Prediction of Videotelemetry Productivity from Clinical Screening Parameters

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The usefulness of EEG videotelemetry study among 48 male and 43 female hospitalized children admitted to a neuropsychiatric unit was examined in relation to a constellation of clinical variables assessed during the evaluation period. The results of a multiple regression analysis of telemetry productivity indicated that an appreciable proportion of variance was explained by the predictors qualifying for entry into the equation. Specificity of the telemetry study, severity of the abnormalities identified on the neurological examination, and certain EEG parameters emerged as the most effective predictors of telemetry yield. Results are discussed in terms of maximizing the benefits derived from the clinical administration of videotelemetry.


Children with uncontrolled seizures who have behavioral problems and difficulty learning and are on multiple medication often pose a diagnostic dilemma and defy effective clinical management. Although informed administration of anticonvulsant therapy is dependent upon clarification of diagnosis, epileptiform abnormalities are not always revealed on repeated standard EEGs even when activated by such procedures as sleep deprivation or strobe. Intensive patient monitoring enhances detection of the frequency of ictal events and permits audiovisual recording of their behavioral manifestations (Carr et al., 1983; Guy et al., 1980; Ives et al., 1976; Oxley et al., 1981; Penry et al., 1975, 1976; Porter et al., 1976). Such monitoring requires hospitalization, best done in a specialized epilepsy unit typically resembling a routine inpatient setting using a wall camera that further restricts the patient's freedom of movement (Mattson, 1980; Porter et al., 1976; So and Penry, 1981). Hospitalization has been shown to decrease seizure frequency in adults (Riley et al., 1981) and restriction of children's ordinary activity level is even more dramatic. Under these conditions, application of behavioral observation to children's daily lives is unlikely to be reliable. Ambulatory cassette EEG monitoring, which enables long-term sampling of activity and is not confined to inpatient use, has recently become commercially available (Davidson et al., 1981; Ebersole and Leroy, 1983; Ives and Wood, 1983; Ives et al., 1981; Leroy and Ebersole, 1983; Stores and Lwin, 1981). However, correlation with behavior requires the maintenance of a patient diary.

Application of free-ranging EEG videotelemetry in the study of childhood epilepsy has been described previously (Garrison and Schimschock, 1980; Rafal et al., 1980). This procedure appears to have clinical utility for documenting seizure type in impulsive hyperactive children who may not cooperate in the use of conventional hard-wired techniques; discovering the influence of subtle ictal events on a child's behavior and performance of learning tasks; identifying seizures against behavioral background noise of clinically similar autisms or automatisms; investigating reflex or evoked epilepsy in those in whom seizure frequency is influenced by stress or environmental factors; and unambiguously identifying pseudoseizures.

It appeared that the amount of useful information yielded by EEG videotelemetry was proportional to the degree to which a diagnostic question had been defined before the electrodes were applied to the head of the child. To facilitate eventual correlation with electrographic findings, it was helpful to anticipate target behaviors resembling seizures or influenced by seizures or by medications. In cases where we suspected that the seizures were activated by stress or other environmental events, it was preferable to bring about those situations during the telemetry. Since school dysfunction was nearly universal among our patients, observation of the EEG during continuous performance tasks, psychological testing, and school work proved valuable in interpreting apparent fluctuations in alertness and off-task behaviors. Although the improved seizure diagnosis and control made pos-
sible by the administration of videotelemetry is of obvious benefit to the child, translation of this clinical gain into improved academic or social functioning often requires integration with other evaluative findings (Klesges, 1983). Moreover, an informative result may consist of more than the simultaneous observation of clinical and electrographic seizures, as in the case of documentation of pseudoseizures, where a negative finding is diagnostic.

This paper presents qualitative and quantitative data yielded by EEG videotelemetry studies of 91 children who also underwent multidisciplinary hospital evaluations. The report focuses on the degree to which the videotelemetry studies were diagnostically contributory.

Method

SUBJECTS

Subjects were 48 male and 43 female children who were admitted to the neuropsychiatric unit and who received EEG videotelemetry study during their hospitalization. The youngest child was 1½ years, and the oldest child was 18 years with a mean of 8.2. Children were referred by neurologists, psychiatrists, and family practitioners, and from the schools and the State Children's Services Division. Most of the subjects had undergone several prior evaluations (Garrison and Schimschock, 1980) and had problems of a severity and chronicity that had defied diagnostic clarification or management plan. Admission was elective, and an effort was made to cluster children by age and severity of dysfunction in order to create a therapeutic milieu.

SETTING AND PROCEDURE

The setting was a self-contained ground floor ward in a university-affiliated general hospital situated in a residential neighborhood. A strong department of neurology attracted referrals from several states. The unit was part of a comprehensive epilepsy program. The space had been modified to be homelike, with colorful furnishings, music, toys, and family-style common areas where meals were eaten together. The milieu was flexibly structured to enable tailoring the evaluations to patients with a wide spectrum of clinical problems ranging from multiple seizures to uncontrolled psychiatric disorders. Local parks and recreation facilities were liberally used to make hospitalization less onerous and to achieve a realistic level of activity with regard to the adjustment of medications to seizures and to the generalization of observations to the home. Parents were encouraged to participate in the evaluations, especially when a psychiatric or neurobehavioral question was present. This encouragement took the form of rooming-in at no charge, observation of testing and routine participation in discharge conferences.

A primary nursing care system was employed. Each patient had a primary worker, a nurse or a child development therapist, with responsibility to provide direct, consistent, one-to-one care. The number of nursing hours per patient day were approximately 15 and thus comparable to that of an intensive or coronary care unit. Costs of hospitalization were paid by private funds, insurance or welfare; no grant or teaching funds were available. Except as needed for medical stabilization, evaluations were determined by clinical need and frequently modified due to financial constraints. Therefore, telemetry was done only if a specific question was posed about the relationship between seizures and behavior. Some children had part of the evaluation as outpatients and were hospitalized only for brief, focused admissions. Psychiatric, psychological and educational evaluations were done as needed. If an educational evaluation had recently been done in the school, or if parents were resistant to psychiatric evaluation, these were selectively omitted.

Systematic intellectual assessment of developmentally delayed and behaviorally disordered children is clinically difficult. We obtained estimates of children's capabilities by flexibly employing parts of different instruments and by testing children over a span of days or during the child's best part of the day where necessary. Thus, although the majority of children had comprehensive multidisciplinary evaluations, the protocol for them was not uniform.

Each child had one or more diagnoses at admission. Following an initial assessment made during the first day or two of hospitalization, an evaluation conference was held to revise the diagnostic impression and to plan a treatment trial. All children underwent neurological examinations. Standard 16-channel EEGs with activation by strobe and sleep and systematic logs of seizure type and frequency enabled formulation of the questions to be addressed by telemetry and selection of the target behaviors warranting close scrutiny. CT scans were done when clinically indicated.

TELEMETRY STUDY

Each study was done in the living area of the unit, under the supervision of the telemetry consultant and in collaboration with the staff and the child's parent if appropriate. Even impulsive, hyperactive children, who were likely to be intolerant of conventional hard-wired techniques, permitted the placement of electrodes by the technician. The study commenced when, left unrestrained and distracted for a few minutes, the child quickly became comfortable in the monitoring situation and unaware of the transmitter and wires. A mobile camera continuously recorded the child's be-
behavior on videotape. Four channels of EEG were displayed on the TV monitor by video reformatter, and eight channels of EEG were recorded intermittently on paper printout.

The 150-foot range of the telemetry transmitter made it possible to study the children in a free-ranging situation anywhere on the unit. This greatly facilitated observation of the interaction between environmental-behavioral events and their EEG concomitants in various structured or spontaneous situations. The study continued, if possible, until target behaviors were observed, so that the duration and protocols of the telemetry studies were not uniform. When seizures or target behaviors were observed, the time was noted from the digital clock video display and recorded for subsequent review by the electroencephalographer. Records were reviewed and edited by the telemetry consultant for conferences with unit staff to determine whether further studies were needed or whether the results of the telemetry study warranted revision in the initial diagnosis or anticonvulsant regimen. When appropriate, the tapes were also reviewed with the patient's parents, who were instructed in the keeping of accurate seizure logs.

PREDICTOR VARIABLES

Admitting problems were classified as neurological, psychiatric, developmental, medical or management. In each of the five areas, problem severity was rated as absent (0), present (1), or clinically unstable (2). Examples of clinically unstable problems were: several seizures daily with or without unpredictable behavior requiring that the child have supervision much closer than expected for his age. An attempt was also made to rate the severity of abnormalities found on the neurological examination. Findings were scored as normal (0); soft signs (1); ataxia (2); one major abnormal finding, such as hemiparesis (3); and more than one such finding (4). CT scans were classified as not indicated (0), normal (1), or abnormal (2).

Seizure type was defined by the absence or presence of each of 7 EEG patterns, including generalized epileptiform activity, focal activity, atypical absence, classical petit mal (3-5 c.p.s. spike-wave pattern), partial complex (temporal lobe focus), myoclonic or markedly abnormal background. For each type, severity was dimensionalized along a continuum ranging from having clinical seizures by history only to having clinically uncontrolled seizures with concurrent EEG findings. Scores were assigned on the basis of absence of EEG findings only (1), clinical seizures only (2), both EEG findings and clinical seizures (3), and clinically uncontrolled seizures with EEG concomitants (4). CT scans were classified as not indicated (0), normal (1), or abnormal (2).

Two predictors were derived from the telemetry study itself. Sessions referred to the number of separate telemetry studies performed on a child. Specificity referred to the degree of focus of the question addressed by the most specific study done on each child. Some children were known or suspected to have seizures and telemetry was done to gain more detailed information. Investigating and recording seizures only was regarded as the least specific purpose (1), one target behavior as moderately focused (2), and more than one target behavior as most focused (3).

An Example of One Target Behavior

T. was a bright and sociable 6-year-old who had a documented generalized seizure disorder occurring occasionally and who also had frequent staring spells, undiminished by increasing anticonvulsants. During EEG videotelemetry, several such spells occurred, predictably provoked by T.'s failures to receive attention from her anxious protective mother, but unassociated with epileptiform activity. This confirmed clinical suspicion that the staring spells were manipulative. Decreasing anticonvulsants and offering focused psychotherapy led to a cessation of the staring behavior, and the child began to participate in more age-appropriate peer activities.

An Example of More Than One Target Behavior

G. was a withdrawn, irritable, educationally crippled 15-year-old with a history of severe infantile child abuse and also of seizures since the age of 5. Target behaviors were staring spells, avoidant truculence, and occasional transient stereotypic hand movements. EEG videotelemetry showed frequent subtle incomplete absence spells which the staff had previously not detected. Thus, it was learned that her frequent absences were causing her irritability and noncompliance and were not, as had previously been ascribed, psychodynamic factors. Her behavior had been managed inappropriately with disciplinary action which only aggravated her hostility and frustration. Also, one prolonged ictal episode was recorded associated with clonic jerking of the right hand, suggestive that seizures might be focal in origin with secondary bilateral synchrony. An unsuccessful trial of ethosuximide was abandoned and carbamazepine was begun. Seizure control improved gratifyingly.

CRITERION VARIABLE

The primary criterion variable was the result of the most specific telemetry study performed on a child. A yield of no ictal events or target behaviors was scored 0. No target behaviors was scored 1, and no ictal events was scored 2. Target behaviors without ictal events was scored 3, and ictal events without target behaviors...
was scored 4. The presence of both target behaviors and ictal events was scored 5 and of both occurring concurrently was scored 6.

OTHER VARIABLES
A few additional variables were of interest but were not included in the primary regression analysis. Such independent variables were the number of medications taken at admission and whether or not the telemetry findings prompted a change in the initial diagnosis or the treatment recommendations.

Results
The results are reported in three parts. First, we present data that describe certain aspects of the sample and of the telemetry studies. Second, we examine the results of a regression analysis of telemetry outcome according to various patient, evaluation and study characteristics. Third, the results of two additional regression analyses of telemetry impact on diagnosis and treatment are described.

SAMPLE AND STUDY
Most of the children had admitting problems in two or more areas. The distribution of admitting problems were neurological, 60% (of these 33% unstable); developmental, 44% (4%); psychiatric, 41% (11%); management, 35% (9%); and medical, 22% (0%).

Neurological examination detected soft signs in 10% of the children, ataxia in 8%, one major abnormality in 15% and more than one such abnormality in 26%. CT scans were deemed indicated in 39 cases and yielded normal results in 14 (36%). Many youngsters manifested more than one type of abnormality on the EEG. EEG findings were positive for generalized epileptiform activity in 39% of cases; focal activity, 49%; atypical absence, 31%; petit mal, 12%; partial complex, 27%; myoclonic, 6%; and markedly abnormal background, 67%.

Most children were on several anticonvulsants at admission \( (M = 2.4) \) and at discharge \( (M = 2.6) \). During hospitalization, 38% of the children had their drug dosage or pattern of administration changed, and 53% had a new drug added to their regimen.

Psychological testing indicated that our population of children was developmentally delayed. The mean IQ on the WISC-R was 64.5. Younger or more severely delayed children assessed with the Binet attained a mean IQ of 61.5. Psychoeducational testing with the Wide Range Achievement Test suggested a high incidence of reading delay. Over 85% of the subjects were more than 2 years delayed, another 9% were less than 2 years delayed, and under 5% were at grade level. Less than half of the sample used expressive language or receptive language at age-appropriate levels.

The average number of telemetry studies per child was 1.4. The average hours per study was 6.0. Forty percent of the studies were for the general purpose of investigating and recording seizures, another 40% were to study the co-occurrence of electrographic abnormalities with one target behavior, and the remaining 20% were to link such abnormalities to two or more target behaviors.

The results of the telemetry studies varied widely. An absence of both ictal events and target behaviors was observed in 13% of the cases. No target behaviors occurred 3% of the time, and no ictal events occurred 8% of the time. Target behaviors without ictal events turned up in 28% of the studies. Ictal events without target behaviors were established in 6% of the cases. Both ictal events and target behaviors occurred among 14% of the children, and both of these findings occurred concurrently in fully 28% of the cases. Telemetry outcome contributed to a revision in 51% of the original primary diagnoses. Examples were changing the diagnoses of seizure type or identifying that target behaviors (e.g., staring or stereotypic movements) were not associated with ictal activity. The original treatment programs were revised in 40% of youngsters as a result of telemetry findings, chiefly, changing anticonvulsant medications or identifying effective behavior approaches to mobilize the child’s attention for learning.

PREDICTION OF VIDEOTELEMETRY YIELD
The primary multiple regression analysis was performed on the telemetry results using the 16 predictors described earlier as independent variables. This procedure estimated the best prediction of telemetry yield based on the clinical data available prior to the study. Variables were entered stepwise into the regression equation until the next variable entered increased the variance explained by less than 1%.

The results of the multiple regression analysis are summarized in Table 1. Ten of the predictors qualified for entry. The specificity of the telemetry study entered first, followed by severity of abnormalities identified on neurological examination (2), severity of EEG partial complex (3), severity of background abnormalities on the EEG (4), severity of EEG myoclonic (5), severity of EEG atypical absence (6), severity of psychiatric problems (7), severity of developmental problems (8), severity of medical problems, (9) and severity of EEG petit mal pattern (10). Expressed in terms of the multiple correlation achieved on the basis of the number of entering predictors (0.61), the proportion of variance explained in the yield of the telemetry study (0.37) was appreciable. Except for psychiatric and medical problems at ad-
mission, greater severity was associated with greater yield.

Based on a subsample of children for whom such data were available, modified corresponding regression analyses were performed using impact on diagnosis and on treatment planning as the telemetry criteria. Approximately the same number of predictors qualified for entry into both equations and degree of focus of the telemetry study again emerged as a robust predictor. However, the proportion of variance accounted for in telemetry outcome was actually higher, substantially so in the case of treatment. Therefore, the proportion of variance accounted for in telemetry outcome was actually higher, substantially so in the case of treatment.

**Discussion**

Results indicated that our neuropsychiatric admissions were characterized by a high incidence of developmental delay, psychiatric disorder and behavioral deviation. However, the main finding was the ability of certain variables assessed during the evaluation period to predict the yield from videotelemetry study. Keeping in mind that multiple regression in the absence of cross-validation tends to capitalize on chance and thus inflate predictive efficiency, it is nonetheless noteworthy and of clinical utility that the most promising predictors could explain more than one-third of the variance in telemetry outcome.

Narrowing the focus of the videotelemetry emerged as especially important. The inpatient setting and intensive work with families facilitated identification of target behaviors. This in turn permitted the formulation of such specific questions as "Is the off-task, staring behavior ictal?" and "Is the sudden blinking and loss of tone voluntary?" The study could then be implemented during the time of day when the target behaviors were most likely to occur. Videotelemetry duration emerged as considerably less salient a factor than focus.

The second best predictor of telemetry productivity was the severity of the abnormalities turned up on the neurological examination. This may reflect the clinical observation that severely neurologically impaired children have more disordered behavior and are more likely to manifest autisms, automatisms and other repetitive behaviors that are easily confused with paroxysmal behaviors of ictal origin. Together with the overall positive association of productivity with severity on most of the neurological predictors and the negative association with severity on the non-neurological predictors, this would appear to support the construct validity of the videotelemetry procedure and of the present research. As would have been expected on an a priori basis, the greater the potential for neurological problems identified in the early phase of the examination sequence, the greater the opportunity for clarification and refinement via telemetry. From a clinical perspective, when abnormal paroxysmal behaviors are determined via telemetry not to be associated with spike-wave complexes, the neurologist can shift away from adjusting anticonvulsant medications and recommend another medical intervention, biofeedback, behavior modification or structured educational approaches instead (Lai and Ziegler, 1981; Upton and Longmire, 1975).

Partial complex seizure disorders are characterized by the occurrence of complicated, apparently organized behavior patterns and often coexist with other behavioral disturbances (Balofsky et al., 1978; Drake and Coffey, 1981; Stores, 1981). If no ictal episodes occur during the standard EEG, videotelemetry may extend and expand the diagnostic observation and succeed in demonstrating that electrographic changes co-occur with the bizarre behaviors.

Because a brief time is sampled, specific ictal abnormalities may be difficult to capture on a routine EEG. In the presence of a compelling history, a diffusely abnormal background EEG increases the likelihood that clinically abnormal behaviors are seizures. The contribution of normal EEG background to telemetry productivity may reflect the effectiveness of the procedure in defining specific behaviors requiring examination and thereby bringing into sharper focus a time sample during which the EEG is more likely to indicate electrographic seizures.

Myoclonic seizures and petit mal seizures are clinically apparent. Although not required to diagnose them, EEG videotelemetry was useful in pinpointing factors that increased their frequency and in observing how the child recovered from the seizure and regained the ability to attend to the on-task activity or to play. Treatment could then be modified to more effectively manage the immediate consequences of the seizures (Browne et al., 1974; Porter et al., 1976).

The clinical appearance of atypical absence seizures

<table>
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<tr>
<th>Step</th>
<th>Predictor</th>
<th>Simple $r$</th>
<th>Multiple $r$</th>
<th>$r^2$</th>
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<tr>
<td>1</td>
<td>Specificity of telemetry study</td>
<td>0.31</td>
<td>0.31</td>
<td>0.09</td>
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<td>2</td>
<td>Severity of neurological abnormalities</td>
<td>0.31</td>
<td>0.41</td>
<td>0.17</td>
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<tr>
<td>3</td>
<td>Severity of EEG: partial complex</td>
<td>0.24</td>
<td>0.49</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>Severity of EEG: background abnormalities</td>
<td>0.24</td>
<td>0.53</td>
<td>0.28</td>
</tr>
<tr>
<td>5</td>
<td>Severity of EEG: myoclonic</td>
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</tr>
<tr>
<td>6</td>
<td>Severity of EEG: atypical pattern</td>
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<td>0.55</td>
<td>0.32</td>
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<tr>
<td>7</td>
<td>Severity of psychiatric complaints</td>
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<td>0.58</td>
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<tr>
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<td>Severity of developmental problems</td>
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<td>9</td>
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<td>Severity of EEG: petit mal</td>
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is difficult to differentiate from inattentive behavior attributable to other causes. Using videotelemetry, the duration and severity of postictal confusion could be more carefully assessed (Goode et al., 1970; Klesges, 1983; Stores, 1973).

Viewing EEG videotelemetry recordings with families and school personnel proved helpful from an educational perspective. In particular, parents and teachers were taught to observe and describe seizures more accurately, especially when the children had frequent seizures with subtle manifestations superimposed on abnormal, self-stimulatory or off-task behaviors. For children with abnormal EEGs whose odd, paroxysmal or automatistic behaviors were not associated with EEG findings or telemetry, it was possible to redirect treatment, using behavioral, educational and psychiatric approaches and sometimes to reduce the level of anticonvulsant medication.

References


