failure to identify a patient with seizure cycles was because all of our patients were receiving anticonvulsant medications. Determining whether or not changes in the pattern of seizure occurrence occur with medications may be of great

importance, as this observation would imply the existence of underlying control parameters that could potentially be manipulated (Mackey and Milton, 1987).

Our results indicate that the occurrence of seizure cycles and/or clustering in the general population of epileptic patients is quite rare. A recent report has suggested that when rigorously defined, catamenial epilepsy may also not be as common a phenomenon in women with partial seizures as previously thought (Rask et al., 1987). However, it is certainly true that patients exist who have regular seizure recurrences and/or clustering (Fig. 1) (Griffiths and Fox, 1938; Almqvist, 1955; Halberg, 1978; Newmark and Penry, 1980). Future investigation will be needed to identify subgroups of patients with different patterns of seizure occurrence and to determine their clinical significance. The statistical methods we have illustrated here should aid the clinician in identifying these patients and, in particular, in distinguishing those patients with true clustering.

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RÉSUMÉ

Un relevé quotidien des crises a été effectué de façon prospective chez 24 patients épileptiques (19 présentant des crises partielles complexes, 3 des crises partielles élémentaires et 3 des crises généralisées). Ces patients ont été sélectionnés consécutivement, ont été jugés fiables dans le relevé des crises et dans l'observance thérapeutique. Les relevés ont été effectués pendant une moyenne de 237 jours (61 à 365) et une moyenne de 18 crises par patient a été enregistrée (de 5 à 76). La distribution des crises a été étudiée par les moyens adaptés aux phénomènes répétés dans le temps. Chez 2 patients nous avons constaté une tendance à l'espacement des crises. Chez 12 patients, la fréquence des crises n'a pas été différente d'une répartition suivant la loi de Poisson. Les 10 patients restants présentaient une distribution exponentielle des intervalles entre les crises mais ne répondaient pas aux autres critères de la loi de Poisson. 3 d'entre eux présentaient des crises en séries; aucun ne présentait de cyclicité des crises. Nous concluons que la distribution des crises est, chez la plupart des patients, le fait du hasard, mais que, chez environ 50% des patients, cette répartition ne suit pas une loi de Poisson. Ces observations indiquent qu'une distribution cyclique ou en série des crises n'est pas fréquente chez les épileptiques, mais n'excluent pas la possibilité que les crises peuvent avoir été provoquées par quelque évènement survenant au hasard, comme un manque de sommeil ou un stress particulier.

(P. Genton, *Marseille*)

RESUMEN

Se han elaborado diarios con respecto al número de ataques, de modo prospectivo, en 24 enfermos epilépticos (19 con ataques complejos parciales, 3 con ataques simples parciales y 3 con ataques generalizados primarios) que se seleccionaron consecutivamente; Tenían patrones de ataques estables, eran historiadores fiables y eran conocidos por su nivel de confianza en la administración de medicamentos. Los diarios se mantuvieron durante un promedio de 237 días (rango de 61 a 365) registrándose un promedio de 18 ataques por paciente (rango de 5 a 76). Los patrones de los ataques fueron analizados utilizando metodología apropiada para la serie de acontecimientos en el tiempo (proceso puntual). Dos pacientes mostraron una reducción de la tendencia a la frecuencia de ataques. En 12 pacientes la aparición de los episodios fue indistinguible de la del proceso de Poisson. Los restantes 10 pacientes tenían una distribución exponencial de los intervalos de ataques pero no encajó en otros criterios para un proceso Poisson; 3 de ellos mostraron evidencia de "ataques acumulados". Ninguno presentó un ciclo de ataques. Se concluye que el patrón aparición de ataques en la mayor parte de las personas epilépticas es aleatorio pero que en, aproximadamente el 50%, no ocurre de acuerdo con un procese Poisson. Estas observaciones indican que los ciclos de los ataques y/o su "acúmulo" no son comunes en enfermos epilépticos pero no excluyen la posibilidad de que los ataques hayan sido precipitados por un acontecimiento que ocurra aleatoriamente tales como la privación del sueño o el incremento de stress.

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