10. Frank, V. H.: Paresthesia: evaluation of 16 cases. J Oral Surg 17: 27–33, November 1959.
11. Rud, J.: The split-bone technic for removal of impacted third molar. J Oral Surg 28: 416–421, June 1970.
12. Howe, G. L., and Poyton, H. G.: Prevention of damage to the inferior dental nerve during the extraction of mandibular third molars. Brit Dent J 109: 355–363, November 1960.
13. Friedman, J. W.: The case for preservation of third molars. J Calif Dent Assoc 5: 50–56, February 1977.
14. American Dental Association, Council on Dental Care Programs: Code on Dental Procedures and nomenclature. J Am Dent Assoc 92: 647–652, March 1976.
15. American Dental Association, Bureau of Economic and Behavioral Research: Dental fees charged by general practitioners and selected specialists in the United States, 1979. J Am Dent Assoc 102: 657–679, May 1980.
16. Friedman, J. W.: The case for the preservation of third molars. J Calif Dent Assoc 5: 50–56, February 1977.
17. Waldo, D. R., and Gibson, R. M.: National health expenditures, 1981. Health Care Financ Rev: 1–36, September 1982.
18. Report to Congress: Dental auxiliaries could save costs. Am Dent Assoc News, May 12, 1980.
19. Friedman, J. W.: PSROs in dentistry. Am J Public Health 65: 1298–1303, December 1975.
20. Beideman, R. W., Johnson, O. N., and Alcox, R. W.: A study to develop a rating system and evaluate dental radiographs submitted to a third party carrier. J Am Dent Assoc 93: 1010–1013, November 1976.

Routine EEG vs. Intensive Monitoring in the Evaluation of Intractable Epilepsy

THOMAS R. PERRY, MD
ROBERT J. GUMNIT, MD
JOHN R. GATES, MD
ILO E. LEPPIK, MD

Dr. Perry is a research fellow in the Department of Neurology, University of Minnesota. Dr. Gumnit is professor of neurology and director of the Comprehensive Epilepsy Program, Dr. Gates is assistant professor of neurology, and Dr. Leppik is associate professor of neurology at the same university.

This work was supported by Program Project Grant NS-16308 from the National Institute of Neurological and Communicative Disorders and Stroke.

Tearsheet requests to Robert J. Gumnit, MD, Professor and Head, Department of Neurology, St. Paul–Ramsey Medical Center, 640 Jackson St., St. Paul, Minn. 55101.

SYNOPSIS

Appropriate treatment of patients with intractable seizures requires precise identification of the type (or types) of seizure the patient experiences and correlation of this information with data from electroencephalography localizing the focus of the seizure in the brain. For such patients, the technique of "intensive monitoring" has gained rapid acceptance in the past several years as the investigative method of choice.

Intensive monitoring usually entails prolonged electroencephalographic recording with simultaneous videotaping of the patient. Another common technique is prolonged monitoring of the patient's electroencephalogram (EEG) by radiotelemetry, during which time the patient is closely observed by trained personnel for suspected seizures.

To compare the quality of information obtained from intensive monitoring with that from careful routine electroencephalography, the authors reviewed the medical records of 100 consecutive patients who had received both kinds of study after being referred for treatment in the special Epilepsy Treatment Unit of the University of Minnesota's Comprehensive Epilepsy Program (CEP).

Success of each method was defined by ability to record an actual seizure. The routine EEG examination recorded actual seizures in 7 percent of patients in the study. With video EEG, following careful withdrawal of anticonvulsant drugs, seizures were recorded in 70 percent of patients. Telemetered EEG recorded seizure activity in 50 percent of those patients for whom the other two methods had failed to detect seizures.

Intensive monitoring revealed that 60 percent of patients for whom the routine EEG study had recorded only one seizure type actually suffered from two or more types. Clinical diagnosis was changed in 84 percent of the patients. In this study, intensive monitoring was found to be far superior to the routine EEG examination as an aid to precise diagnosis of intractable seizure disorders.

EPILEPSY IS A MAJOR HEALTH PROBLEM in the United States. An estimated 2 million Americans have some form of epilepsy, and there are 200,000 new cases every year (*1*). The Commission for the Control of Epilepsy and Its Consequences estimated that in 1975 the overall cost of epilepsy to the nation was $3 billion—only 9 percent of which was spent on treatment.

A large part of the problem is that epilepsy is very difficult to diagnose and treat effectively. Epilepsy is not a single disease: it is a term applied to patients suffering from recurrent seizures, and these seizures may be caused by many different diseases.

For the most part, the many causes of epilepsy are beyond the "cure" of modern medicine. Instead, the physician strives for adequate seizure control so that the patient can lead a more normal life. This strategy has been partially successful. Studies in the 1960s and early 1970s suggested that at that time medical management provided complete seizure control in about half of all epilepsy patients, partial control in a fourth, and no control in the remaining fourth (*2*).

Patients in the "no control" group are said to have intractable epilepsy. Although they constitute a relatively small proportion of the total population of epilepsy patients, the cost in human suffering to themselves and their families—and in dollars to society—is disproportionately large. But many patients who appear to belong to this category can be helped by appropriate medication—and in certain cases surgery—if the precise nature of their seizures can be defined.

From the early 1950s until recently, the accepted method of diagnostic evaluation of epilepsy remained constant. Physicians made the diagnosis on evidence provided by a routine interictal (between seizure) electroencephalogram (EEG) and an eyewitness description of the patient's seizures by relatives or close friends. To make the diagnosis of epilepsy and start treatment, physicians do not have to observe a seizure themselves—and in fact rarely do.

'Many patients [with seemingly intractable epilepsy] can be helped by appropriate medication—and in certain cases surgery—if the precise nature of their seizures can be defined.'

This method of evaluation is successful in the vast majority of cases. But for the patient with seemingly intractable epilepsy, the selection of appropriate treatment requires more precise information about the type (or types) of seizures the patient suffers, their clinical and EEG manifestations, duration, and frequency. For these patients, the technique of "intensive monitoring" has in the past several years gained rapid acceptance as the investigative method of choice.

Intensive monitoring can be implemented in several ways, but the essence of the technique is simultaneous "capturing" of the clinical and EEG features of seizures. This usually entails prolonged EEG recording (usually for about 6 hours at a time) with simultaneous videotaping of the patient. Another common technique is monitoring of the patient's EEG by radiotelemetry over a prolonged period (often up to several days), during which the patient is closely observed by trained personnel for suspected seizures. With both methods, the careful withdrawal of antiepileptic medications is frequently used to precipitate seizures.

Although several articles (*3–8*) have testified to the value of intensive monitoring, there have been no studies that have directly compared its usefulness with that of the routine EEG in the evaluation of intractable epilepsy. For this reason, we carried out a retrospective study of the records of 100 patients who had received both routine EEG studies and intensive monitoring upon referral to the Comprehensive Epilepsy Program (CEP) of the University of Minnesota.

The Comprehensive Epilepsy Program

The Minnesota CEP was initially developed under a contract with the National Institute of Neurological and Communicative Disorders and Stroke. The program carries out a broad range of clinical research studies; education for health professionals, epilepsy patients, and their families; and coordination of community services for epileptics. The program's center of activity, based at University of Minnesota hospitals, is the Epilepsy Treatment Unit, which provides an orderly sequence of outpatient screening and evaluation; inpatient medical, psychological, and social evaluation; and long-term post-discharge care in milieus that vary from independent living to more protected environments.

Special diagnostic studies are part of an organized

EEG and video monitoring record the initial moments of a generalized tonic-clonic seizure. The seizure begins with a grimace and cry, followed by vigorous limb movements and jerking. Moments later the patient is unconscious

and carefully coordinated treatment plan. Patients admitted to the hospital receive extensive EEG studies during their stays, which average about 5 weeks.

Soon after admission, a routine EEG is performed in the regular University Hospital EEG laboratory. This examination is a 40-minute recording, using special nasopharyngeal electrodes. Sleep deprivation, light stimulation, and hyperventilation of the patient are employed in an attempt to stimulate a seizure during the recording.

A video EEG study is carried out a week or more later, usually following a careful withdrawal of some portion of the patient's antiepileptic medication. Typically, the video EEG is an approximately 6-hour, 25-channel EEG recording with concurrent video and audio monitoring. A real-time clock and 8 channels of EEG are superimposed on the video image of the patient for later playback and analysis should a seizure occur. Video monitoring is repeated if needed—often several times.

If routine and video EEGs fail to detect seizures, EEG telemetry is performed. The procedure employs a portable radio transmitter, attached to the patient, and a separate, stationary receiving unit with recording capability. Sixteen channels of EEG are recorded digitally on tape, together with real-time clock data, for later playback and analysis should a suspected seizure be observed. Telemetry can last for several hours to several days, during which time the patient pursues his or her normal activities in the treatment unit.

Electroencephalographers certified by the American Board of Qualification in Electroencephalography interpret all records.

Study Methods

Patient selection. Records of consecutive patients admitted to the CEP between March 20, 1980, and July 1, 1981, were reviewed until 100 patients were found who met the following criteria:

—The admission under study was their first to the CEP.

Table 1. Seizure types identified by routine EEG and intensive monitoring (video EEG and EEG telemetry) in 100 patients [1] in the Minnesota Comprehensive Epilepsy Program

Seizure type	Number of seizure types identified by		
	Routine EEG [2]	Video EEG [2]	EEG telemetry [3]
Simple partial	0	8	1
Complex partial	2	30	11
Partial with secondary generalization	1	6	8
Absence	1	4	0
Atypical absence	1	10	1
Primarily generalized tonic clonic	0	1	0
Tonic	0	3	0
Myoclonic	1	1	0
Atonic	0	3	0
Unclassified	0	2	0
Pseudoseizure	1	13	1
Electrical	6	[4] 0	[4] NA
Total	13	81	22

[1] Each patient had 0–2 seizure types.
[2] Performed for all patients.
[3] Performed for 41 patients in whom routine EEG and video EEG had failed to detect seizures.
[4] See "Discussion" for explanation.
NOTE: NA = not applicable.

—While hospitalized, they had received both routine EEG and video EEG studies. (For 41 of these patients, in whom routine EEG and video EEG had failed to provide adequate data, EEG telemetry was also performed.)

Data collection. Data extracted from the 100 records selected for study included diagnosis on referral; final diagnosis from the CEP; clinical manifestations and EEG characteristics of seizure events recorded by routine EEG, video EEG and EEG telemetry when performed; and duration of video EEG and EEG telemetry.

The final diagnoses from the CEP conformed with the revised International Classification (*9*); however, the diagnoses of the referring physicians generally did not. We therefore added the obsolete seizure disorder terms "grand mal" and "petit mal" to our tabulation scheme to reflect common referral diagnoses.

Results

The seizure types that were recorded by routine EEG, video EEG, and EEG telemetry are shown in table 1.

On routine EEG the ictal yield (percentage of patients for whom at least one seizure type was recorded) was 13 percent; however, when electrical seizures (those for which no clinical manifestations were noted by the EEG technologist) were excluded, the ictal yield dropped to 7 percent.

The ictal yield on video EEG was 70 percent. On EEG telemetry (performed on 41 patients), the ictal yield was 50 percent.

For many patients, the video EEG recorded two seizure types although the routine EEG had recorded only one. Overall, the video EEG detected two seizure types in 60 patients, one in 39 patients, and none in 1 patient. The improved yield of video EEG with drug withdrawal, compared with routine EEG, has a P value of $< .0000000000000001$.

In our study, after all EEG examinations had been completed, we failed to record an actual seizure with adequate EEG documentation in only 15 patients. Of these 15, 5 had a final diagnosis of nonepileptic disorder, and the remaining 10 were treated on the basis of interictal electrical discharges and observation by our nurses.

Diagnoses by referring physicians and final diagnoses by the CEP are shown in table 2. The diagnoses were changed in 84 percent of the patients. This change is statistically significant: in individual cases, one can predict with 99 percent confidence that the referring diagnosis will be changed 74 to 94 percent of the time.

The referral diagnosis was correct for only 3 of the 9 patients with pseudoseizures. The referring physicians correctly diagnosed 30 of the 55 patients with complex partial seizures. Even after intensive monitoring and prolonged inpatient observation, the type of seizure suffered by 2 patients remained unclassified at the time of their discharge.

Table 2. Comparison of referral diagnoses and final diagnoses, after intensive EEG monitoring, for 100 patients [1] in the Minnesota Comprehensive Epilepsy Program

Seizure type diagnosed	Number of seizure types—referral diagnoses	Number of seizure types—final diagnoses
Simple partial	2	11
Complex partial	40	55
Partial with secondary generalization	0	23
Absence	1	4
Atypical absence	0	7
Primarily generalized tonic clonic	0	6
Tonic	0	2
Myoclonic	3	1
Atonic	1	1
Unclassified	38	2
Pseudoseizure	3	19
Grand mal	27	0
Petit mal	11	0
Total	126	131

[1] Each patient had 1–3 diagnoses.

Discussion

Any evaluation of epilepsy must address two issues. First, are the patient's seizures epileptic? Second, if they are, then what are their pertinent characteristics?

The one reliable way to answer these questions is to record the clinical and EEG features of actual seizures. It is on this basis that we compared the effectiveness of routine EEG and intensive monitoring. The results of our study indicate that intensive monitoring with appropriate reduction of anticonvulsants is significantly superior to routine EEG in the detection and characterization of ictal events.

In a similar study, Mattson (*4*) reported an ictal yield of 2.5 percent with routine EEG and 55 percent with video EEG. Our ictal yield of 13 percent with routine EEG (electrical seizures included) is probably a reflection of the severity of disease seen in our patient population. We obtained a 70 percent ictal yield with video EEG. It is important to note that both studies used a judicious withdrawal of antiepileptic medications to precipitate seizures. In both our study and Mattson's, there are significant differences between ictal yield with routine EEG and that with video EEG.

For 41 of the patients included in our study, EEG telemetry was used effectively as a backup investigation when seizures had not been detected by routine EEG or video EEG. The sensitivity of EEG telemetry in detecting seizures is quite extraordinary when one considers the high ictal yield (50 percent) in this group. Others have done similar studies of EEG telemetry without quite such favorable results. Callaghan and McCarthy (*10*) and Woods and Ives (*11*) reported ictal yields of 30 percent on video EEG and 50 percent with telemetry in the patients they studied. The results of all of these studies indicate that EEG telemetry, in part because of its longer duration, detects ictal events missed on routine EEG, video EEG, or the two combined. Long-term recording in the freely moving patient makes telemetry especially useful to the physician in determining frequency and origin of a known seizure type.

An important advantage of video EEG is the permanent visual record it provides of the patient's behavior during a seizure. A physician reading a routine EEG during which a seizure occurred must rely on the technologist's written description of the seizure. Such descriptions, although often excellent, are limited because of the brief, transient, and complex clinical presentation of many seizures. The record on videotape, however, allows repeated review so that the clinical characteristics of the seizure can be precisely determined and the relationship of these characteristics to the onset and evolution of EEG abnormalities can be studied.

Correlation of the clinical and EEG features of seizures has a marked effect on the diagnosis of specific seizure types, as illustrated in tables 1 and 2. The most common seizure type detected by routine EEG (table 1) was "electrical." (Electrical seizures are periods in which there is abnormal EEG activity typical of a seizure but no alteration in the patient's behavior or responsiveness.) No seizures of this type were reported for video EEG in table 1 because further recording of additional seizures, during which patients' responsiveness was tested, invariably clarified the diagnosis of seizure type. No electrical seizures during EEG telemetry were reported in table 1 because the EEG record was only examined during those periods when patients' behavior, during close monitoring, suggested that a seizure was occurring.

A video EEG record is crucial to the diagnosis of pseudoseizure. This diagnosis depends on the observation of seizurelike spells in the absence of simultaneous ictal EEG abnormalities. The diagnosis can be especially difficult to sort out because many of these patients have frequent epileptic seizures in addition to their nonepileptic spells. Video EEG appears to be the only practical means of making the discrimination. Its usefulness in this regard is a major advantage, since 19 percent of the patients referred to our program left with a final diagnosis of nonepileptic disorder of psychogenic origin.

'In our study, intensive monitoring by video EEG and EEG telemetry was far superior to the routine EEG in providing necessary information for reliable diagnosis of patients with intractable seizure disorders.'

Video EEG was also the only investigation that repeatedly allowed us to make the diagnosis of atypical absence seizures. Distinguishing an atypical absence seizure from a complex partial seizure can be very difficult and depends upon subtle differences between the two types in clinical and EEG features.

Overall, intensive monitoring altered or clarified the referral diagnosis in the vast majority of patients, as illustrated by table 2. The referring physicians often had used either no diagnosic classification or an obsolete and ineffective one, since the diagnoses "unclassified," "petit mal," and "grand mal" were quite frequent. The prominence of complex partial seizures among the referral diagnoses is probably a reflection of the high prevalence of this seizure type among persons with epilepsy, its distinctive clinical manifestations and EEG presentation, and the fact that the criteria for this diagnosis have been relatively constant through several revisions of the international classification.

Alterations in diagnosis as a result of intensive monitoring have profound impact on therapy. Patients who have only nonepileptic spells (pseudoseizures) have no need for the antiepileptic medication that is frequently prescribed for them, although psychiatric intervention is warranted. The medical treatment for a generalized seizure disorder, such as atypical absence epilepsy, is quite different from that for a partial seizure disorder, such as complex partial epilepsy. The greater precision and accuracy of a diagnosis based on intensive monitoring leads to more appropriate therapy and often raises the possibility of surgery. Indeed, if surgery is considered as a treatment for epilepsy, then intensive monitoring—especially EEG telemetry—is essential to determine if all the seizures detected originate from the same focus in the brain.

Conclusions

In our study, intensive monitoring by video EEG and EEG telemetry was far superior to the routine EEG in providing necessary information for reliable diagnosis of patients with intractable seizure disorders. The additional cost of intensive monitoring appears to be entirely justified when one considers the benefits of improved seizure control that are a direct result of a more accurate evaluation.

Ictal yields of the magnitude reported in this study can only be expected when monitoring is carried out as part of an organized diagnostic and treatment scheme. Brief video EEG or telemetered EEG recordings cannot be expected to have the same value when carried out in an unselected patient population, in the absence of an organized diagnostic plan and team.

References

1. Commission for the Control of Epilepsy and Its Consequences: Plan for nationwide action on epilepsy. DHEW Publication No. (NIH) 79–1115. U.S. Government Printing Office, Washington, D.C., 1978.
2. Epilepsy Foundation of America: Basic statistics on the epilepsies. F. A. Davis Co., Philadelphia, 1975.
3. Binnie, C. D., et al.: Telemetric EEG and video monitoring in epilepsy. Neurology (NY) 31: 298–303 (1981).
4. Mattson, R. H.: Value of intensive monitoring. *In* Advances in epileptology: Xth Epilepsy International Symposium, edited by J. A. Wada and J. K. Penry. Raven Press, New York, 1980, pp. 43–51.
5. Porter, R. J., Penry, J. K., and Lacy, J. R.: Diagnostic and therapeutic reevaluation of patients with intractable epilepsy. Neurology (NY) 27: 1006–1011 (1977).
6. Porter, R. J., Theodore, W. H., and Schulman, E. A.: Intensive monitoring of intractable epilepsy: a two-year followup. *In* Advances in epileptology: XIIth Epilepsy International Symposium, edited by M. Dam, L. Gram, and J. K. Penry. Raven Press, New York, 1981, pp. 264–268.
7. Ramani, S. V., Quesney, L. F., Olson, D., and Gumnit, R. J.: Diagnosis of hysterical seizures in epileptic patients. Am J Psychiatry 137: 705–709 (1980).
8. Sutula, T. P., Sackellares, J. C., Miller, J. Q., and Dreifus, F. E.: Intensive monitoring in refractory epilepsy. Neurology (NY) 31: 243–247, March 1981.
9. Commission on Classification and Terminology of the International League Against Epilepsy: Proposal for revised clinical and electroencephalographic classification of epileptic seizures. Epilepsia 22: 489–501 (1981).
10. Callaghan, N., and McCarthy, N.: Twenty-four-hour EEG monitoring in patients with normal, routine EEG findings. *In* Advances in Epileptology: XIIth Epilepsy International Symposium, edited by M. Dam, L. Gram, and J. K. Penry. Raven Press, New York, 1981, pp. 357–359.
11. Woods, J. F., and Ives, J. R.: Prolonged monitoring of the EEG in ambulatory patients. *In* Advances in Epileptology: VIIIth Epilepsy International Symposium, edited by J. K. Penry. Raven Press, New York, 1978, pp. 109–113.