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An online diary for tracking epilepsy

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ABSTRACT

My Epilepsy Diary is a free Web-based application on the public website epilepsy.com, available for patients to track epilepsy and to aid clinicians with data-based, individualized management. The first aim of this descriptive study was to outline electronic diary functions. Second, the study retrospectively profiled a large cohort of 2010 calendar year diary users including demographics, seizure types, temporal distribution of seizures, triggers, and use and side effects of antiepileptic drugs (AEDs). A total of 1944 users provided demographic information and 1877 recorded seizure data. Most (64%) users were women. Average age was 29.9 ± 16.0 years. A total of 70,990 seizure entries and 15,630 AED entries were logged. Events were apportioned as 79% seizures and 21% seizure clusters. Specific AEDs were detailed in 7331 entries: monotherapy was used in 18% and polytherapy in 82%. Mood-related side effects were most commonly reported in 19% of 1027 users.

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1. Introduction

In approximately one-third of patients with epilepsy, antiepileptic medications fail to adequately control seizures [17]. In the clinical setting, management of drug-resistant epilepsy is challenging because of poor reporting of breakthrough seizures and inaccurate or nonexistent information about the dosages, duration, and side effects of previous drug trials. Clinicians must use all available tools to improve the management of epilepsy and facilitate rational clinical decision making. In epilepsy clinics, calendar diaries of seizure frequencies can be crucial for care, as recall is faulty and emphasizes the most recent and dramatic events [6]. In addition, paper diaries are easily lost or misplaced. With the growing use of the Internet and new computer technology, Web-based health resources may aid in gathering the required detailed symptom and medication tracking needed for individualized epilepsy management [3,22]. In addition, data collection for research from patients with access to computers becomes potentially feasible on an international scale.

Ideally, clinicians would have accurate information about seizure types, frequency and clusters, triggers, compliance, and medication trials to create a tailored management plan. These variables need to be considered in light of the patient's comorbidities and the psychosocial circumstances. The National Institute of Neurological and Communicative Diseases and Stroke (NINCDS) has formulated consensus on a set of common data element forms to encourage consistent data collection in epilepsy clinical trials. A basic recommended seizure diary form is available at http://www.commondataelements.ninds.nih.gov/epilepsy.aspx. Tracking the data is difficult and time consuming for patients and their caregivers and requires organization and diligence. Web-based technology may make record keeping more manageable [20].

My Epilepsy Diary (http://www.epilepsy.com/seizurediary) is a free Web-based application on the public website *epilepsy.com* (http://www.epilepsy.com), created for patients to record detailed information in an electronic calendar book with the ultimate goal of helping providers optimize and individualize patients' treatment plans. The online diary is a service of The Epilepsy Therapy Project, a nonprofit organization, developed in conjunction with the software firm, Irody. Another recent epilepsy diary, called Seizure Tracker, can be found at *seizuretracker.com*. The first aim of this descriptive study is to outline the various functions of the *epilepsy.com* electronic diary. Second, the study retrospectively profiles the diary users including demographics, prevalence of seizure types, temporal distribution of seizures, seizure triggers, and use and side effects of antiepileptic medications.

2. Methods

The diary was introduced in September 22, 2009 and, by the end of 2010, had 7786 registered accounts. This count surpassed 10,000 users by April 2011. Diary users must register once and log in online to enter information; caregivers and parents are able to create accounts for infants or children and data from all ages were accepted. Users entered data by selecting choices from prefilled drop-down menus and by entering free text into boxes on the screen. Background general

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medical and seizure history including seizure triggers, duration, and epilepsy and nonepilepsy medications, including dosages, can be entered. Users input characteristics of their seizure types by selecting prefilled descriptors about seizure onset and seizure semiology and also entering information into free text data fields (Fig. 1). On the electronic calendar, several types of events can be logged including seizures or seizure clusters, mood, medication side effects, and taken, missed, or extra medications. Entries can be retroactive at any time and the events can be logged onto the calendar by day and even time of day. In addition, female users can track menstrual cycle and flow. Attachments, including photos, documents, files, and videos, can be uploaded to the diary. Users are also able to fill out a "Seizure Response Plan" form, which includes a list of emergency and health care contacts and outlines of treatment plans.

Access to My Epilepsy Diary through mobile device applications via the Apple iPhone/iPod Touch was introduced in April 2010 and via Google Android in December 2010. With the Web browser or the mobile device applications, users can set personal reminders for specific dates and times that can be sent by e-mail, or via text/short message service (SMS) to remind the users to take or refill medications, to log in to the diary, or to attend appointments.

Patients or their caregivers can download data, then print and bring the information to their clinic appointments for clinicians to review. If users grant access to their diaries, their health care providers can download data through the "Clinical Portal" website to facilitate clinic visits and guide clinical decision making.

This was a retrospective, descriptive study of the database of diary users comprising data entered for the 2010 calendar year. For analysis in this article, data logged by active users during 2010 were downloaded into spreadsheets and test diaries were eliminated. Users were not obligated to complete all fields of the diary; therefore, the number of users for each data point varies. Where the user considered a group of seizures too numerous to count, the episode was recorded as one seizure cluster. Seizure clusters were tracked separately from seizure counts.

A board-certified neurologist classified seizures by reviewing the user's entered selections of the seizure descriptors and free text data fields (Fig. 1); no review of medical records was available. The categories used for seizure classification included: unknown; partial, otherwise unclassified; simple partial; complex partial; secondarily generalized tonic–clonic; generalized tonic–clonic, onset unknown; generalized tonic–clonic; generalized absence; generalized myoclonic; generalized tonic; generalized clonic; generalized atonic; and infantile spasms. For example, if a user designated a seizure type as "petit mal" or "absence" and selected typical descriptors such as "no warning" and duration less than "30 seconds," the seizure was classified as "generalized absence." However, because the electronic diary does not require that all available fields be completed, the seizure type was designated as "unknown" if there was insufficient or unclear information about descriptors of seizure onset or seizure semiology. Foreign language entries were not counted. Entries designated "pseudoseizure" or "nonepileptic" in the free text fields were excluded.

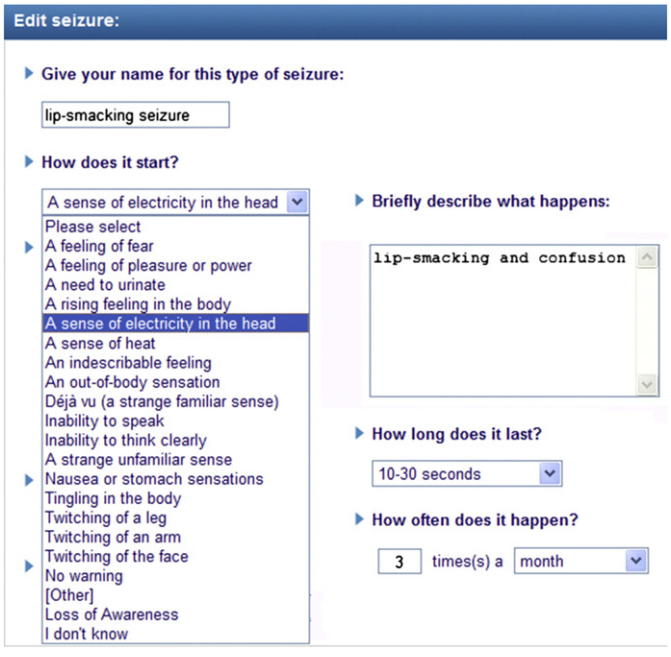

Fig. 1. Sample input screen wherein a user inputs both prepopulated and free text descriptors of seizure types including onset, semiology, duration, and frequency.

3. Results

In 2010, a total of 1944 users provided demographic information and logged 70,990 seizure entries (Table 1). Of the 1384 users who recorded their gender, the majority were women (890, 64%). Average age among the 1733 diary users who entered age information was 29.9 ± 16.0 years.

Eight hundred sixteen users entered their country of residence; approximately 69% of the users in 2010 were from the United States. Marital status was entered by 756 users; 54% were single or divorced and 42% were married or partnered. Highest education level reached was selected by 749 users from a drop-down menu: 19% completed some high school or lower, 14% obtained a high school diploma, 27% finished some college, and 33% obtained a college degree or had post-college training. The database tracked the method by which users accessed My Epilepsy Diary in 3302 users, with some users accessing the diary by more than one method. The majority of users, 91%, accessed the diary via the Internet, on average 32.4 times per year. Use of mobile device applications to log in to the diary accounted for 24%. The database recorded 551 personal reminders that were sent from the diary to e-mail accounts in 36% and by text/SMS in 64%.

In 2010, 1877 users logged 52,511 total events, which were apportioned as 79% seizures and 21% seizure clusters. Approximately 62%

Table 1
Baseline characteristics of users in 2010.

	N	%	Mean	SD
Total users	1,944			
Sex	1,384			
Male	494	36		
Female	890	64		
Entries of age	1,733			
Age (years)			29.86	15.95
Total entries	86,620		44.56	105.42
Entries seizure diary	70,990		36.52	97.86
Entries AEDs	15,630		8.04	18.37
Country of residence	816			
United States	563	69		
Outside United States	253	31		
Marital status	756			
Single	357	47		
Married	266	35		
Divorced	53	7		
Partnered	56	7		
Widowed	2	0.3		
Other	22	3		
Education level	749			
Some elementary	68	9		
Graduated elementary	15	2		
Some high school	60	8		
Graduated high school	107	14		
Some college	204	27		
Graduated college	138	18		
Some graduate study	31	4		
Graduate degree	80	11		
Other	46	6		

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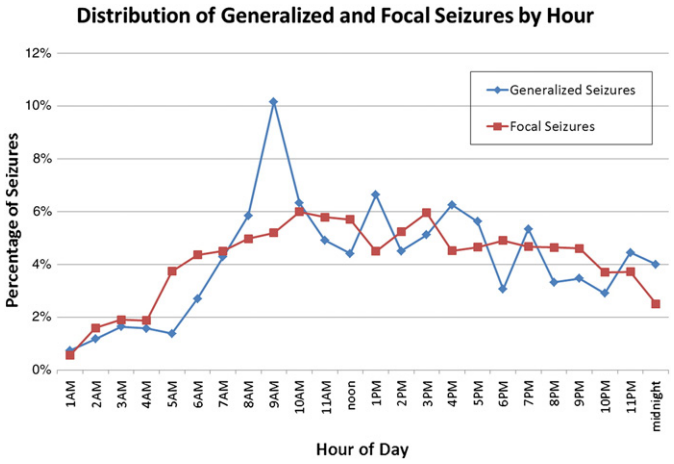

Fig. 2. Temporal distribution of generalized (blue diamonds) and focal (red squares) seizures for diary users in 2010. Percentage of seizures (y axis) at each hour of the 24-hour day (x axis) is plotted.

of the seizures were logged at specific times during the day. A graph of seizures, separated into generalized and focal seizures by each hour of the day, was generated (Fig. 2). For generalized seizures, events tended to occur in the morning, with 34% occurring between 5 and 11 AM, whereas focal seizures were fairly evenly distributed throughout the day and evening. Few seizures were logged at night, with 11% of generalized and 12% of focal seizures entered between 11 PM and 5 AM. χ^2 testing on equivalence of distributions of seizures by 6-hour blocks of time yields a χ^2 of 81.5 (Yates' $\chi^2 = 81.1$), $P = 0.00$, $df = 3$, indicating a highly significant different distribution in timing of focal and generalized seizures [23].

Age at first seizure (including a febrile seizure) was entered by 776 users. Seizure onset occurred before 2 years of age in 14%, between 2 and 12 years in 34%, between 13 and 20 years in 25%, between 21 and 40 years in 22%, and between 41 and 64 years in 5%. Of the 741 users who logged data about febrile seizures, 11% reported a history of febrile seizures, 74% had no febrile seizures, and 14% were unsure. Among users who entered historical data about febrile seizures, 11% of users with complex partial seizures endorsed a prior history of febrile seizures.

Triggers for seizures were logged by 1877 users. The most common precipitating factor was menses, which was selected by 65% of total users. The second most common trigger was related to the sleep–wake cycle, with sleep deprivation or inadequate sleep in 7%, and when waking up from sleep or occurring during sleep in 6%. Change in mood or emotional stress was listed as a trigger in another 6%. Of users who entered data about triggers, a total of 6% selected that they did not know of any identifiable triggers of seizures.

The distribution of seizure types among the users is illustrated in Fig. 3, taking note that an individual user could be represented by multiple seizure types. A total of 2670 unique users logged 4361 seizure types averaging 1.63 different seizure types per user. The most common category of seizure was complex partial at 24%, followed by simple partial at 17%. Focal seizures (i.e., simple partial, complex partial, partial otherwise unclassified, and secondarily generalized tonic–clonic seizures) accounted for 58% of seizure types. Generalized seizures (i.e., generalized absence, generalized tonic–clonic, generalized tonic–clonic unknown onset, generalized myoclonic, generalized atonic, generalized tonic, generalized clonic, infantile spasms) constituted 27% of the total seizure types. Fifteen percent of the events were classified as unknown.

There were 15,630 diary entries related to antiepileptic drugs (AEDs), detailed in Table 2. Overall, 18% of users were managed on monotherapy, whereas 82% were on polytherapy for epilepsy. The most commonly taken AED in 2010 was levetiracetam in 1506 diary users, followed by lamotrigine in 1070 users. Data regarding AED compliance were entered by 1985 users during 2010: these users recorded 2074 instances of missing AEDs, 1376 entries of taking extra AEDs, and 26,688 times when they took their AEDs. In 2010, 22% of users who entered compliance data admitted to missing at least one AED.

There were 1027 users who reported 3246 side effects with an average of 3.16 side effects per user (Table 2). The most common side effects were mood related at 19% and included users who selected "psychological problems," "depression," "anxiety," "agitation," "anger or hostility," and "apathy." Severity of the mood side effects was mild in 44%, moderate in 30%, and severe in 26%. Feeling sleepy or tired was the next most prevalent adverse effect reported in 15%, rated as mild in 42%, moderate in 30%, and severe in 28%.

4. Discussion

This study demonstrates the feasibility of tracking a population of individuals with epilepsy with an online diary. Although the primary purpose of the diary was assistance with clinical care, a conglomerate set of anonymous data permitted a "snapshot" of characteristics of a segment of the epilepsy community.

The typical diary user in 2010 was a middle-aged, single or divorced woman who had graduated high school. Women held 64%

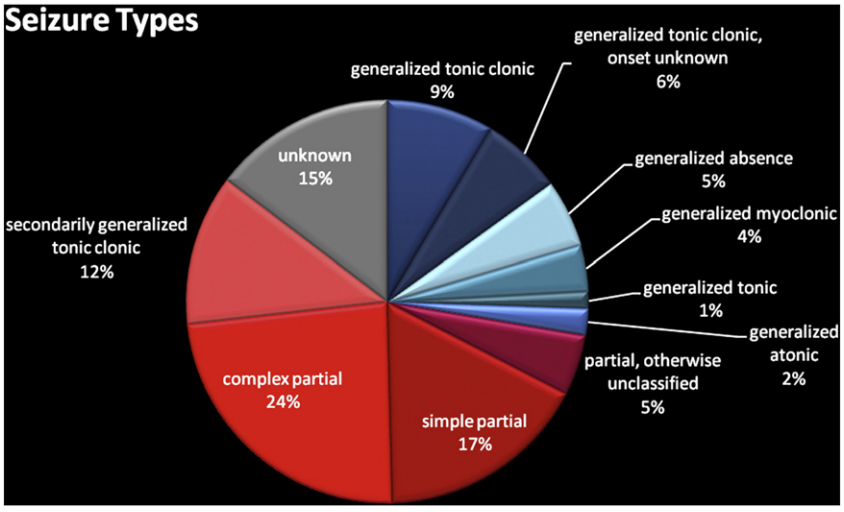

Fig. 3. Pie chart representing percentages of different seizure categories among diary users in 2010.

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Table 2
Antiepileptic drugs and side effects.

	N	%
AED regimens logged	7331	
Monotherapy	1334	18
Polytherapy		
2 drugs	1635	22
3 drugs	1287	18
4 drugs	940	13
>4 drugs	2135	29
Users reporting side effects	1027	
Side effects reported	3246	
Combined mood side effects	651	19
Sleepiness, fatigue	479	15
Memory, attention, cognitive problems	427	13
Headache	281	9
Dizziness, lightheadedness	256	8
Unsteady gait	152	5
Double vision, blurred vision	146	4
Incoordination	131	4
Gastrointestinal upset	130	4
Tremor, shaking	126	4
Speech changes	90	3
Weight change, appetite change	83	3
Other	294	9

of the diary accounts. Age averaged 29.9 ± 16.0 years. This segment of the epilepsy population was motivated to document and track their disease online. Patients older than 46 were underrepresented in the diary, so the data are skewed toward a younger cohort of patients with epilepsy who are likely to be more comfortable using computers, electronic devices, and the Internet. The high education level of the cohort, with 60% reporting some college, is likely a reflection of computer literacy among the diary users. However, 19% of users had education limited to or less than some high school, suggesting that the diary can be accessible to users of limited education or, perhaps, by their caregivers. U.S. residence was listed for 69%, but about a third of users were from outside the United States, reflecting the worldwide scope of the Internet.

Online seizure tracking may select for a population with more intractable or difficult-to-control epilepsy as opposed to patients with well-controlled seizures who have little incentive to chart information about their seizures. Indeed, among our diary cohort, users likely had drug-resistant epilepsy because 82% of users were managed on polytherapy drug regimens. The cohort was biased toward a severe medically intractable subset of patients, as even among the polytherapy group a large proportion, 29%, were concurrently taking more than four AEDs. The most common perceived trigger for seizures was the menstrual cycle, selected by 65% of users, which highlights the prevalence of female users. This estimate of a menstrual trigger is much higher than that in some previous reports [9] of at least a doubling of seizure frequency around menses in one of three women. The difference may be a consequence of self-reported identification of menses as a trigger, whereas previous medical literature has defined catamenial epilepsy as at least a twofold increase in seizures around specific phases of the ovulatory cycle [9].

Rapidly consecutive seizures with a return to baseline between episodes have been thought to be more likely to arise from a single seizure focus, especially if occurring within 8 hours of a prior seizure and, therefore, may not be independent events [9]. Our study estimated that about 21% of the seizures were seizure clusters compared with wide-ranging estimates in the medical literature of the prevalence of clustering from 14 to 60% [9]. A prospective daily diary study with 87 compliant users estimated that 43% of subjects met the clinical definition of three seizures in a 24-hour period, whereas 22% met statistical criteria for seizure clustering [10]. Identifying seizure clusters is important for patient care, to look for underlying triggers of clusters and to set a personalized threshold for patients and caregivers to administer rescue medications or seek medical attention.

With respect to the seizures and clusters logged by users in 2010, 62% entered seizures at specific times during the 24 hours in a day. A few studies based on limited numbers of seizure diaries examined the temporal distribution of seizures. A pooled analysis of three different studies of 66 subjects estimated that 53% of seizures did not follow a Poisson distribution, suggesting that seizures do not occur randomly during a 24-hour period [12,26]. Our study includes a large number of epilepsy diaries to investigate the circadian patterns of seizures. In 585 diary users who reported generalized seizures, 34% occurred between the hours of 5 and 11 AM, keeping with the phenomenon initially described by Janz in 1953 as “awakening grand mal epilepsy” [14,27]. By contrast, 1265 diary users logged focal seizures that were evenly distributed throughout morning, afternoon, and evening compared with a midday peak in partial seizures previously reported in the literature [12]. It is important to note that seizures are entered retroactively and logged events may not represent the time of the seizures but may reflect the time that seizures were recorded. Seizure reporting is subject to recall bias and often users with generalized or complex partial seizures have amnesia or altered awareness and may not log all of their events, especially events occurring during sleep.

An electronic diary may result in underreporting in circumstances in which the patient and caregiver are unaware that a seizure has occurred. Assays of seizure awareness in video-EEG monitoring units have shown impaired recall of seizures in 23% [11], 33% [5], 44% [15], 55% [13], and 61% [1]. Self-reporting also does not allow for complete exclusion of all nonepileptic events or other imitators of seizures. The opposite problem of false-positive registration of nonseizure events also can be problematic for diaries in either paper or electronic format. One study of outpatient ambulatory 24-hour EEGs [25] in 502 patients compared EEG patterns of seizures with patient-recorded diary information. Among 47 records containing EEG evidence of partial seizures, 86.6% of the recordings included push-button event markers by the patient or family in the absence of concurrent EEG changes. Not all partial seizures are accompanied by scalp EEG changes [4], but many of these events were probably false-positive seizure reports.

Only limited prior literature discusses seizure diaries. Neugebauer and associates [21] investigated test–retest reliability of seizure diaries. The investigators phoned 84 subjects who were maintaining a seizure diary, and asked them to state the number of seizures that they had entered for the previous day, without looking at their diaries. Absence of an entry or an uninterpretable entry was documented in 30 of 84 subjects. For those who did make an entry, 64 of 66 seizures were correctly recalled on the day after the seizure. Glueckauf and colleagues [8] compared retrospective and prospective seizure counts in diaries kept by 32 patients with drug-resistant focal seizures and in diaries kept by 17 caregivers. Each estimated seizure frequency for the prior 2 months, and then prospectively completed a seizure diary for 1 month. Median seizure frequency estimate was 8.5 for the 2 retrospective months and 9.0 for the prospective month, reflecting good consistency by the patients. Caregivers were less consistent, estimating 5.0 and 4.0 seizures per month for the 2 retrospective months versus 1.0 for the prospective month. This study did not verify accuracy of seizure counts.

Interpretation of our study results is limited in several respects. First, this is a self-selected subgroup of people with epilepsy biased toward users with drug-resistant epilepsy. The seizures must be bothersome enough that the subject is motivated to maintain a diary. The patient or caregiver must be comfortable using computers or smart phones. Internet access must be available. Users fill in only desired selected fields of the diary; therefore, the data set is incomplete. Reliability of classification of seizure types is limited in accuracy given user-reported entries; insufficient descriptors of seizures contributed to a large percentage, 15%, of seizures classified as “unknown.” The length of time the user has been registered and the amount of activity

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by individual users of the electronic diary are highly variable. Self-reported retrospective data are subject to recall and response bias. Time stamping of the data is possible with electronic diaries, but we did not analyze time of entry as a measure of promptness of entry in this study.

Electronic diaries have advantages over paper diaries. Direct comparison of the two modes of entry has not been accomplished for seizure diaries, but such comparisons have been made for patient-recorded pain diaries. A randomized cross-over study was performed by Gaertner and co-workers [7]. The electronically recorded diary was preferred by subjects, was used more often, and was less subject to fabricated data than was the paper diary. Another trial of headache and chronic pain found information collection to be similar with paper and electronic diaries, but clear patient preference for using the electronic diary [19]. Electronic diaries can automatically record time on data entry, which can assist in subsequent data validation. This issue was explored by asking pain patients to chart their pain levels at three specific times every day for 3 weeks, simultaneously using an electronic diary and a paper diary [24]. The paper diaries indicated 90% compliance within 15 minutes before or after the assigned recording times, but time stamps on the electronic diaries indicated a true compliance of 11%. This implies that subjects altered their paper entries to conform with the study rules and not with the true time of entry.

Entry by a handheld device was used by 24% of our study population. A systematic review of handheld electronic versus paper diaries kept for various medical conditions [2] observed better compliance with handheld devices in five of nine studies and the reverse in one. Four of four studies reported a user preference for the handheld diary, and three of three studies documented greater data accuracy with the handheld diary.

Experience to date with the diary demonstrates that it is a useful method for tracking seizures by some patients. Though information entered may be subject to recall and response bias, the electronic diary provides more data points for the clinician compared with the typical patient encounter with no available seizure record. Information is not misplaced and can be made accessible in tabular or graphic form to the treating medical team. Data entered by individual users can be extracted anonymously for the whole population of diary users to answer demographic questions, within limits of selection bias, and to make generalized observations about seizures and side effects after therapeutic changes. Future possibilities for development of epilepsy diaries in function and in research studies include analysis of diary automatic reminders to improve compliance, increased use of electronic diaries for clinical trials, comparison of seizure and side effect data before and after antiepileptic drug changes, and linkage of the diary to automated sensors, such as seizure-detecting accelerometer watches [16,18] and pillbox compliance monitors.

Conflict of interest statement

No funding was taken from industry for the study. Dr. Le and Ms. Shafer report no conflicts of interest. Dr. Bartfeld is an employee of the software firm Irody, Inc., and Dr. Fisher is a consultant to Irody, Inc.

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