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Longitudinal Digital Mood Charting in Bipolar Disorder: Experiences with ChronoRecord Over 20 Years

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ABSTRACT

Introduction Longitudinal study is an essential methodology for understanding disease trajectories, treatment effects, symptom changes, and long-term outcomes of affective disorders. Daily self-charting of mood and other illness-related variables is a commonly recommended intervention. With the widespread acceptance of home computers in the early 2000s, automated tools were developed for patient mood charting, such as ChronoRecord, a software validated by patients with bipolar disorder. The purpose of this study was to summarize the daily mood, sleep, and medication data collected with ChronoRecord, and highlight some of the key research findings. Lessons learned from implementing a computerized tool for patient self-reporting are also discussed.

Methods After a brief training session, ChronoRecord software for daily mood charting was installed on a home computer and used by 609 patients with affective disorders.

Results The mean age of the patients was 40.3 ± 11.8 years, a mean age of onset was 22 ± 11.2 years, and 71.4 % were female. Patients were euthymic for 70.8 % of days, 15.1 % had mild depression, 6.6 % had severe depression, 6.6 % had hypomania, and 0.8 % had mania. Among all mood groups, 22.4 % took 1–2 medications, 37.2 % took 3–4 medications, 25.7 took 5–6 medications, 11.6 % took 7–8 medications, and 3.1 % took >8 medications.

Conclusion The daily mood charting tool is a useful tool for increasing patient involvement in their care, providing detailed patient data to the physician, and increasing understanding of the course of illness. Longitudinal data from patient mood charting was helpful in both clinical and research settings.

Introduction

Affective disorders, including major depressive disorder (MDD) and bipolar disorders (BD), are common, recurrent, and complex mental disorders with enormous consequences for patients, families, and society [1]. Depressive disorders are a major burden on a society, including medical costs, drug costs, workplace absenteeism, and reduced productivity [2, 3]. The lifetime course of depressive illness affects individual suffering and functioning as well as the socio-economic burden [4–7]. The median age of onset of MDD and BD is between 20 and 30 years [8], followed by a large variation in disease trajectories. Although some people only experience a single episode of depression [9], about 70–90 % of patients with affective disorders have at least one recurrence [10, 11]. For both MDD and BD, the risk of recurrence increases with the number of prior episodes [12].

Importance of longitudinal study

The frequent recurrences and serious consequences of affective disorders emphasize both the need to understand individual experiences and the importance of a collaborative approach to treatment [13]. A longitudinal study of the course of affective disorders is an essential methodology for understanding disease trajectories, treatment effects, symptom changes, and long-term outcomes. From a historical perspective, Emil Kraepelin used Zählkarten (diagnostic cards) to describe patient demographics and psychopathology and to study the longitudinal course of patients with psychotic disorders [14, 15]. The data on these cards eventually led to Kraepelin's dichotomous classification: the distinction between manic-depressive insanity and dementia praecox (schizophrenia).

Today, the value of a longitudinal study of the core symptoms of affective disorders is well established. Longitudinal tracking is essential for detecting prodromal phases of recurrences, recognizing patterns of longitudinal disease course, and evaluating treatments. Teaching patients to recognize early signs of recurrence and disease patterns is an important, effective, and empowering approach to improving disease management [16].

Tools for the longitudinal study

One commonly recommended intervention for the longitudinal study of affective disorders is daily self-charting of mood, sleep, medication, life events, and other illness-related variables. Daily patient mood charting complements clinician monitoring and can easily be combined with other psychosocial interventions that benefit both the patient and the clinician. Daily recording may capture observations that would be missed if data were only collected at clinic visits, and help differentiate between episodic and non-episodic disorders and detect subsyndromal symptomatology. Several paper-based instruments for daily mood recording have been developed, including the Life Chart Methodology [17] and STEP-BP Mood Chart [18]. ChronoSheet is a paper-based form for self-reporting developed by Peter Whybrow during the 1980s to follow the clinical course of patients with rapid-cycling variants [19]. Paper-based self-reporting instruments have been successfully used in clinical practice and in longitudinal research studies to characterize the long-term course of affective disorders. However, there are problems associated with paper-based tracking, including poor compliance, data entry errors, high costs for data entry, and limited feedback for the patient and clinician [20].

Automated longitudinal tracking

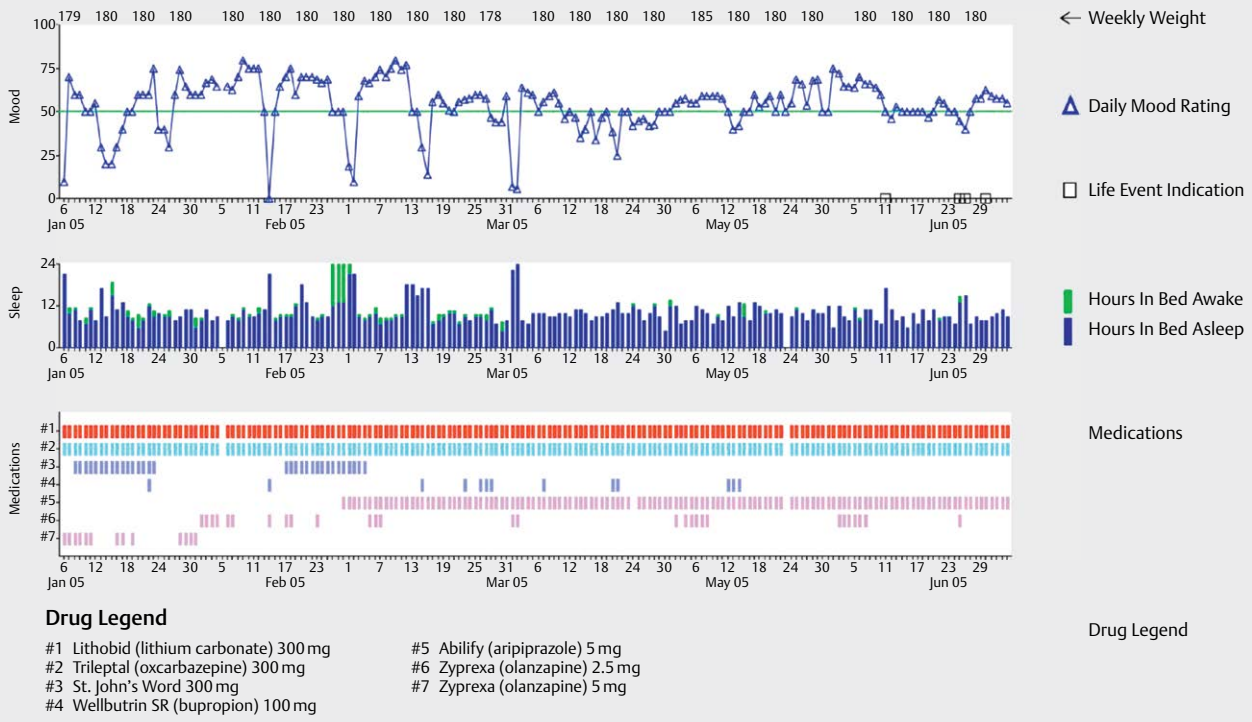
Until the early 2000s, longitudinal tracking and daily self-assessment of patients with AD was primarily paper-based. With the widespread acceptance of home computers in the early 2000s, automated patient tools were developed for mood charting, such as ChronoRecord [21], based upon the ChronoSheet [19]. Automated charting tools eliminated many of the problems of paper-based tools, including the expense of data entry for research studies. Patients installed ChronoRecord on a home computer and recorded mood, sleep, medications, and life events daily, and body weight weekly. ChronoRecord provided monthly charts that displayed the daily patient data that could be printed on demand for both patients and physicians (▶ **Fig. 1**). ChronoRecord was validated by patients with bipolar disorder, demonstrating that patients would accept a technology solution and reliably report daily mood [21, 22]. The immediate feedback improved motivation of the subject to complete a long-term study for many patients and enabled the timely use of clinical information captured during a longitudinal study.

This paper summarizes the daily mood, sleep, and medication data collected with ChronoRecord, and highlights some key research findings. Lessons learned from implementing a computerized tool for patient self-reporting are also discussed.

Methods

Over the last 20 years, ChronoRecord software was used to collect data from 609 patients with affective disorder. In total, 692 patients were registered to use ChronoRecord. Eighty patients did not return any data and 3 patients were missing a diagnosis and excluded from all analyses. All study participants were outpatients with a diagnosis of affective disorder based on DSM IV or DSM 5 criteria. The diagnosis of affective disorder was made by a psychiatrist in a clinical interview, and all patients received treatment as usual. All participants were volunteers recruited from a university mood clinic or private practice at multiple sites [21] and were informed about the study prior to providing written informed consent. The study was approved by each local institutional review board. ChronoRecord software was translated into several languages, including German and Spanish, which allowed the standardization of international data for analysis. All ChronoRecord data stored on the computer of the patient or physician, or the transferred data, are encrypted using a unique password. To maximize patient security and privacy, no patient data is stored on a web server.

Demographic data was obtained by a clinician at the time of enrollment. All data on medications taken, mood, and sleep were entered daily by the patient using ChronoRecord software in their native language. Patents received about a half hour of training on the use of ChronoRecord software, in person or by telephone, before entering data. During the training session, a medication list was created for each patient that included all drugs prescribed for bipolar disorder and any other prescribed or over-the-counter (OTC) drugs that the patient felt impacted their mood. The prescribed



▶ **Fig. 1** ChronoRecord: 180 days of electronic charting of a 41-year-old male with bipolar I disorder.

psychiatric drugs were selected from a list in the software, displayed by both brand and generic names. The patient could add a drug not found in the software and modify their medication list at any time. For each selected drug, the pill strength was chosen from a list of available strengths. Every day, for each drug, the patient entered the total number of pills taken.

ChronoRecord uses a 100-unit visual analog scale between the extremes of mania and depression to rate mood. The mood categories were based on the validation studies [21. 22], which compared patient self-ratings on ChronoRecord to clinical ratings on the Hamilton Depression Rating Scale (HAMD) and Young Mania Rating Scale (YMRS) [23, 24]. A mood entry less than 40 was considered depression, 40–60 euthymia, and greater than 60 hypomania/mania. The depression ratings varied from mild (entry of 20–39) to severe (entry of 0–19), and the mania ratings varied from hypomania (entry of 61–80) to severe (entry of 81–100). During patient training, anchor points were set by having the patient describe the most depressed and most manic states they had ever experienced. Patients often described a mixed episode as the most manic experience. The instructions given were to enter a single daily mood rating that best describes their overall mood for the prior 24 hours, calibrate the mood rating to the anchor points, and try not to let the previous day influence how the current day is rated.

For this summary analysis, the descriptive statistics for the demographic and clinical characteristics of the 609 patients were calculated using SPSS version 28.0.

Results

The demographic characteristics of patients who used ChronoRecord are shown in ▶ **Table 1**. The 609 patients had a mean age of 40.3 ± 11.8 years, a mean age of onset of 22 ± 11.2 years, and were 71.4 % female. The average number of days of data was 227.

The percent of time spent in the mood groups by diagnosis is shown in ▶ **Table 2**. When considering all patients, 70.8 % of days were euthymic, 15,1 % were mild depression, 6.6 % were severe depression, 6.6 % were hypomania, and 0.8 % were mania.

The daily hours of sleep by mood group for all patients is presented in ▶ **Fig. 2**, with 12.4 % of days with less than 6 hours of sleep, 51.7 % between 6 and 9 hours of sleep, and 35.8 % of days with greater than 9 hours of sleep.

The number of daily psychotropic medications taken by the mood group is shown in ▶ **Table 3**. When considering all mood groups, 22.4 % took 1–2 medications, 37.2 % took 3–4 medications, 25.7 % took 5–6 medications, 11.6 % took 7–8 medications, and 3.1 % took >8 medications. The most frequently taken psychotropic medications are shown in ▶ **Fig. 3**.

Discussion

For most patients, affective disorders are a recurrent, serious, lifelong illness. Given the substantial heterogeneity in the polarity, frequency, and severity of episodes, a longitudinal approach is fundamental to understanding the course of affective disorders. The daily self-reported data from patients using ChronoRecord provided an overview of patient status and useful information about affective

disorders. The most frequent symptom that patients with bipolar disorder experienced was depression (▶ **Table 2)**, as found previously [25]. Mild symptoms of both depression [26, 27] and hypomania [28] occurred frequently outside of episodes. Subsyndromal symptoms may be associated with considerable functional impairment, including unemployment [29, 30].

▶ **Table 1** Patient demographics (N = 609)*

Demographic	Category	N	Percent
Gender			
	Male	174	28.6
	Female	435	71.4
Diagnosis			
	BP I	335	55.0
	BP II	192	31.5
	BP NOS	31	5.1
	Unipolar	51	8.4
Disabled			
	No	424	76.3
	Yes	132	23.7
Full-time employment			
	No	306	55.0
	Yes	250	45.0
College graduate			
	No	270	46.8
	Yes	307	53.2
Married			
	No	287	49.7
	Yes	290	50.3

	N	Min	Max	Mean	SD
Hospitalizations	572	0	30	2.2	4.0
Age of onset	576	3	75	22.0	11.2
Age	609	13	79	40.3	11.8
Years of illness	574	0	55	18.5	12.5
Number of mood days	609	1	4769	227.0	456.6

* 692 patients registered to use ChronoRecord. Eighty patients did not enter any data. Three patients did not have a diagnosis code and were deleted from all analyses.

The most useful sleep parameter for self-monitoring was sleep duration [31]. In some patients with bipolar disorder, a change in sleep duration of more than 3 hours may signify an imminent mood change [32, 33]. Additionally, in patients with bipolar disorder, greater serial irregularity in the mood time series was found before the onset of an episode [34].

Most patients take a unique drug regimen of polypharmacy for their affective disorder (▶ **Table 3**); [35, 36]. Considerable non-adherence with taking mood stabilizers was found, even among these patients who were motivated to complete daily mood charting [37]. There was frequent irregularity in the daily dosage of all psychotropic medications taken due to daily omissions and dosage changes [38, 39].

Other clinical knowledge was gained from the use of ChronoRecord. Patient recording of the daily mood rating can provide important information about the course of illness that is not available to the physician when the patient is only assessed at routine office visits. The graphical illustration provided by ChronoRecord (▶ **Fig. 1**) can help the clinician assess the patterns of illness over time, determine the association between symptoms and events such as hormonal changes, seasonal changes, and psychosocial stressors, and evaluate treatment response, especially when multiple medications are involved. Automated mood charting also provides immediate benefits for the patient. Patients who used ChronoRecord frequently commented that the mood chart helps them communicate with the psychiatrist. Instead of just focusing on how they feel the day of the appointment, they can talk about the time between visits.

Challenges of automating mood charting

There are challenges when implementing any technology tool in clinical medicine. The primary challenge of implementing ChronoRecord, or any automated system for mood charting, is that a modification of the daily work routine is required. Clear procedures for clinicians, administrative staff, and patients must define the steps involved in registration, training, data collection, and ongoing technical support. Regardless of the technology involved, both staff and patients must receive adequate training to use a new technology, an adequate budget must be allocated, and a staff member must be assigned overall responsibility for the ongoing use of the new technology. Technology platforms change over time, and products and procedures may need to be updated.

▶ **Table 2** Daily patient mood ratings by mood group and diagnosis (N = 138246 days)

	Diagnosis									
	Bipolar I		Bipolar II		Bipolar NOS		Unipolar		All	
Mood Group	Days	Percent	Days	Percent	Days	Percent	Days	Percent	Days	Percent
Severe depression	2939	4.4	5533	10.0	20	0.6	679	5.1	9171	6.6
Mild depression	10421	15.7	7704	14.0	376	11.1	2420	18.0	20921	15.1
Euthymia	47310	71.4	38846	70.4	2629	77.5	9075	67.5	97860	70.8
Hypomania	5076	7.7	2481	4.5	356	10.5	1258	9.4	9171	6.6
Mania	514	0.8	595	1.1	10	0.3	4	0.0	1123	0.8
All	66260	100.0	55159	100.0	3391	100.0	13436	100.0	138246	100.0

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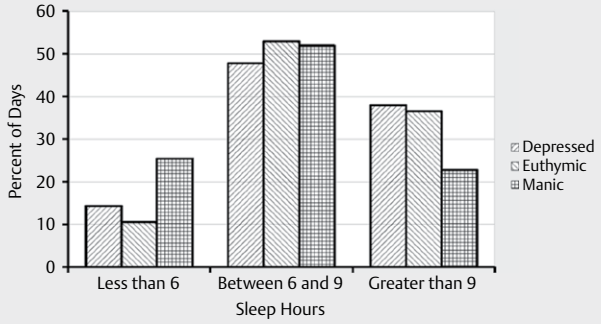
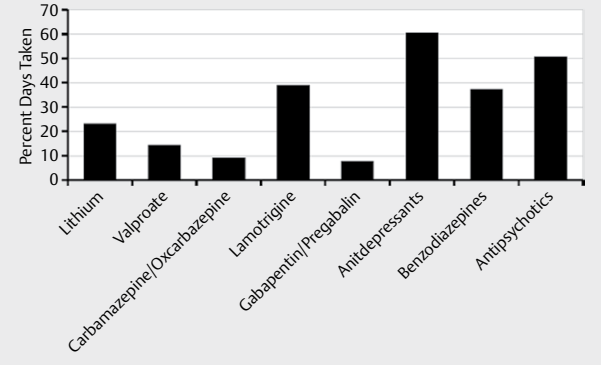
▶ **Table 3** Daily number of psychotropic medications by mood group (N = 135647)

Number of Medications	Mood Group							
	Depressed		Euthymic		Manic		All	
	Days	Percent	Days	Percent	Days	Percent	Days	Percent
1 Medication	1066	3.6	7555	7.9	814	8.1	9435	8.0
2 Medications	3061	10.4	16640	17.3	1239	12.3	20940	15.4
3 or 4 Medications	9769	33.1	36754	38.3	3935	39.2	50458	37.2
5 or 6 Medications	9247	31.3	23131	24.1	2541	25.3	34919	25.7
7 or 8 Medications	4744	16.1	9795	10.2	1133	11.3	15672	11.6
> 8 Medications	1646	5.6	2201	2.3	376	3.7	4223	3.1
All	29533	100.0	96076	100.0	10038	100.0	135647	100.0



▶ **Fig. 2** Daily hours of sleep by mood group.



▶ **Fig. 3** Most frequently taken daily psychotropic medications.

Other lessons were also learned from the development and implementation of ChronoRecord. A product designed for the general public must be easy to use and the output easy to understand. Initial training and ongoing human support for a technology product should be available to both patients and physicians. Encouragement from the physician is important to increase patient use of technology. However, the individual patient must be interested in mood charting, and not all patients are. The ChronoRecord data was collected as a convenience sample which required testing for sample bias before publishing results. ChronoRecord also showed that patient data entry could be collected and monthly charts distributed securely using an encrypted attachment to an email.

In conclusion, many patients with affective disorders will accept and use a technology product for recording daily mood ratings over long periods. The tool is useful for increasing individual participation in their care, providing detailed data to the physician, and providing data for research, including longitudinal studies. Patient mood charting with a validated tool such as ChronoRecord has helped confirm that daily self-reporting is useful in clinical as well as research settings.

Author Contributions

MB and TG wrote the initial draft. All authors reviewed and approved the final manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare.

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