LEARNING MANUAL OF PSG CHART

POLYSOMNOGRAM, SLEEP STAGE SCORING, INTERPRETATION

Sleep Computing Committee, Japanese Society of Sleep Research

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Preface

In 1967, the Association for the Psychophysiological Study of Sleep (APSS) chartered a committee of sleep researchers to establish a standard system for visually scoring stages of sleep. The Committee's terminology and scoring system (edited by Alan Rechtschaffen and Anthony Kales, co-Chairpersons of the Committee) were quickly adopted after its 1968 publication under the auspices of the UCLA Brain Information Service as 'A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects.' The manual and its recommendations have been well accepted and the system has spread across the world.

The proposal to standardize recording techniques and scoring criteria was intended to increase the comparability of results reported by different investigators. Researchers who have applied the system correctly have increased the reliability of their sleep stage scoring. In the several decades since its publication, however, a number of serious areas of unreliability in the 1968 standard scoring system have been identified. In particular, researchers developing computer-based automatic sleep staging systems have encountered numerous vague and ambiguous areas in the current standard.

At the 15th Annual Meeting of the Japanese Society of Sleep Research (JSSR) in 1990, Terashima's report from the Japanese Conference for Sleep Analysis emphasized the need to re-examine the definitions of sleep stages when developing computer staging systems based on the standard scoring system. The results of multiple comparisons among institutes and laboratories using methods for automated sleep staging based on the standard scoring system were unexpectedly poor. The lowest level of congruence between automation and records staged visually using the 1968 standard system was found for Stage 1 sleep, with the second worst agreement (still less than 70%) for sleep Stages 3 and 4.

To increase both the within- and between- researcher agreement in sleep stage identification and to foster the development of computer algorithms for automatic analyses of sleep, a need for additional definitions was recognized. In 1991, the Subcommittee for Automatic Sleep Staging (SASS) was formed by the JSSR. The Subcommittee comprised 53 investigators and seven project leaders selected for their skill in scoring sleep records: S. Sugita (Chair), M. Okawa (co-Chair), T. Kobayashi, T. Hori, A. Miyasita, S. Shirakawa and Y. Atsumi. In 1995, based on their 5 year discussions, the Subcommittee proposed supplementary definitions and amendments for the Standard Scoring System to the JSSR. These proposals were reported in the JSSR Newsletter (1996; No. 13, February 1, pages 5–13).

In 1997, at its 22nd Annual Meeting, the JSSR restructured the SASS to form the Sleep Computing Committee (SCC). The SCC working group has now formalized Supplements and Amendments to the Standard Scoring System based upon the 1995 SASS proposals. The Committee has met several times for discussion and to test their new definitions using carefully selected representative polysomnographic recordings. The final JSSR Sleep Computing Committee proposals have been published in Japanese as the 'Learning Manual of PSG Chart: Polysomnogram, Sleep Stage Scoring, Interpretation.' The Committee has now prepared the English language version of their proposals for evaluation and empirical testing by sleep researchers all over the world.

July 2012 Sleep Computing Committee,
Japanese Society of Sleep Research

Contents

SUPPLEMENTARY AND AMENDED DEFINITIONS FOR INTERNATIONAL CRITERIA FOR SLEEP STAGE SCORING

The JSSR's proposals to supplement and amend the currently used criteria for sleep staging (*A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*, Rechtschaffen A, Kales A (eds). BIS/BRI University of California, Los Angeles, 1968; hereafter, the 'standard criteria (SC)') are detailed below. .

1. Movement time: MT

When research purposes are not met by the SC, different movement time criteria may be used. However, in such cases, the modified criteria should be clearly stated and the degrees of modification should not exceed those in the following examples.

1) MT is judged following the SC, with the addition of scoring parts of the recording with higher muscle tones and degrees of artifact as 'gross movement' or 'movement with duration more than 50% of an epoch', and the number of such segments is reported.
2) Even when an epoch fulfils the SC definition of MT, the epoch may still be scored as a stage of sleep using additional criteria (below). In this case, an SC-defined epoch of MT can simultaneously be defined as an epoch of sleep and a body movement epoch.

Examples of criteria:

(a) MT epoch is scored as the same stage as the *preceding* epoch

(b) MT epoch is scored as the same stage as the *following* epoch.

2. Judgement of sleep Stage 1

The following supplementary definitions are used for scoring a transition from stage wake to stage 1 sleep. Stage 1 is not necessarily defined as a sleep onset (sleep onset is defined below).

Definition of alpha waves

Alpha waves are electroencephalographic waves with a frequency of 8 Hz or more but less than 13 Hz.

Definition of a vertex sharp wave (V-wave)

A vertex sharp wave is a sharp waveform distinguished from background activities at or near Cz (C3, C4), with an amplitude of 75 μV or greater, and with a frequency of at least 5 Hz but no more than 14 Hz.

Slow eye movements

Slow eye movements (SEM) can be difficult to detect in recordings that were not made using long time constants. The following definitions are considered to apply for recordings made under recommended conditions. Slow eye movements waveforms do not manifest saccade-like sharp, abrupt, movements. Rather, SEM are smooth sinusoidal eye movements with amplitudes of 100 μV or more, and 10 s or less in duration.

Time constant:

Longer time constants of 1.5 s or more are recommended to minimize deformations of SEM signals and to enhance the detection of SEM.

Amplification:

Amplification of 200 μV/5 mm is recommended. This amplification allows observation of subtle eye movements without appreciably increasing the likelihood of signals saturating the amplifier.

Derivation:

Monopolar recordings from both outer canthi are recommended to distinguish eye movements from contamination such as superimposition of electroencephalographic (EEG) waveforms.

Supplements for poor alpha wave subjects:

For subjects whose central EEG alpha waves during resting wake occupy less than 50% of the analysis epoch when the eyes are closed, one of the following criteria should be used to judge stage 1 sleep. When using these exception criteria, the resting wake EEG should be recorded both before bedtime and after awakening from all-night sleep recording along with observations to confirm that subjects are behaviorally awake.

1. In subjects whose occipital EEG alpha activity occupy more than 50% of the analysis epoch during wake with eyes closed, SC should be applied.
2. Electroencephalogram of various frequencies but less than 8 Hz and 20 μV or more in amplitude, which is considered as EEG, suggesting lower vigilance

level comparing resting wake with eyes closed condition, occupies more than 50%. In the absence of true alpha band activity, alpha-like activity in EEG frequencies below 8 Hz may be used to suggest lower vigilance levels when it is of 20 μV or greater amplitude, increases during resting wake with the eyes closed, and occupies 50% or more of an epoch.

3. When the preceding criteria (2) are applied, confirmation of SEM activity is also recommended.

3. Judgement of sleep stage 2

The following supplementary definitions of the K-complex should be considered.

1. The K-complex waveform begins with the abrupt onset of a negative sharp wave, which is immediately followed by a high amplitude positive slow wave. Polyphasic (notched) negative-positive waves are sometimes observed just before the onset of the negative K-complex sharp wave. The duration of a K-complex must be longer than 0.5 s. Its peak-to-peak amplitude must be greater than 200 mV. Wave-forms must be visually distinct from background EEG activities and a waveform should not be identified as a K-complex if it occurs within 5 s preceding or following high voltage delta waves (defined below). The K-complex waveform may or may not be accompanied by sleep spindle activity (defined below). Termination of a K-complex is identified by the peak of a trailing negative wave, which follows the major positive component, neglecting other overlapping waves (Fig. 1).

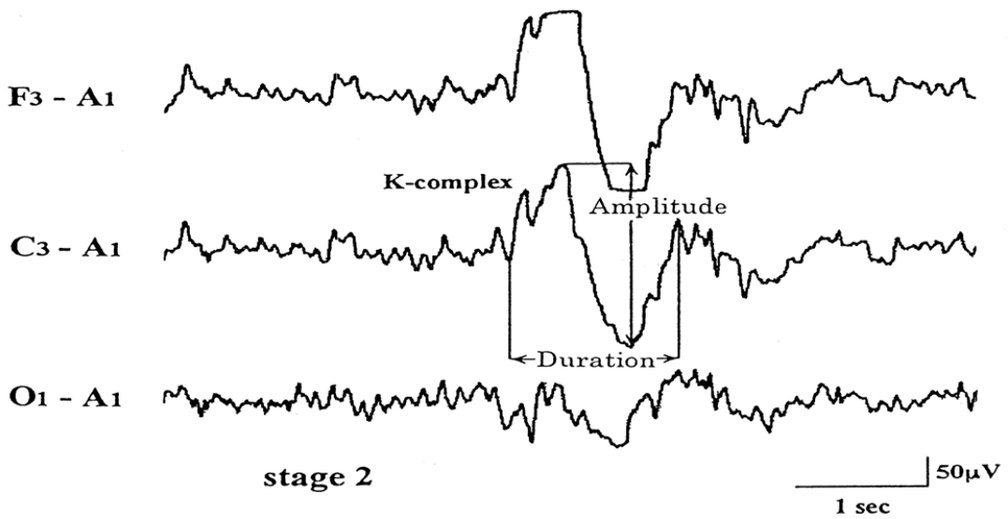


Fig.1

2. Sleep spindles are defined as trains of 12–16 Hz waves of 10 mV or greater amplitude, composed of at least six consecutive waves, or a train duration longer than 0.5 s. The appearance of the waveform train is not specified in the definition (i.e. a ‘spindle’ shape is not a requirement for identification as a sleep spindle). Although the mean frequency of a single train of waves can be used as a single descriptor for identified sleep spindles, its use must be clearly reported. Similarly, if a different amplitude threshold is used to identify sleep spindle activity, the threshold value must be clearly reported.

Definition of sleep onset

Sleep onset may be defined as necessary for research purposes, but should include the first epoch scored as one of the standard sleep stages (1, 2, 3, 4, or REM) after the lights are darkened or a subject goes to bed. Researchers must report their definition of sleep onset. Researchers are expected to specify the sleep stage criteria used for the judgement of sleep onset, including all criteria for the duration of sleep stage(s), its (their) duration, and the time course of sleep etc. as in the following examples.

1. In this example, the first epoch judged as one of the sleep stages is defined to be sleep onset. However, if the first stage is stage 1, the epoch can be judged as sleep onset only if it is followed by consecutive epochs of sleep stages 2, 3, 4 or REM.
2. In this example, the first epoch judged as one of the sleep stages is defined to be sleep onset. However, if the first stage is stage 1, the epoch is judged as sleep onset on the condition that stage 1 or the other stages continue for a specific length of time (e.g. 3 or 5 min).
3. In this example, the first epoch judged as sleep stages 2, 3, 4, or REM is defined to be sleep onset. (A definition to attach importance on the appearance of Stage 2.)
4. In this example, the first epoch judged as sleep stages 2, 3, 4, or REM is defined to be sleep onset. However, the epoch is judged as sleep onset on the condition that sleep stages 2, 3, 4 or REM, follows for a specific duration (e.g. 3 or 5 min).
5. The expressions of ‘stage 1’ or ‘stage 2’ in the example definitions can be modified to use ‘vertex sharp wave’ or ‘sleep spindle’ criteria as desired.

4. Judgement of stages 3 and 4

If slow waves with frequencies below 2 Hz and with amplitudes greater 75 mV occupy between 20 and 50% of an epoch, that epoch is judged as stage 3 sleep. If the slow waves occupy more than 50% of an epoch, that epoch is judged as stage 4 sleep. However, because these definitions do not contain any descriptions of complex composite waveforms, it can often be difficult to judge stages 3 and 4 under the SC.

1. We add the following supplements to the definition of high amplitude slow waves given above.

   (i) When the combined period of two contiguous EEG waveforms is 0.5 s or longer (i.e. the frequency of the composite wave is 2 Hz or lower), that wave complex can be scored as one slow wave if the amplitudes of the two waves satisfy the requirement B ≥ A/2 (Fig. 2).

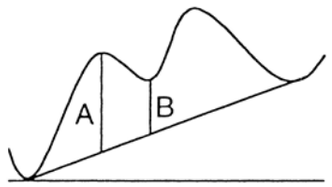


Fig.2

   (ii) When fast waves appear superimposed on a slow wave, the amplitude of the slow wave is still measured from peak-to-peak, including the superimposed waves.

   (iii) The onset of an individual slow wave must follow a trough satisfying the requirement B ≤ A/2 (Fig. 3).

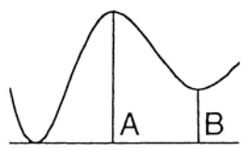


Fig.3

2. When bursts of slow wave activity precede or accompany an arousal response or high amplitude EMG (e.g. body movements), those bursts should not be considered slow waves for EEG stage scoring, but as one form of the arousal response. Such portions of a record should be considered part of the preceding or following epoch when stage scoring. Furthermore, the terms ‘movement arousal’ or ‘EEG arousal’ are recommended over the general term ‘arousal response’, following the definition of American Sleep Disorders Associa-tion (EEG arousal: scoring rules and examples. Sleep 1992; 15: 173–184).

5. Judgement of stage REM

Addition of the following supplement to the definition of rapid eye movements (REMs)

The same time constant, gain, electrode placements and montage can be used to record both SEM and REM. The REM waveform must appear as a saccadic movement, with rapid changes in angular velocity at the onset and termination of eye movement. Since small eye movements often appear during the transitions to and from REM sleep, a low amplitude criterion of 40 mV or greater (1 mm pen deflection under above-mentioned recording condition) is recommended. In recordings at 15 mm/s (or the equivalent digital display), REM activity should be identifiable as a 45° or greater angular departure from the baseline. Researchers should specifically report any modifications to the above -mentioned criteria.

Addition of the following definition of twitches (phasic EMG activity)

A twitch is defined as a skin-recorded EMG discharge with duration shorter than 0.5s, or the EMG discharge accompanying the contraction of a single muscle unit. The term ‘these transient changes may be disregarded’ in the standard manual (p. 8) is ambiguous. Therefore, the muscle activities satisfying the above-mentioned definition of twitch may be disregarded, while a transient increase in tonic EMG not satisfying the definition may be regarded as a sign of movement arousal.

Supplements and modifications for distinguishing the end of and interruptions of stage REM

Rechtschaffen and Kales (1968) discussed the difficulty of identifying the onset of REM sleep:

> A special case frequently arises where a movement arousal interrupts the continuity of stage REM, the mental-submental EMG quickly reverts to the stage REM level following the movement arousal, the EEG remains relatively low voltage, mixed frequency, and there is a resumption of REMs or change to stage 2 one or more epochs following the movement arousal. The problem is whether to score the interval following the movement arousal and the resumption of REMs or change to stage 2 as stage 1 or stage REM. (p.10, Part C).

The general guidelines for distinguishing between Stage 1 and stage REM support little more than scorer judgement. The following partially modified guidelines have been arranged to aid the discrimination of Stage 1 from REM sleep.

The following cases justify scoring as stage 1:

(i) epochs follow long or intense movement arousals;

(ii) epochs contain slow eye movements;

(iii) epochs contain persisting alpha activity follow-ing a movement arousal;

(iv) epochs contain well-formed vertex spikes;

(v) epochs contain waveforms similar to, but not fulfilling the definitions of sleep spindles or K-complexes. Such cases may be considered as supporting evidence that the interval between the movement arousal and unambiguous Stage 2 or REM has been Stage 1.

The following case justifies scoring as stage REM:

(i) epochs contain well-formed saw-tooth waves.

6. Definitions of sleep parameters

The following definitions of sleep parameters fre-quently used in sleep science and sleep medicine are listed for reference.

1. Total recording time (TRT): The duration of time from the start to the end of a recording.
2. Time in bed (TIB): The duration of time from ‘lights out’ to final awakening.
3. Total sleep time (TST): The amount of actual sleep time in a recording.
4. Sleep efficiency (SE): The ratio of total sleep time to time in bed (i.e. (TST／TIB) × 100).
5. Sleep period time (SPT): The duration of time from sleep onset to final awakening.
6. Time spent in each of the sleep stages based on total recording time (TRT). TS1: Time spent in Stage 1. TS2: Time spent in Stage 2. TS3: Time spent in Stage 3. TS4: Time spent in Stage 4. TSR: Time spent in stage REM.
7. Percentage of the sleep stages.

   (i) Percentage of the sleep stages based on sleep period time (SPT). %SW: Percentage of stage W. %S1: Percentage of Stage 1. %S2: Percentage of Stage 2. %S3: Percentage of Stage 3. %S4: Percentage of Stage 4. %SR: Percentage of stage REM.

   (ii) Percentage of the sleep stages based on total sleep time (TST). %S1: Percentage of Stage 1. %S2: Percentage of Stage 2. %S3: Percentage of Stage 3. % S4: Percentage of Stage 4. %SR: Percentage of stage REM.
8. Wake time after sleep onset (WASO), intermittent awakening: The total time spent awake during sleep period time (SPT).
9. Number of arousals: The number of arousals occurring in sleep period time (SPT).
10. Number of stage shifts: The number of occasions of sleep stages shifting from one to another.
11. Sleep latency: The duration of time from ‘lights out’, or bedtime, to the onset of sleep.
12. REM sleep latency: The interval from sleep onset to the first appearance of stage REM sleep in a recording.
13. REM activity: REM activity is identified as one or more REM in a unit of time and often expressed as the total number of such units.
14. REM density: REM density is a function that expresses the frequency of eye movements per unit of time during stage REM.
15. Number of REM episodes: The number of REM episodes that appear during sleep period time. If REM sleep continues with interruptions by wake or other sleep stages, such REM episodes are con-sidered as a single REM episode when the inter-ruption is less than 15 min.
16. Sleep cycle: The first sleep cycle is the period from sleep onset to the end of the first REM sleep episode. Later sleep cycles are defined as the periods from the end of a REM sleep episode to the end of the subsequent REM sleep episode.
17. REM sleep interval: The REM sleep interval is the interval between the end of a REM sleep episode and the beginning of the subsequent REM sleep episode. Time awake is generally excepted from the interval.

Several points to keep in mind for using this learning manual

The main purpose of this learning manual of PSG chart is to help researchers who have recently started studying sleep science to learn sleep stage scoring of polysomnogram. This manual is also very useful for sleep stage scoring experts to improve inter-scorer accordance by following "Proposed supplements and amendments to 'A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects,' the Rechtschaffen & Kales (1968) standard" (Psychiatry and Clinical Neurosciences 55: 305-310, 2001). This article was published after long discussions in the Subcommittee for Automatic Sleep Staging (SASS) in the Japanese Society of Sleep Research (JSSR).

We recommend to refer to "A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects (1968), Rechtschaffen & Kales Editors"(R & K manual), when this manual is used. Researchers who are not familiar with sleep stage scoring should read this manual from the first page. By doing so they can master sleep stage scoring and to learn the nocturnal sleep pattern. Sleep stage scoring experts could use this manual as a reference. However, they should read "Supplementary and Amended Definitions for International Criteria for Sleep Stage Scoring" for further understanding.

The data used in this manual was recorded from a young male adult using a standard polygraph. However, the paper chart was digitally produced by a laser printer, therefore the wave form distortion caused by ink-pen writer is not observed. These distortions include round edge of sharp waves and lower amplitude of EMG signals.

The present PSG chart uses 1.5 cm/s paper speed, therefore 1 page indicates 20 seconds. The 6 channels of this chart are EEG (C3, O1), EOG (L, R), mental EMG, and ECG. The calibration voltages (50 μV) are indicated on the right side of each channel.

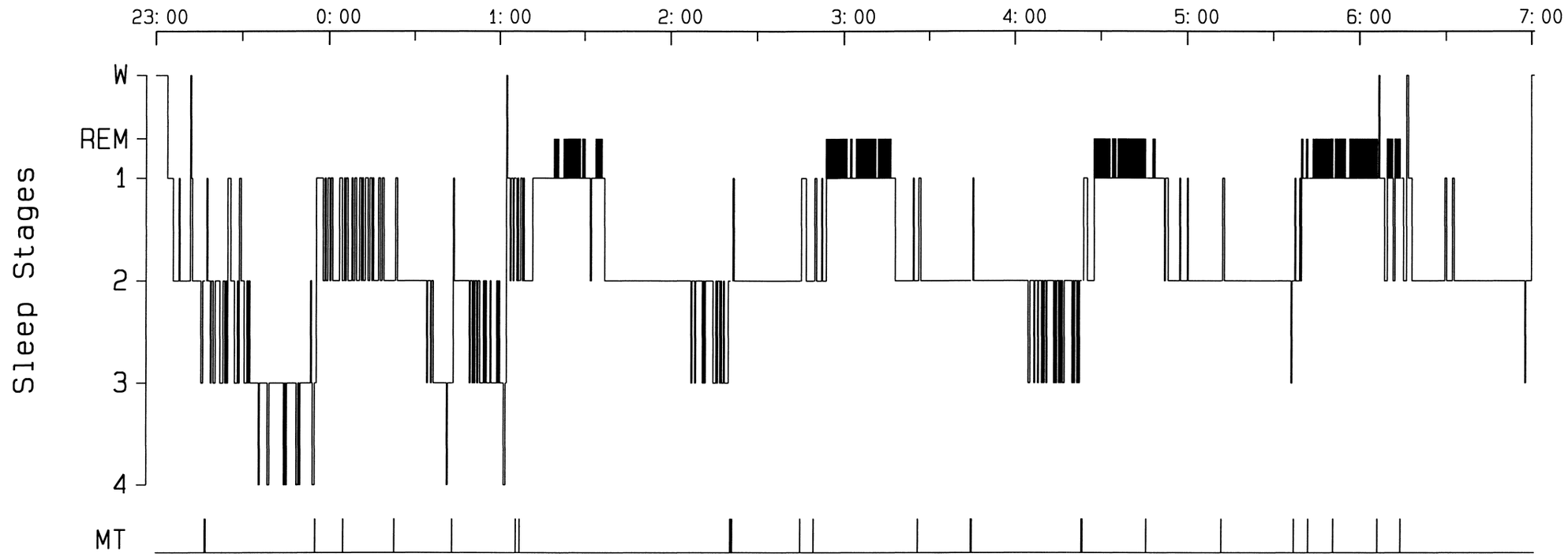
On page 7, hypnogram, montage and recording conditions are shown. Hypnogram is a useful material to express a subject's sleep and wake structure of a night or even several days on a polysomnogram. The hypnograms in this manual follow the style which many sleep researchers have used. The abscissa indicates the time of the day. The ordinate indicates awake, stage REM, stage 1, stage 2, stage 3 and stage 4 from top to the bottom. Stage REM is usually in thick lines.

While the montage of PSG chart should be selected according to the purpose of recording, a standard montage is used in this manual. The EEG from occipital and ECG are not necessary when the propose of recording is only to score subjects' sleep stages. However, at least nose and mouth breathing, thoracic and abdominal breath movement, and tibial EMG (L/R) should be recorded when the purpose of recording is to diagnose a certain sleep disorder. The recording conditions of EEG, EOG, mental EMG, and ECG are shown. Calibration of signals must be done before recording. Calibration signal should also be included in the record. It can affect the results of scoring stages of sleep. Refer to other manuals about PSG recording method.

On page 8-11, we show characteristic polygraph patterns for sleep stage scoring. New researchers should be familiar with these patterns for the first step of sleep study. The PSG chart after page 14, should be useful for studying polygraph patterns. Identification and measurement of slow wave with high amplitude are often difficult for new sleep researchers. Pages 10, and 11 indicate several examples of high amplitude slow waves during stage 3 and 4. By referring these examples, readers are encouraged to line under wave patterns which are considered as high amplitude sleep slow waves.

Each sleep stage is defined by the R&K manual. Therefore the final goal of scorers is to memorize and understand all the criteria for scoring. New learners who have not memorized all the criteria should start browsing through this manual and reading explanations. Then, try sleep stage scoring and reconfirm the accuracy by comparing their score with this manual. When questions arise, readers should go back to the explanations to understand them completely.

Sleep Diagram

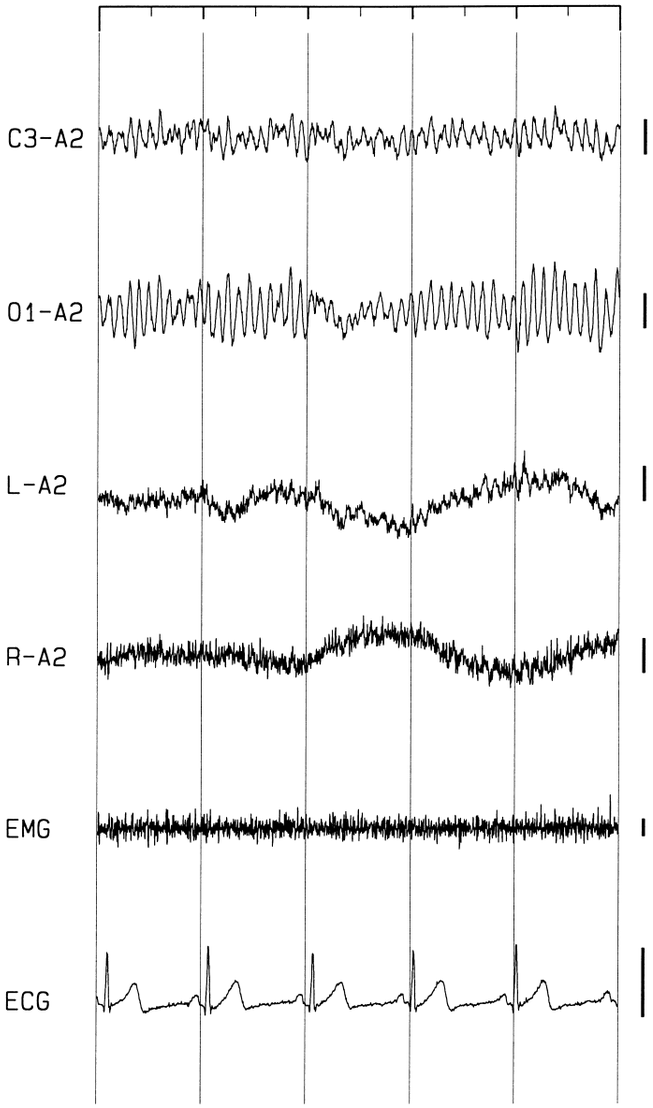


Healthy male subject, 28 years old, the polysomnogram was recorded in a sleep lab chamber

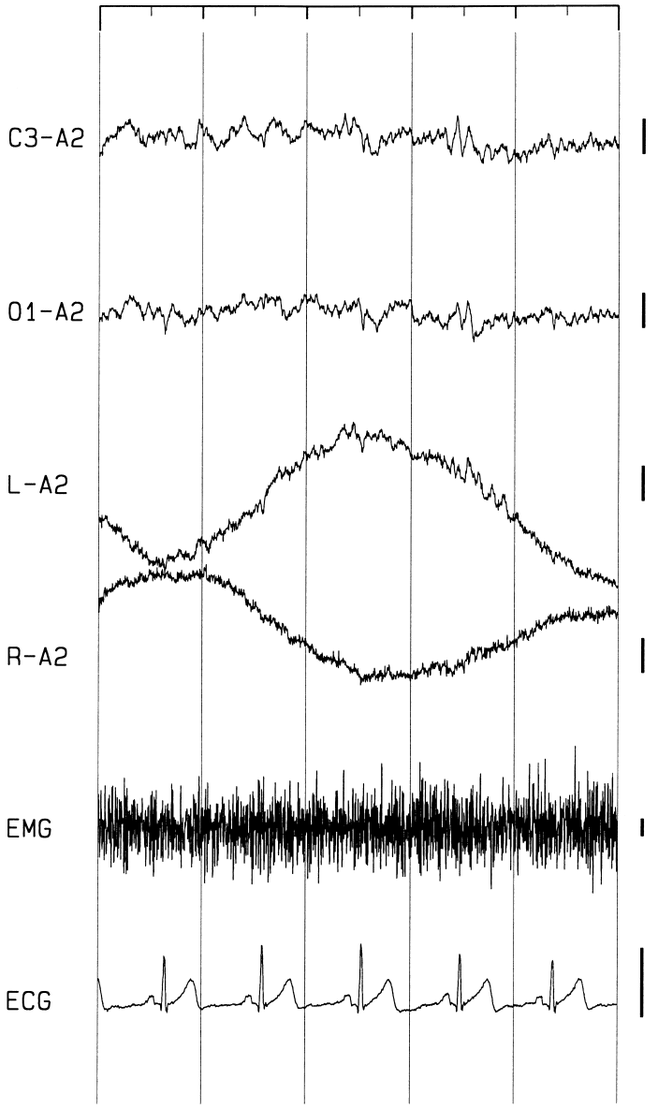
Recording Conditions

Channels	Electrode settings	Time constant (sec.)	Gain (sensitivity)
1	C3-A2	0.3	50μV/5mm
2	O1-A2	0.3	50μV/5mm
3	Left eye-A2	3.0	50μV/5mm
4	Right eye-A2	3.0	50μV/5mm
5	ChinEMG	0.003	50μV/2.5mm
6	ECG	0.3	1mV/10mm

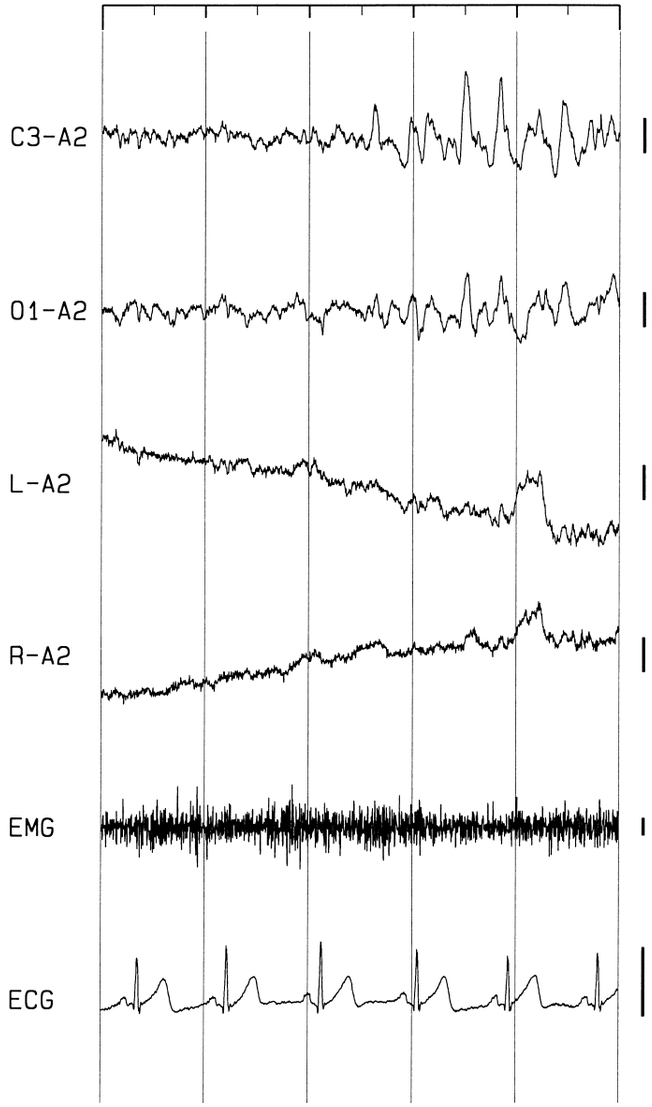
Characteristic polysomnographic patterns for scoring sleep stages



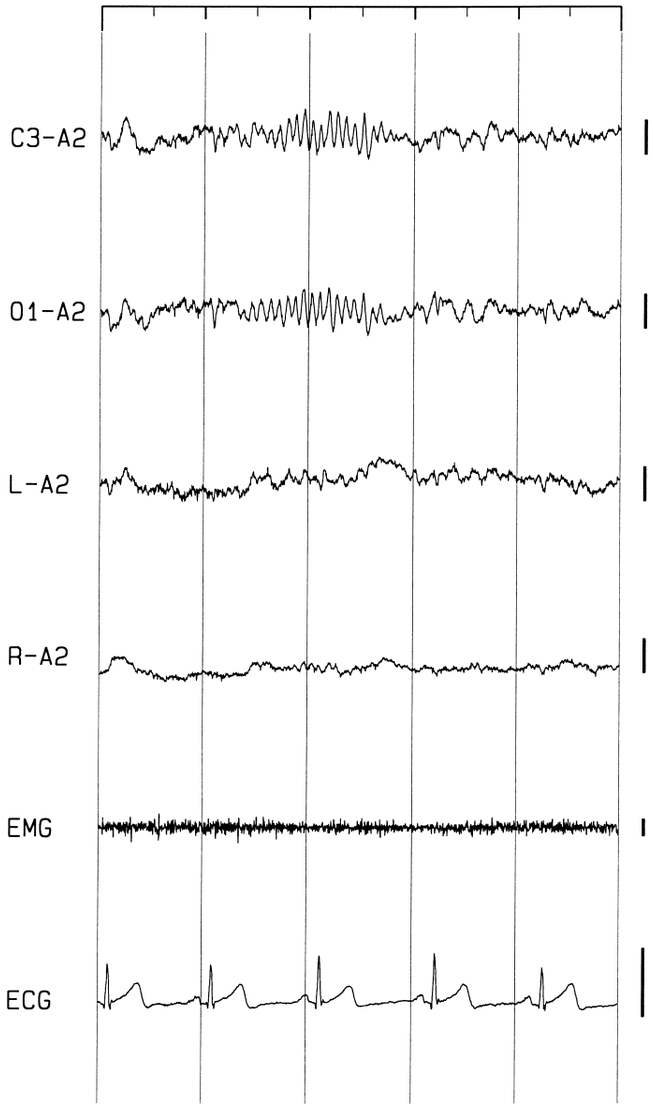
stage W α waves



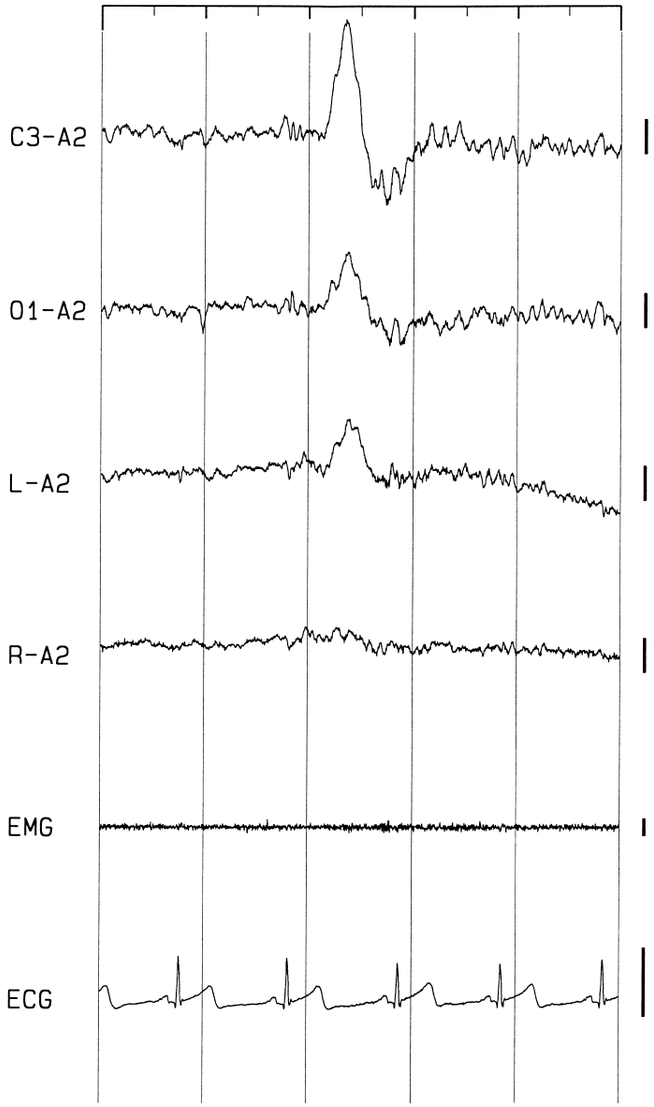
stage 1 low voltage, mixed frequency EEG (higher than 2 Hz, lower than 8 Hz)



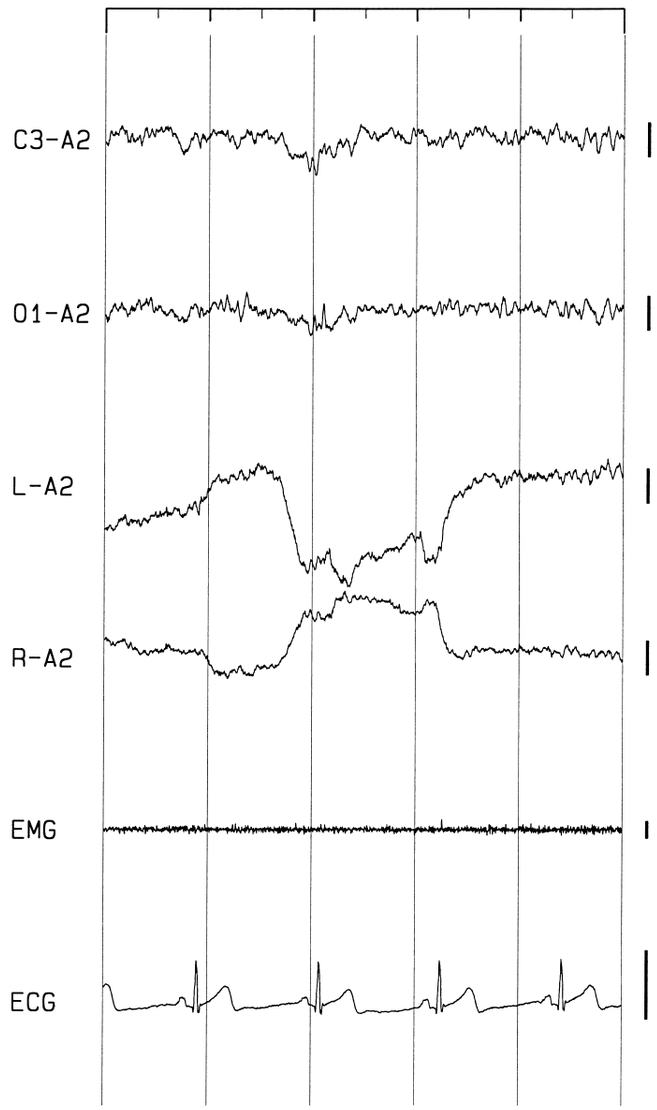
stage 1 vertex sharp waves



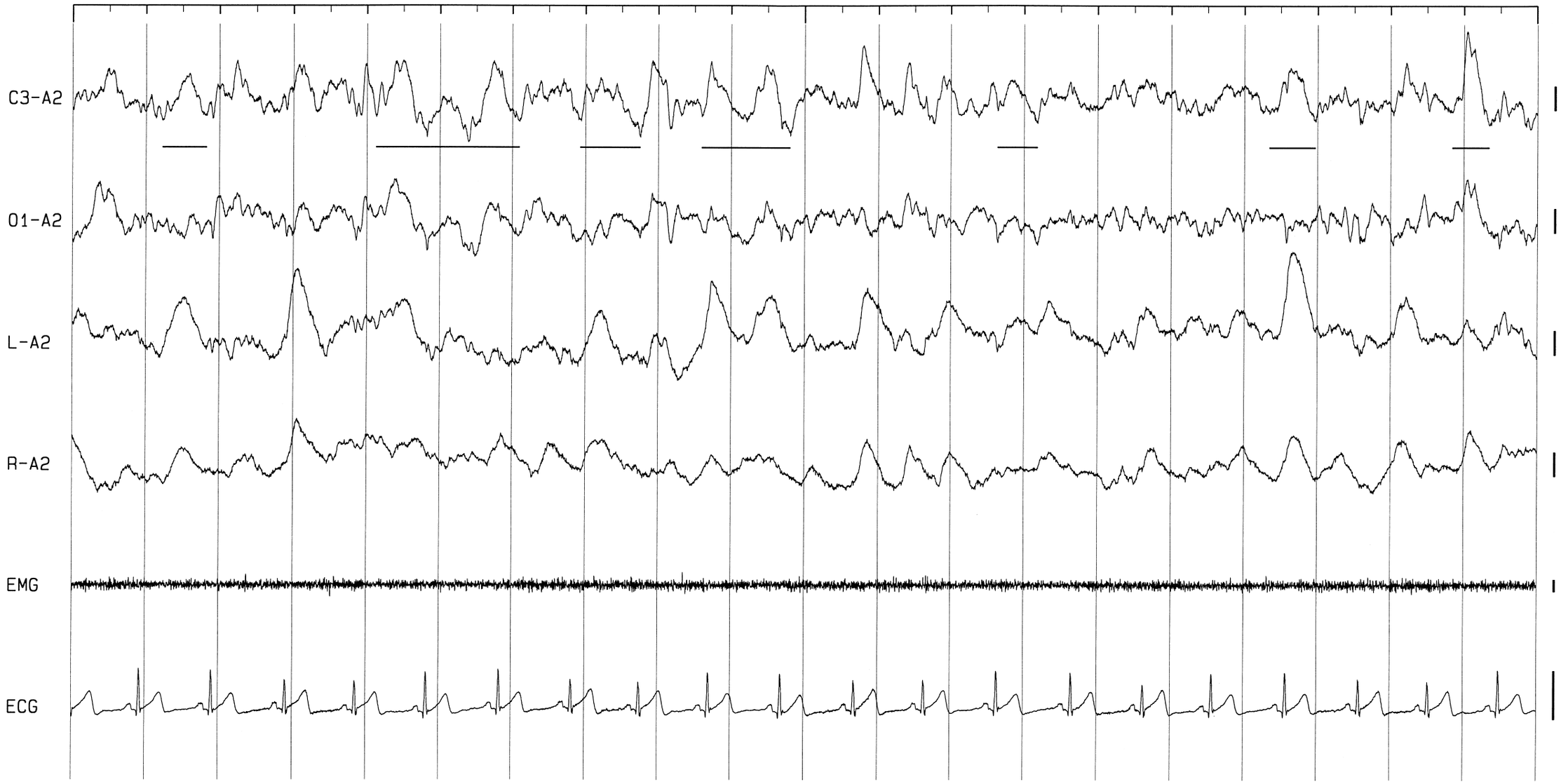
stage 2　sleep spindle



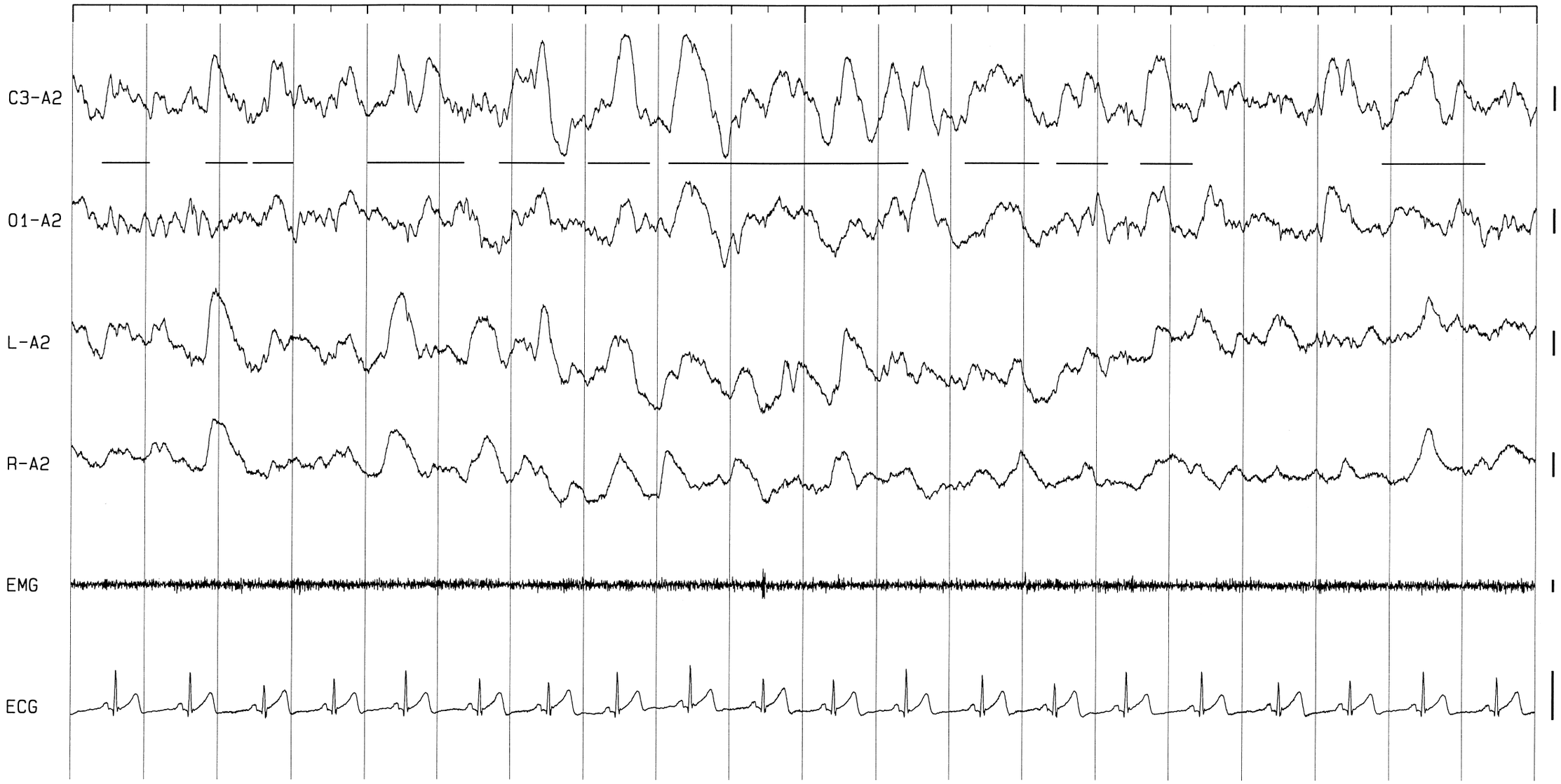
stage 2　K-complex



stage REM　Rapid Eye Movements (REMs)



stage 3: Underlined portions of C3-A2 EEG indicate high amplitude slow wave activities (2 Hz or slower, greater than 75 μV from peak to peak). Percentage of the high amplitude slow wave activities is larger than 20% , but not more than 50%

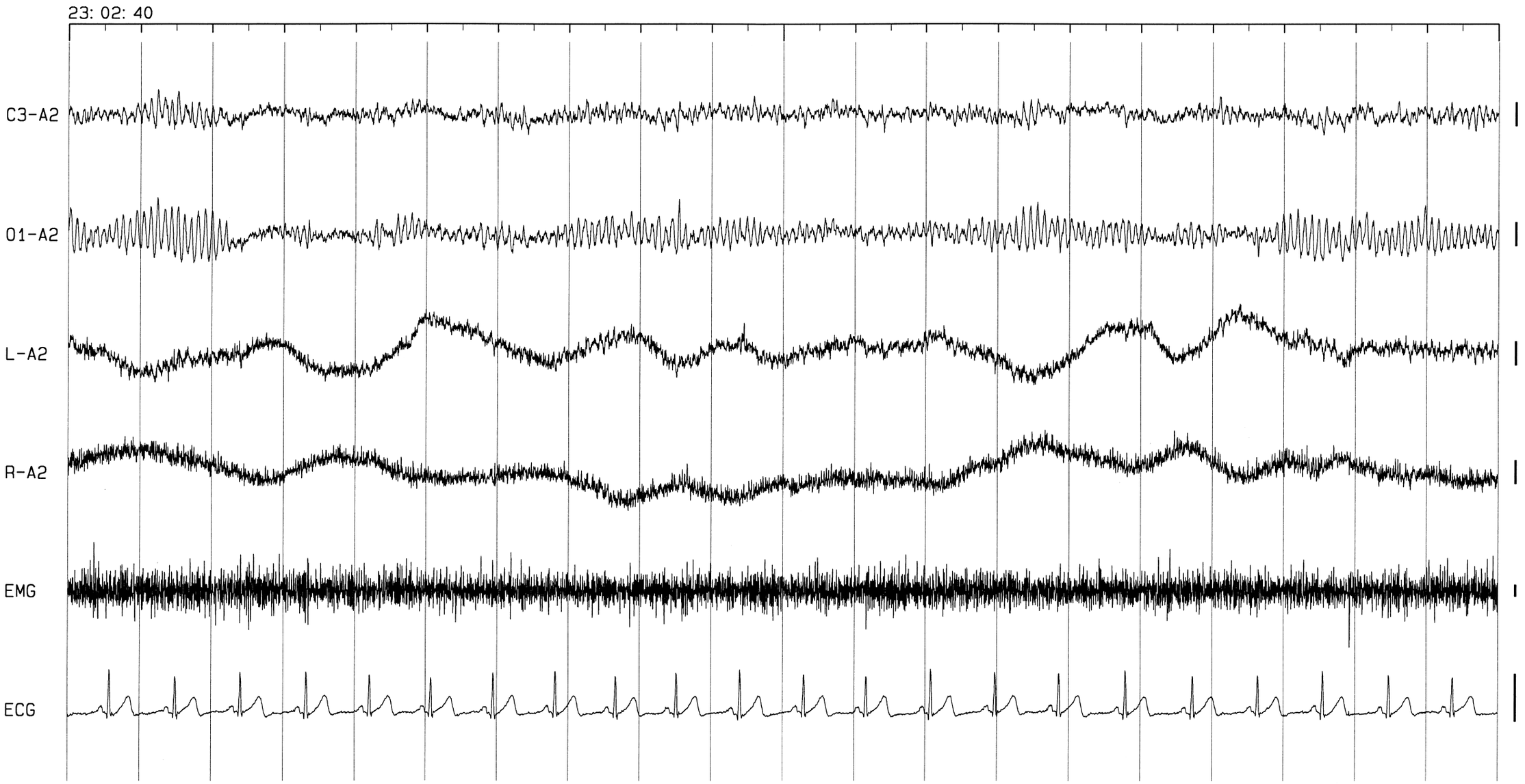


stage 4: Underlined portions of C3-A2 EEG indicate high amplitude slow wave activities (2 Hz or slower, larger than 75 μV from peak to peak). Percentage of the high amplitude slow wave activities is more than 50%.

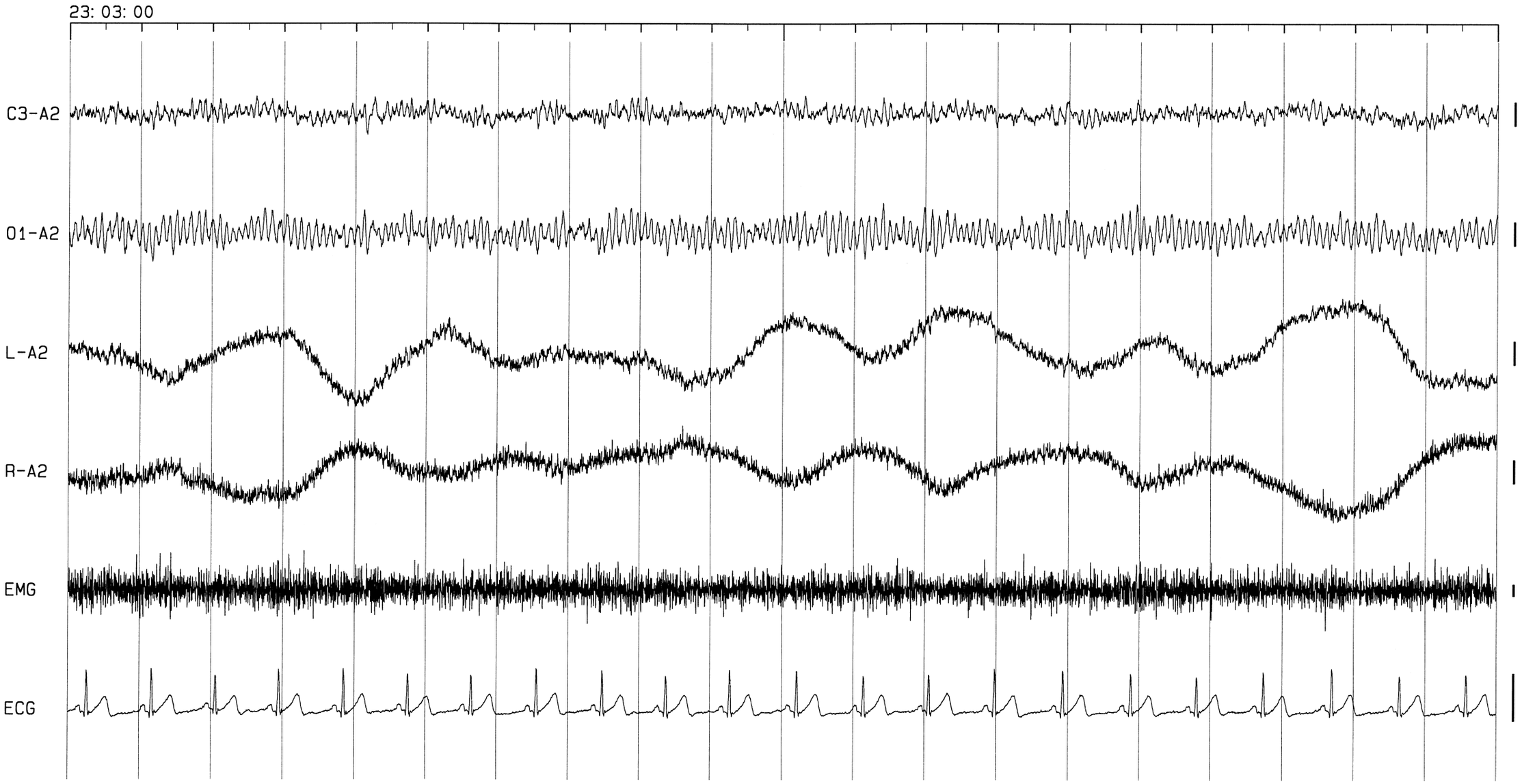
1. Sleep onset process:

Scoring of sleep stages from wakefulness until stage 2 through stage 1.

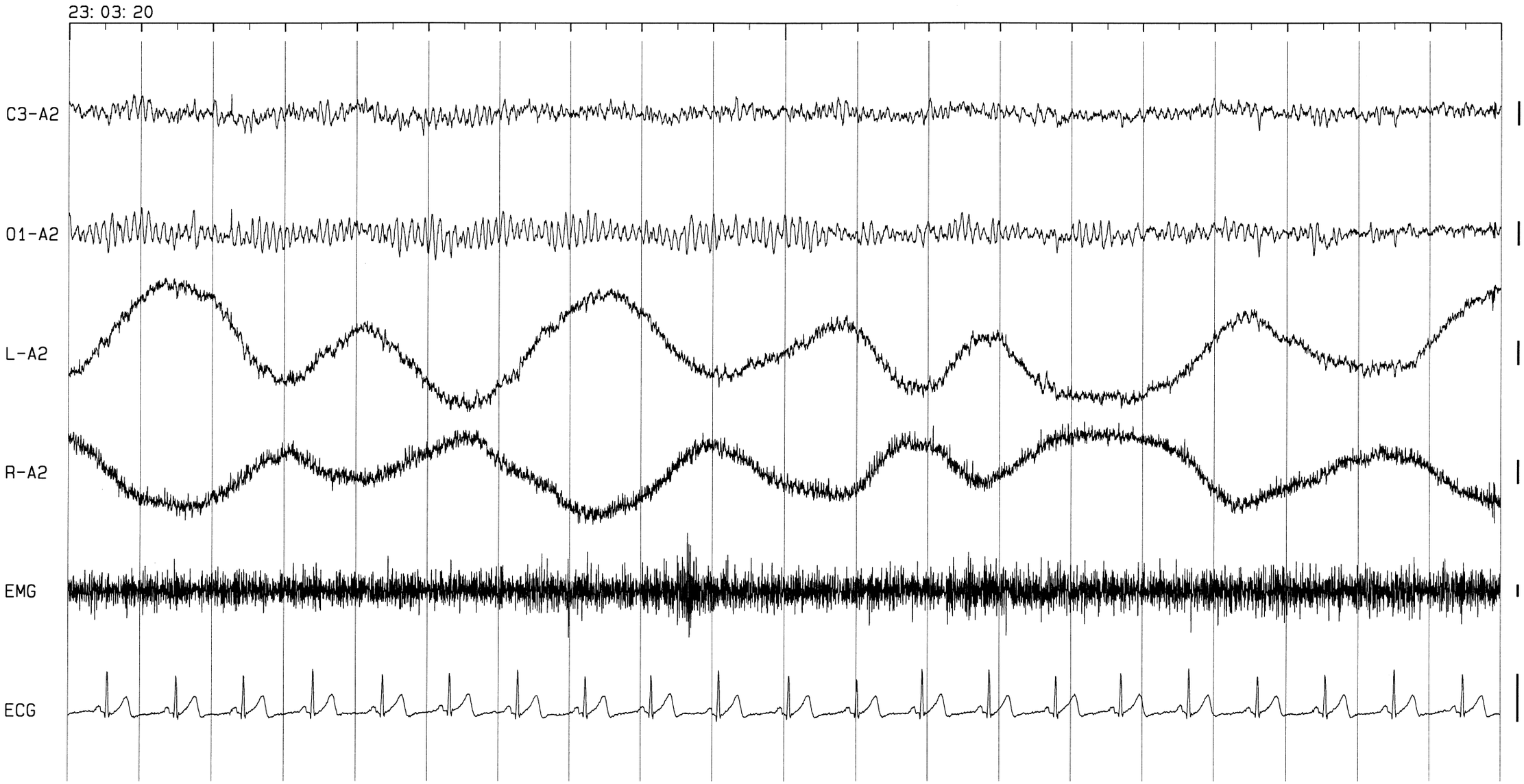
Scoring of stage 1 and 2, and judgment of their continuity



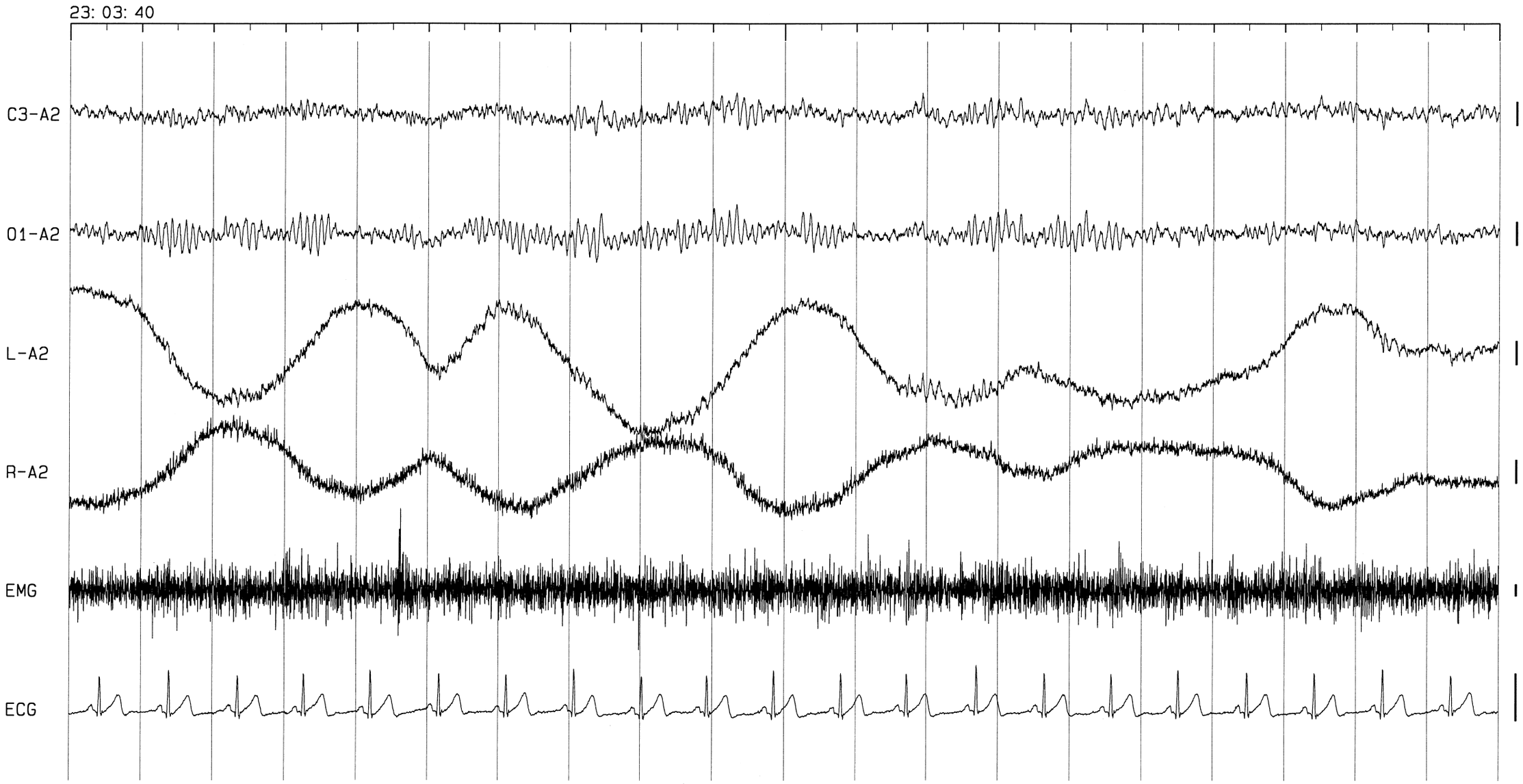
stage W: While the amplitude of alpha activity at C3 is small and the alpha activity lack its continuity, the waves which are typical of stage 1* are not observed and the percentage of alpha activity is more than 50% at O1. *: Refer to page “23:04:00”



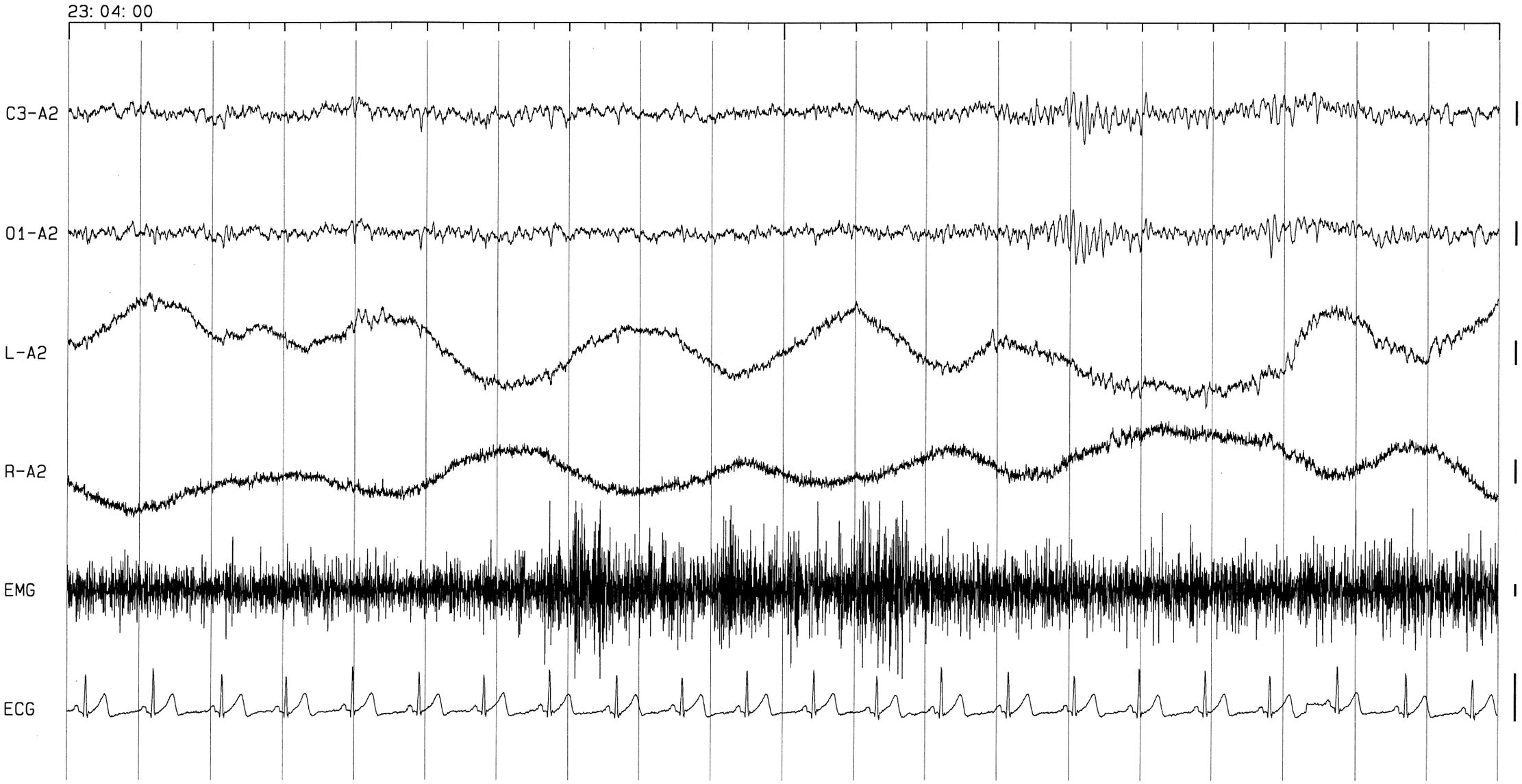
stage W: Percentage of alpha activity is more than 50% at C3.



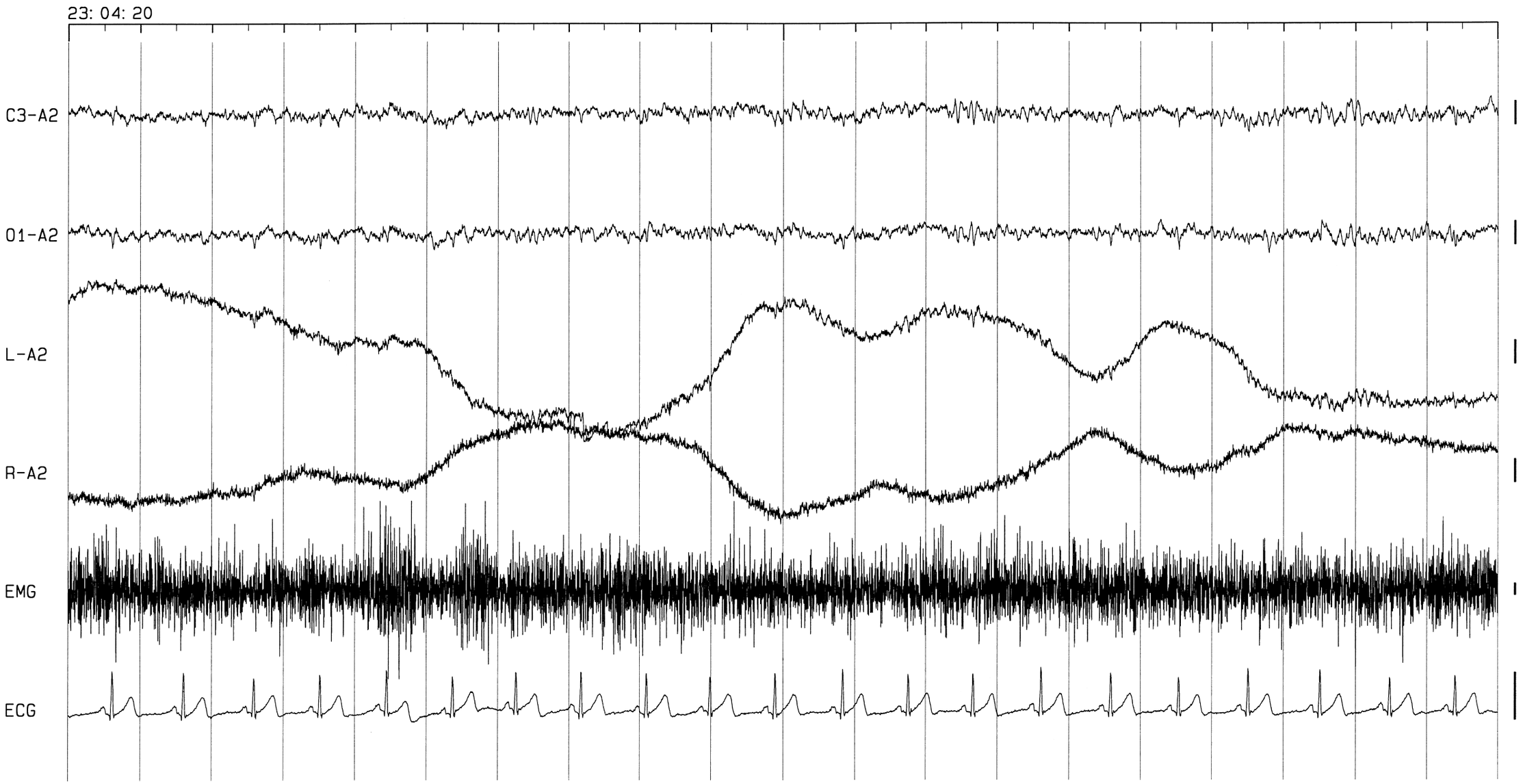
stage W: While slow eye movements are observed, the waves which are typical of stage 1 are not found at C3 and percentage of alpha activity is more than 50% at O1.



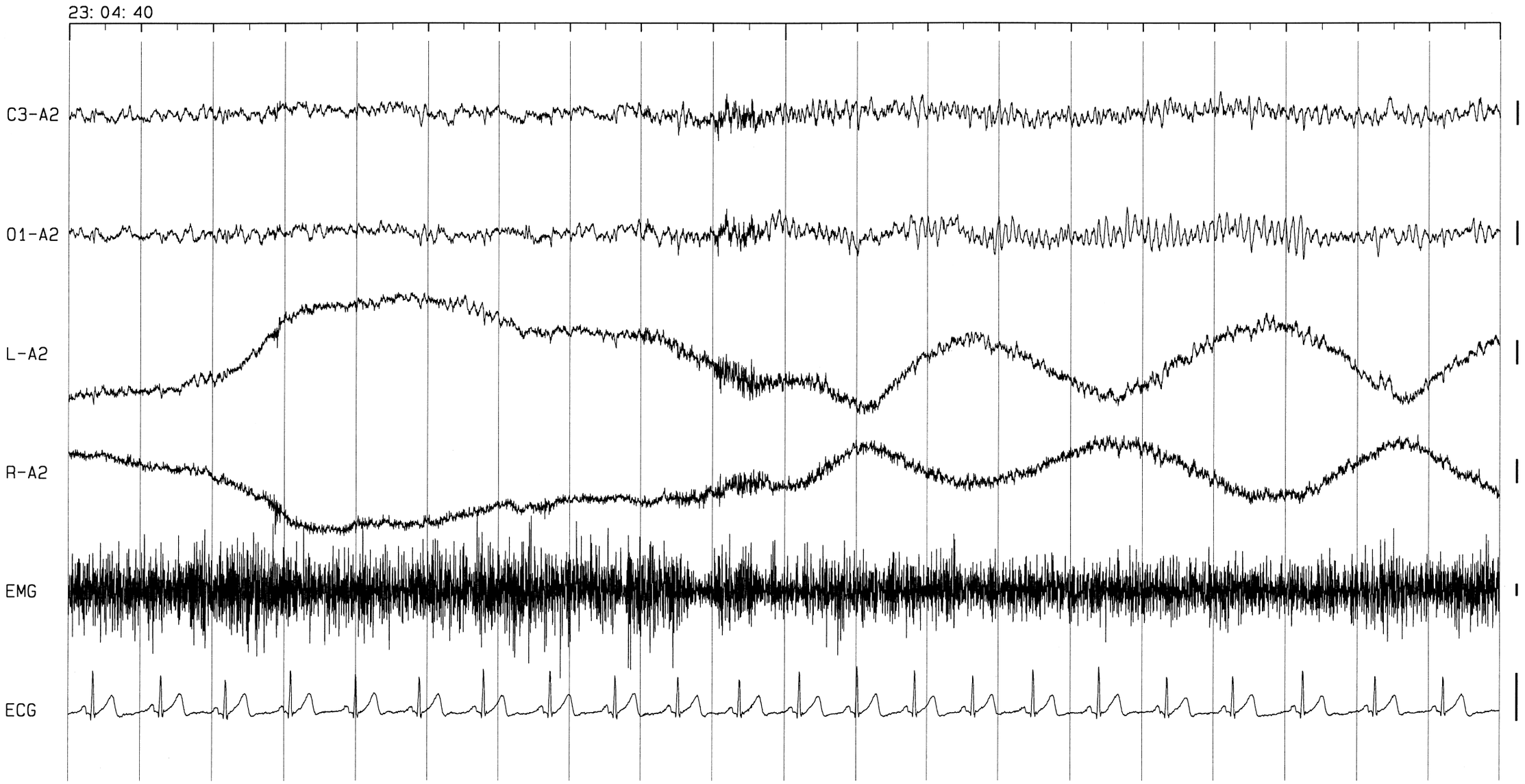
stage W: Similar to the previous page.



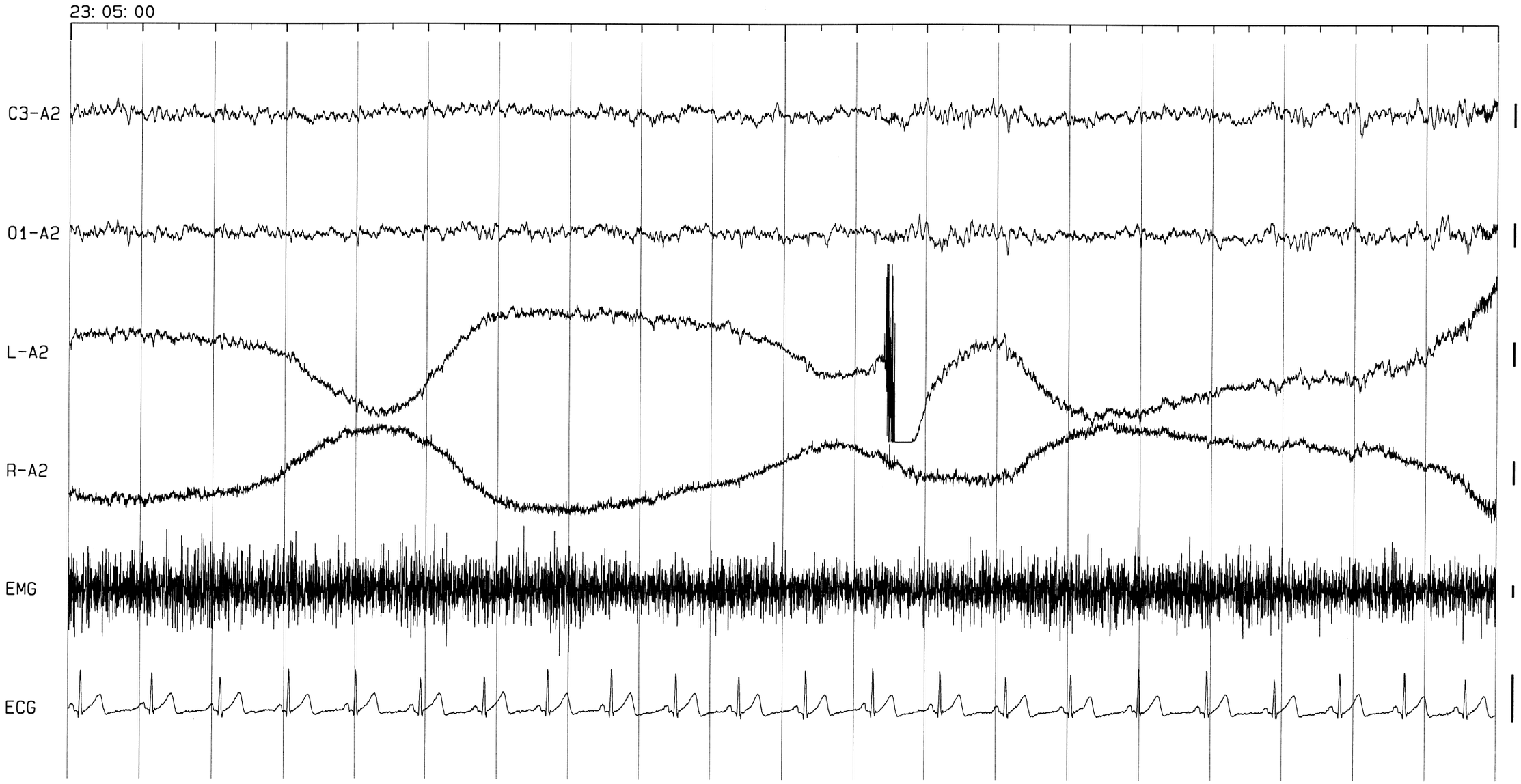
stage 1: Percentage of alpha activity is not more than 50% at C3 and O1. The waves which are typical of stage 1* and slow eye movements are observed.
*: Stage 1 is defined as the sleep stage in which the low voltage and mixed frequency EEG (higher than 2 Hz, lower than 8 Hz) is observed.



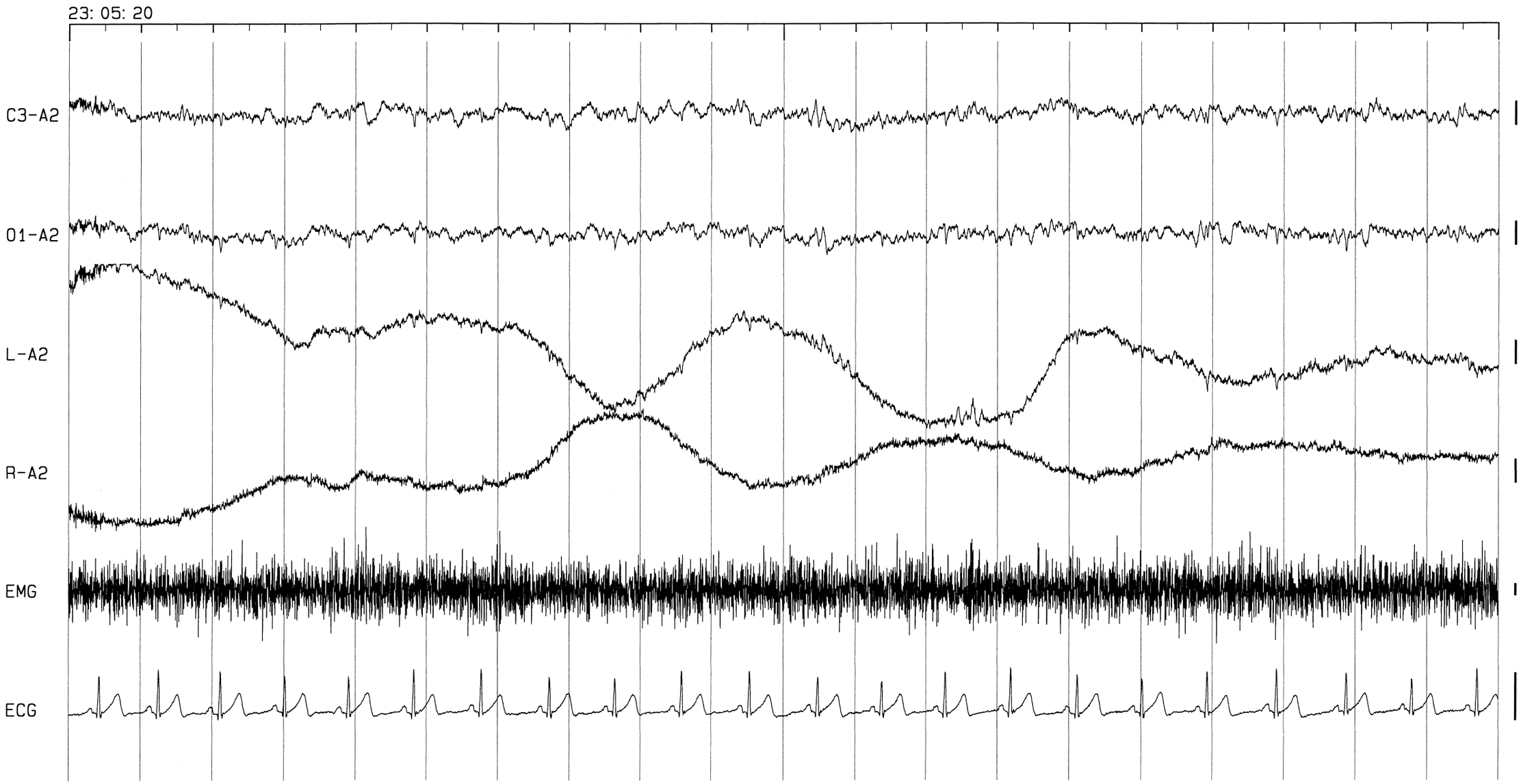
stage 1: The waves which are typical of stage 1 and slow eye movements are observed.



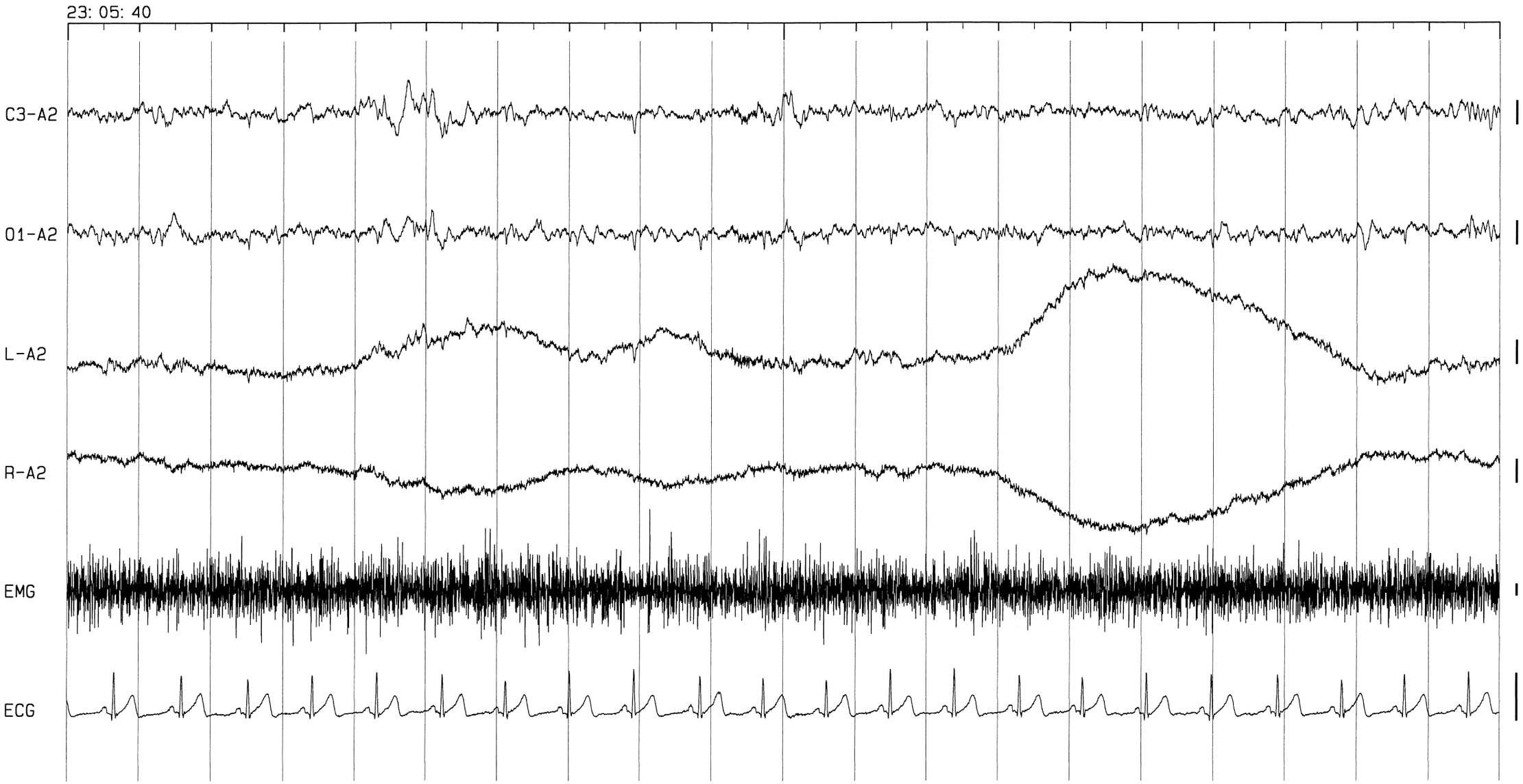
stage 1: Percentage of alpha activity is not more than 50% and slow eye movements are observed.



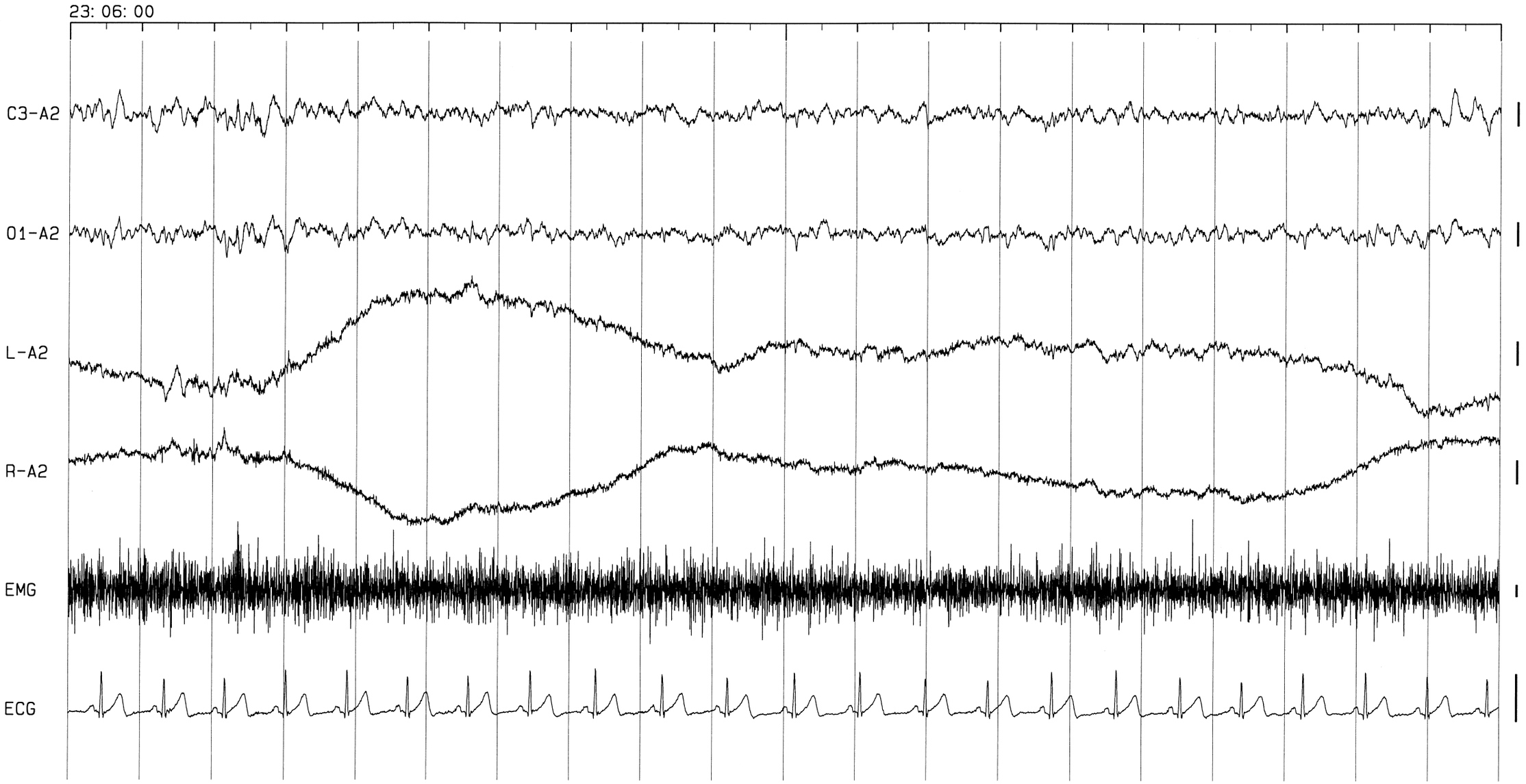
stage 1: The waves which are typical of stage 1 and slow eye movements are observed.



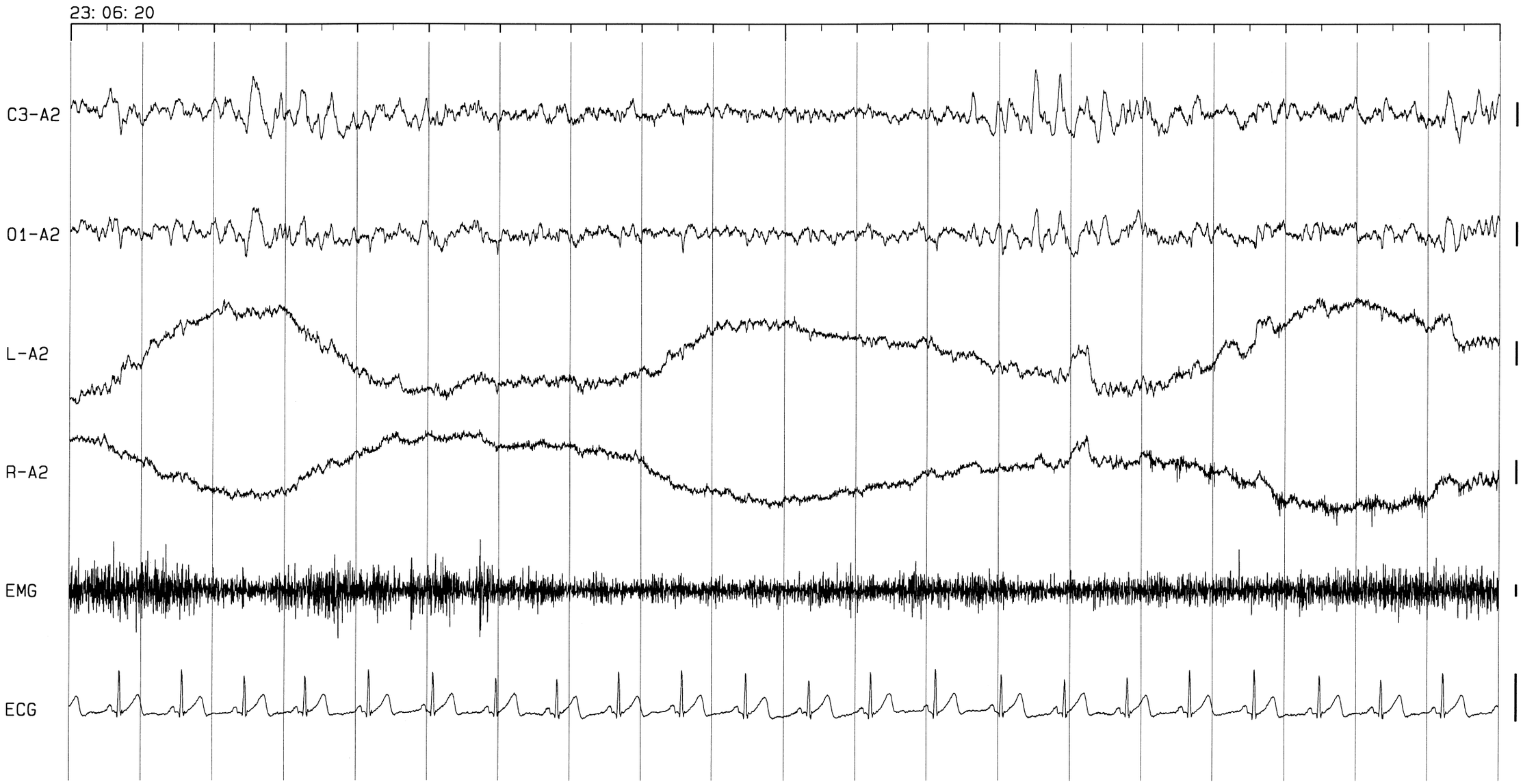
stage 1: The waves which are typical of stage 1 and slow eye movements are observed.



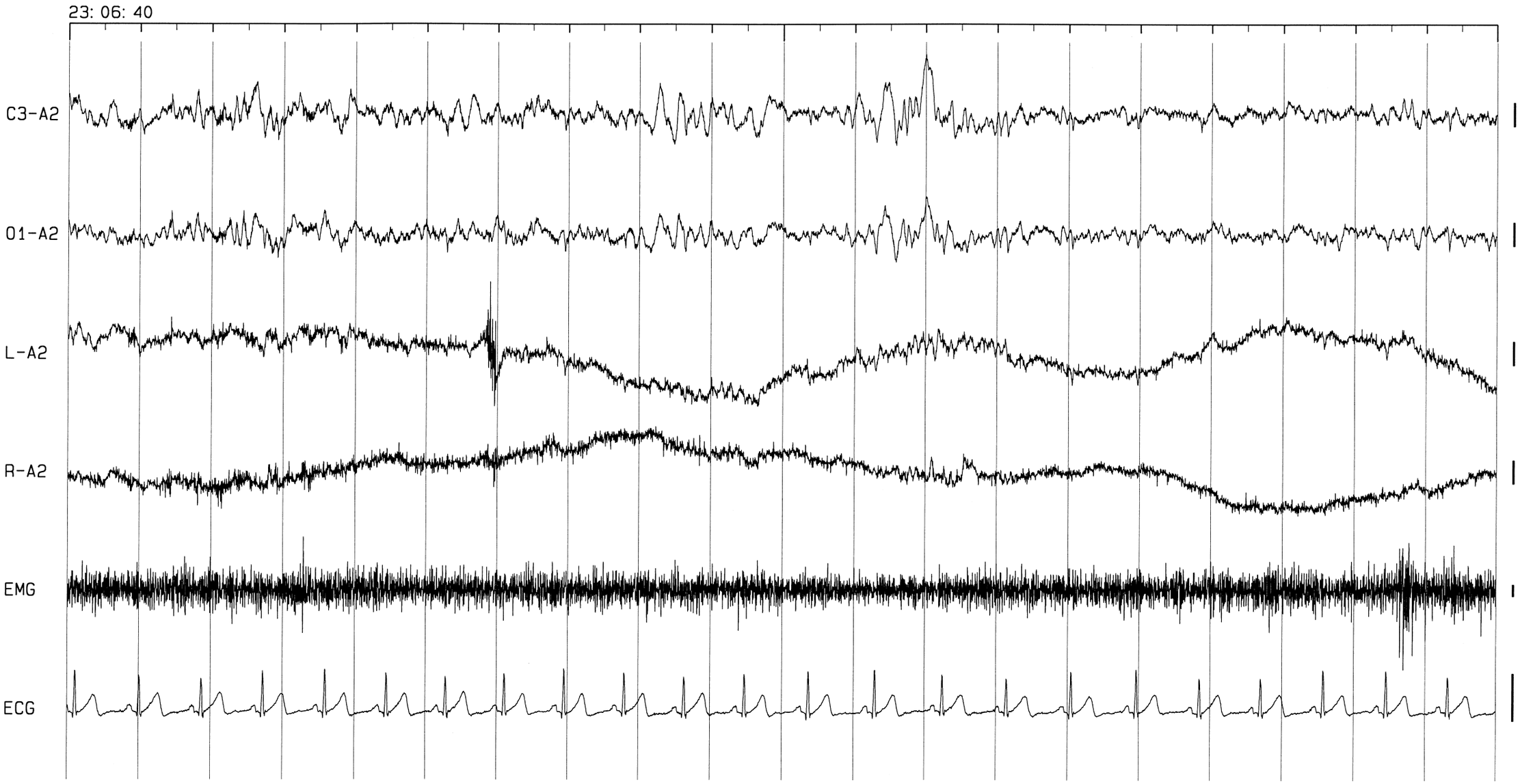
stage 1: Vertex sharp waves and slow eye movements are observed. A sleep spindle is recognized at the end of this page.



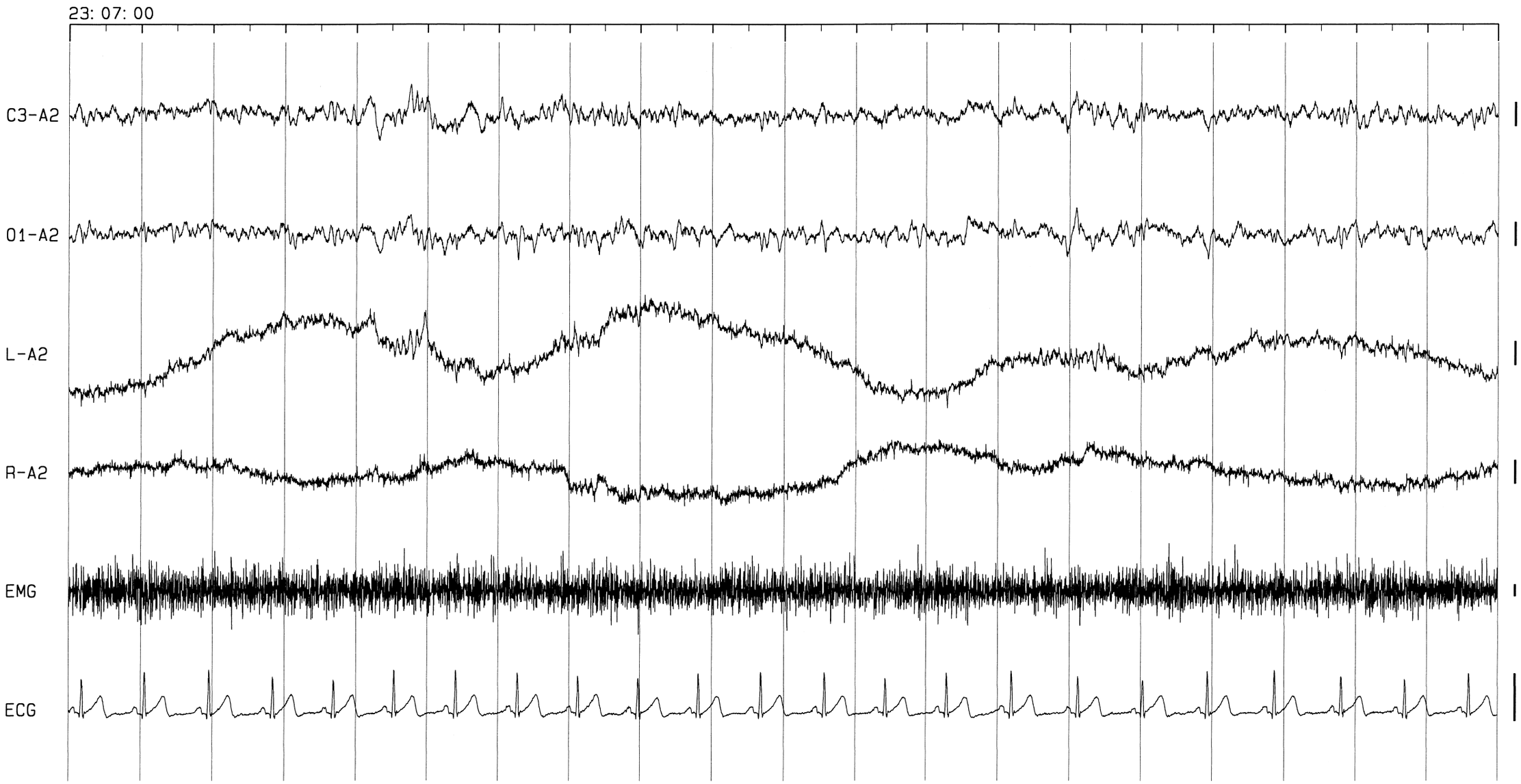
stage 2: This page is scored as stage 2 because no movement arousal or EMG increase are observed and the sleep spindle is on the previous page.



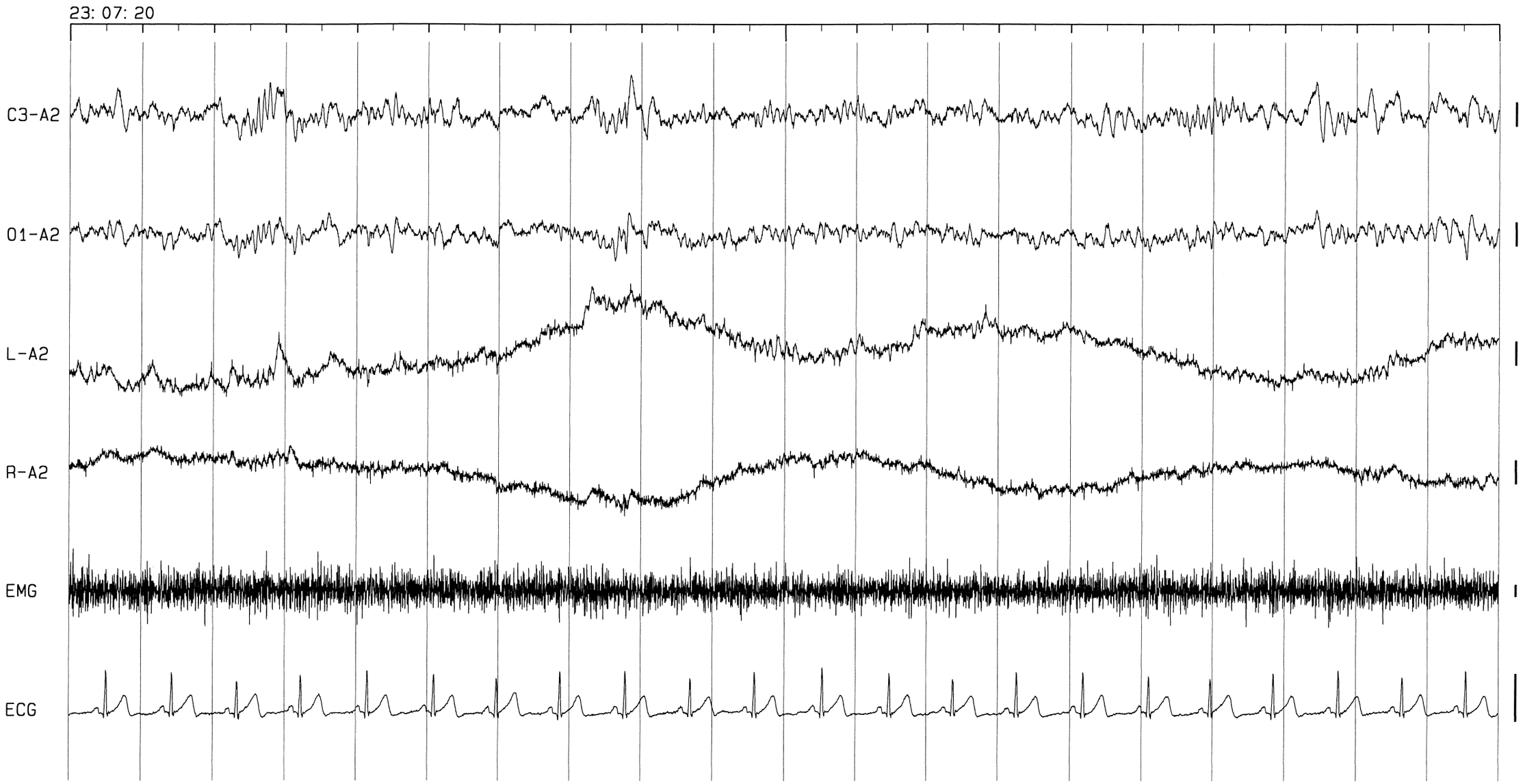
stage 2: While there are vertex sharp waves, no movement arousal or EMG increase are observed. This page is scored as stage 2, as the same as the previous page.



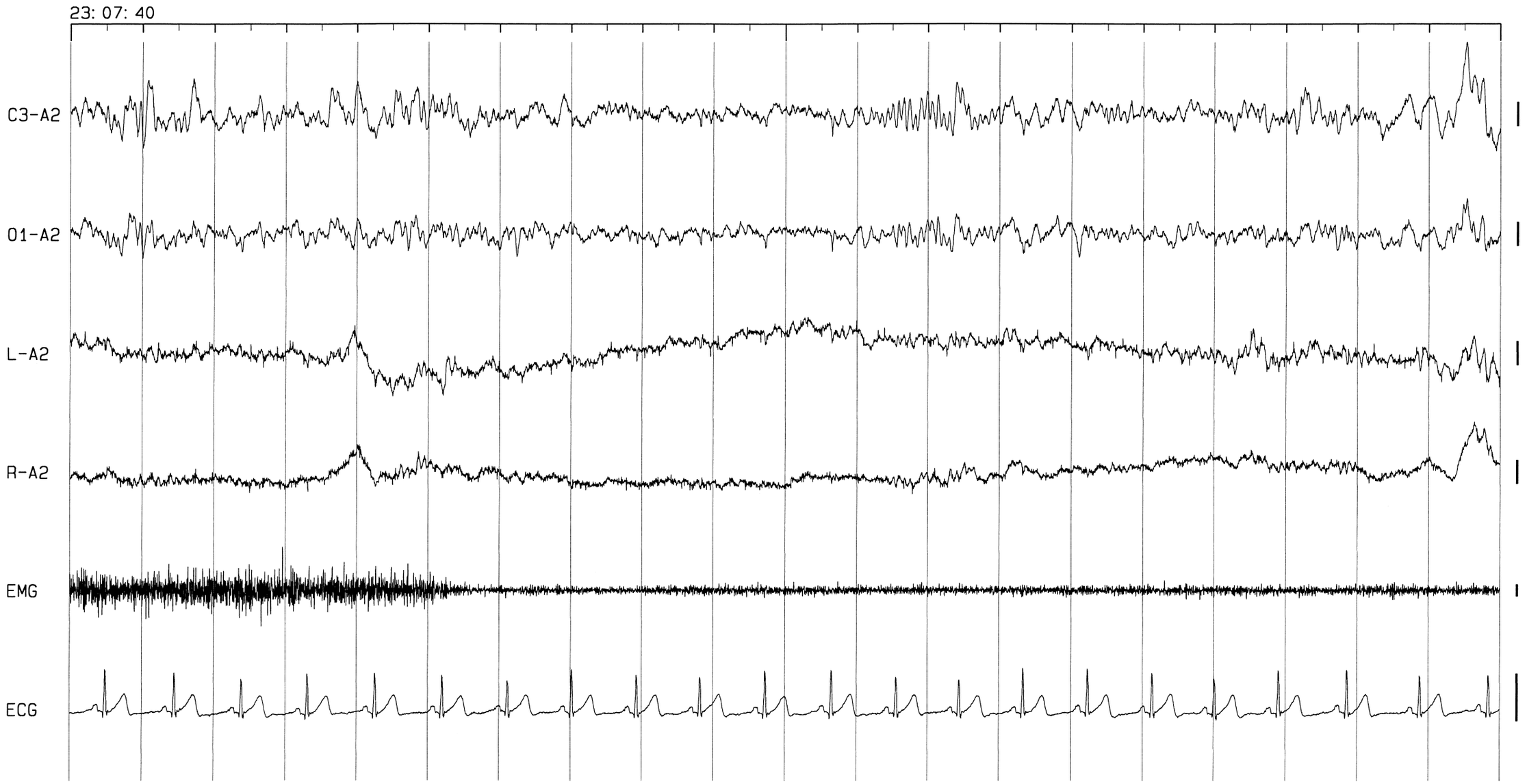
stage 2: No movement arousal or EMG increase are observed. This succeeding page is also scored as stage 2, the same as the previous page.



stage 2: No movement arousal or EMG increase are observed. This succeeding page is also scored as stage 2, the same as the previous page.



stage 2: No movement arousal or EMG increase are observed. A sleep spindle appeared in the second half of this page.



stage 2: A sleep spindle is observed in the second half of this page.

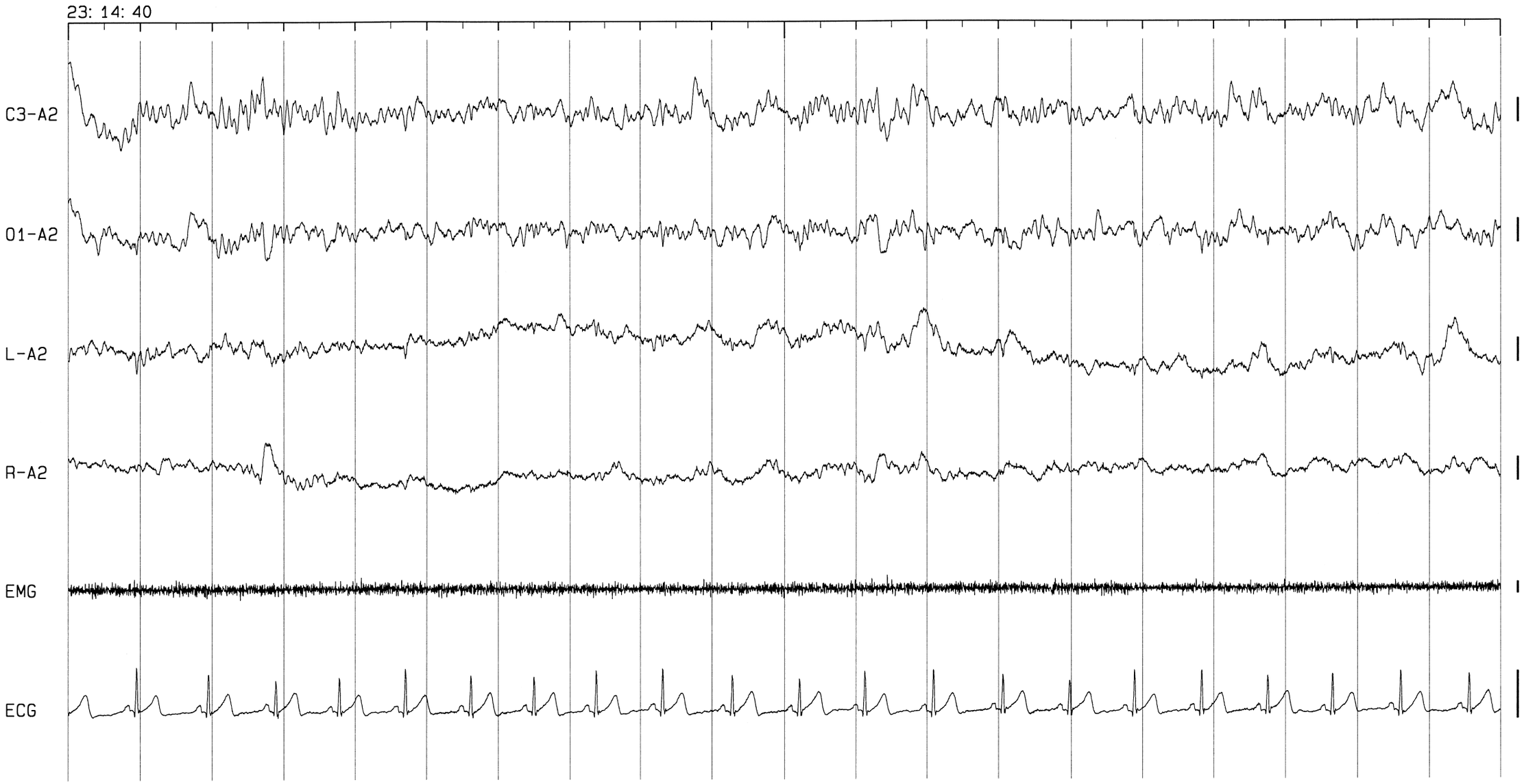
2. Scoring of NREM sleep and MT (movement time)

Identification of sleep spindles and K-complex, and their time position within a scoring epoch.

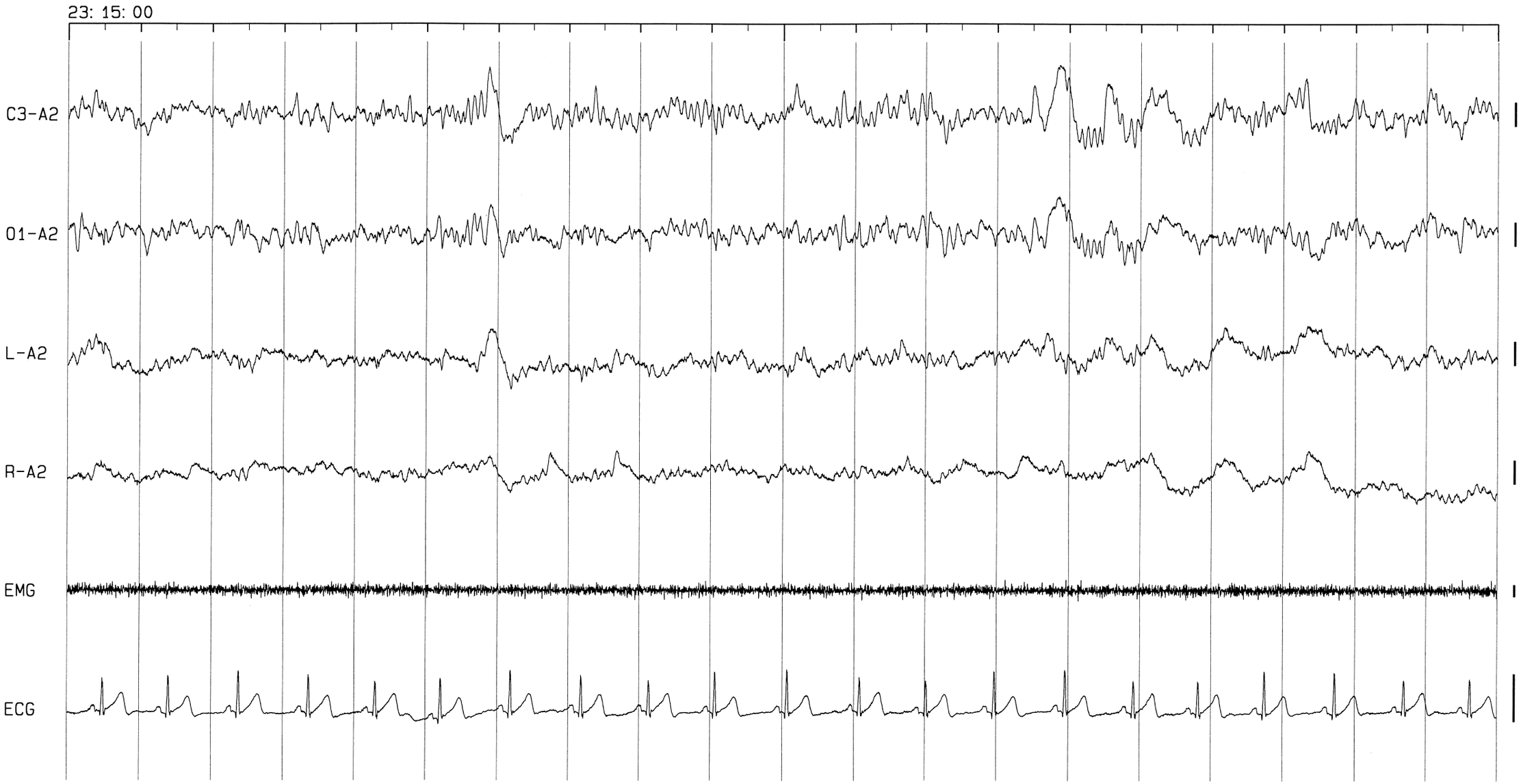
Scoring stage 2 and 3, when they appear alternately

Changes and continuations of stages

Scoring of MT (movement time) and stage changes

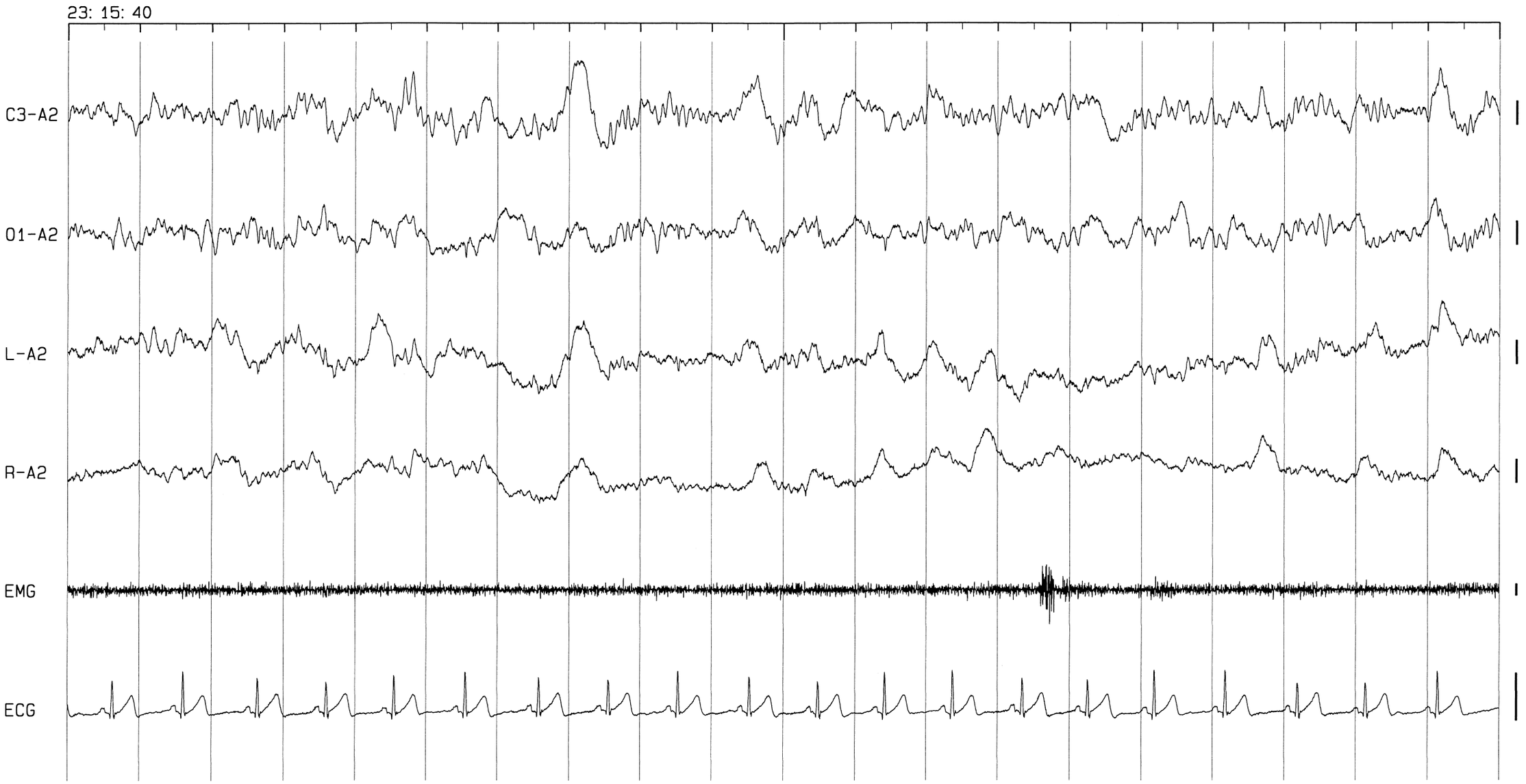


stage 2: Sleep spindles appear in this epoch.



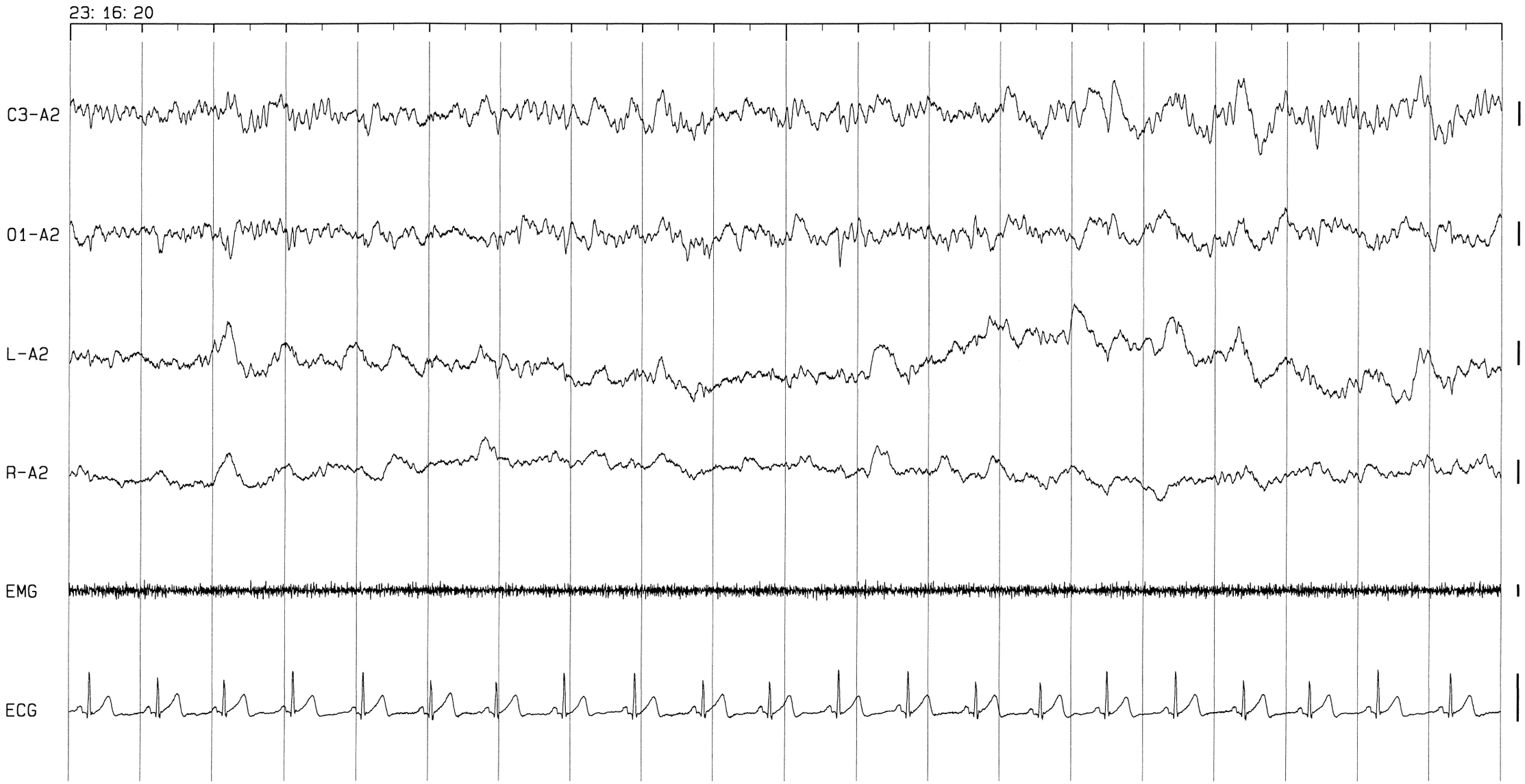
stage 2: Sleep spindles and K-complexes appear in this epoch.

stage 2: Sleep spindles appear and only less than 20% of the epoch is occupied by high amplitude slow wave activities.

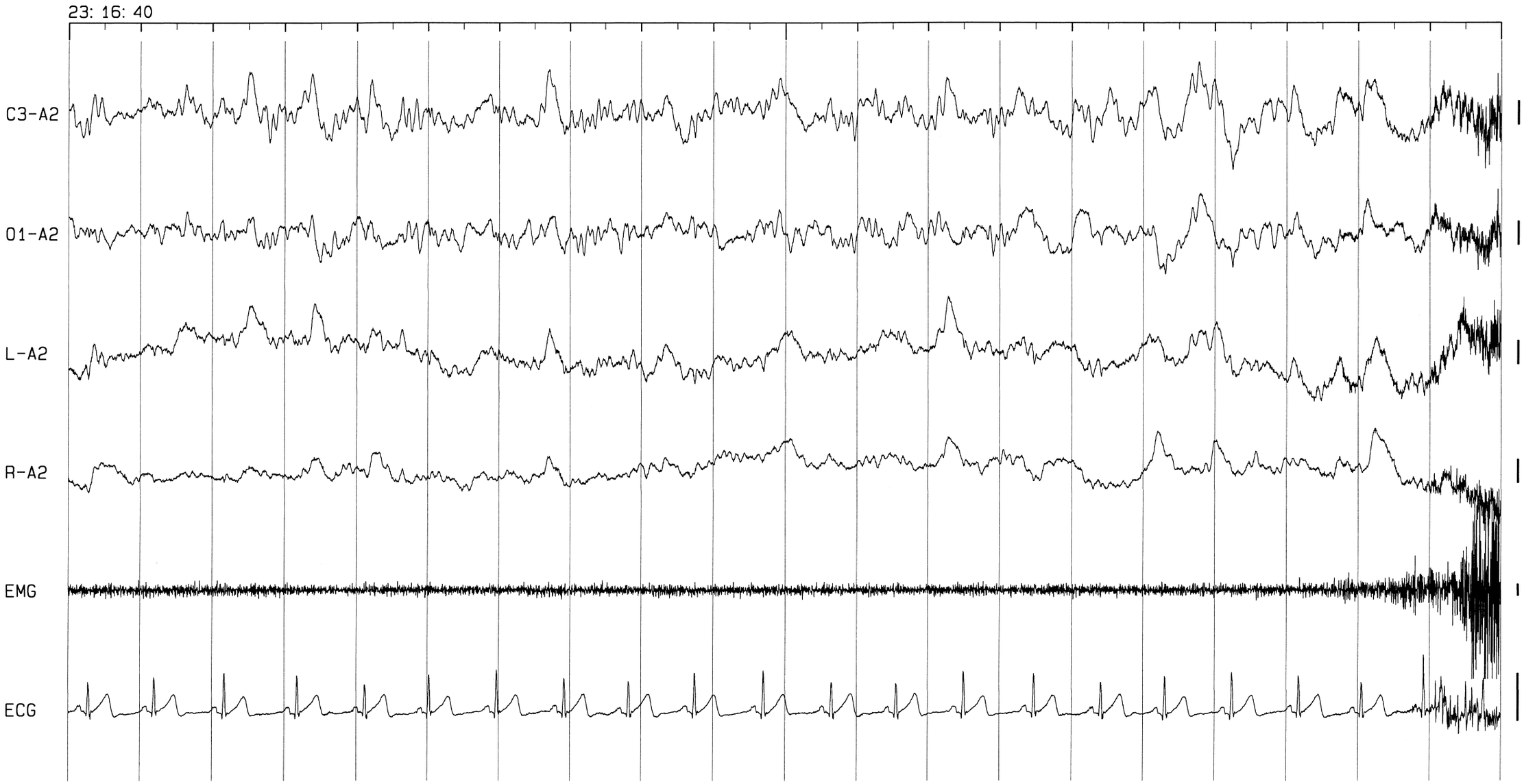


stage 3: Over 20% and less than 50% of the epoch is occupied by high amplitude slow wave activities.

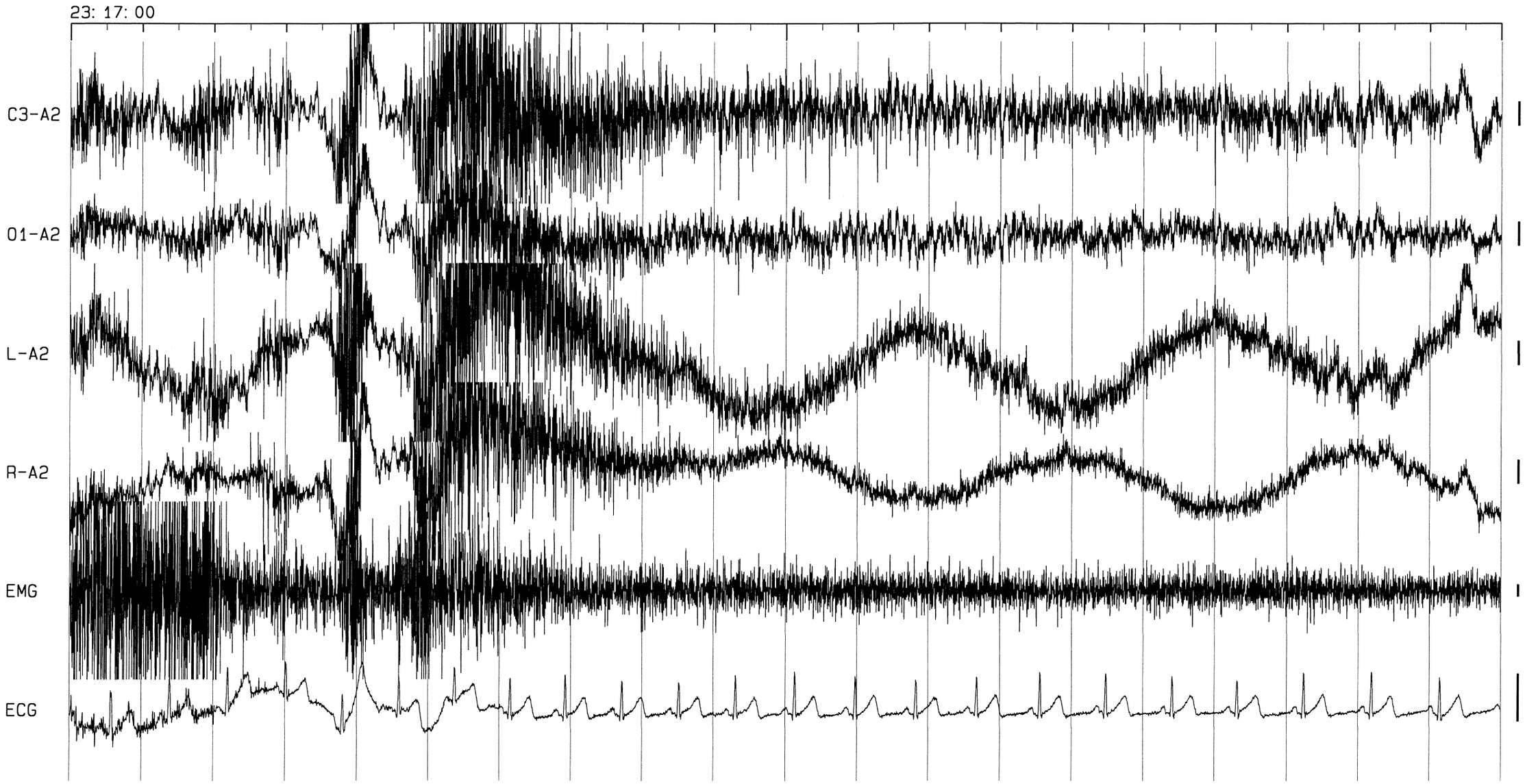
stage 3: Over 20% and less than 50% of the epoch is occupied by high amplitude slow wave activities.



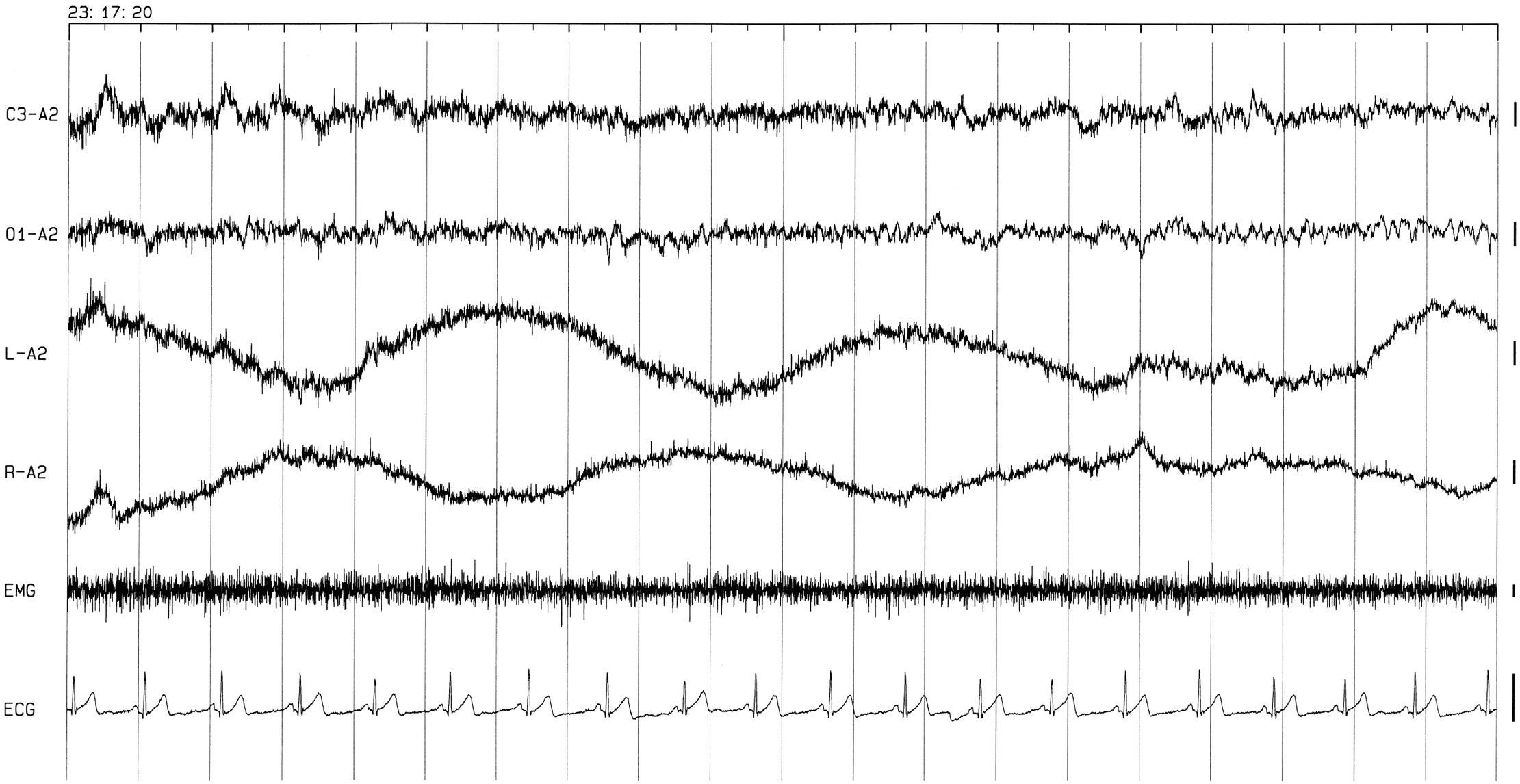
stage 2: Sleep spindles appear and only less than 20% of the epoch is occupied by high amplitude slow wave activities.



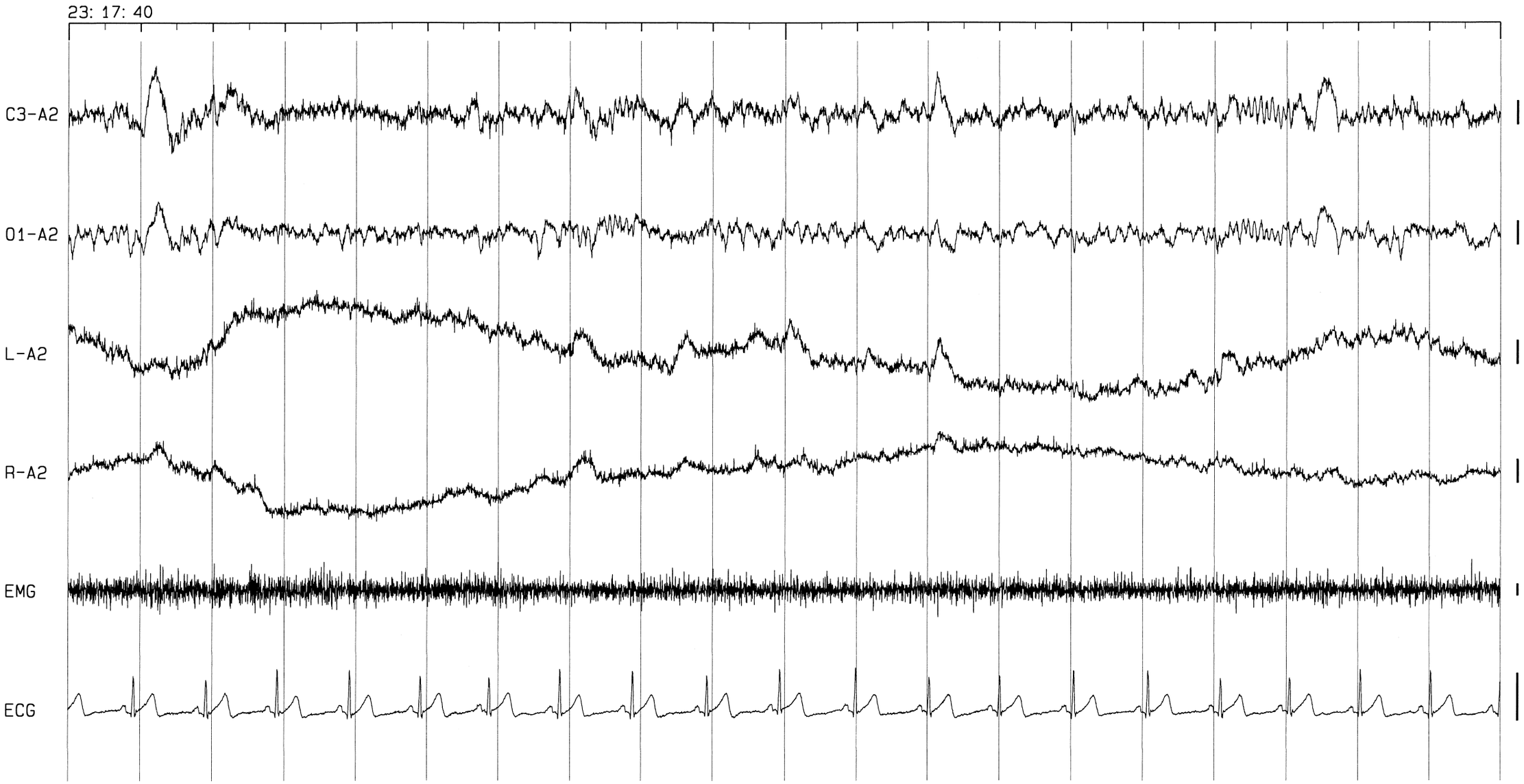
stage 2: Sleep spindles appear and only less than 20% of the epoch is occupied by high amplitude slow wave activities. A movement arousal is observed at the end of this epoch.



MT: EMG increases significantly. Over 50% of the epoch was obscured by EMG artifact. The epoch was scored as MT rather than as any sleep stage.



MT: EMG increases significantly. Over 50% of the epoch was obscured by EMG artifact. The epoch was scored as MT rather than as any sleep stage.

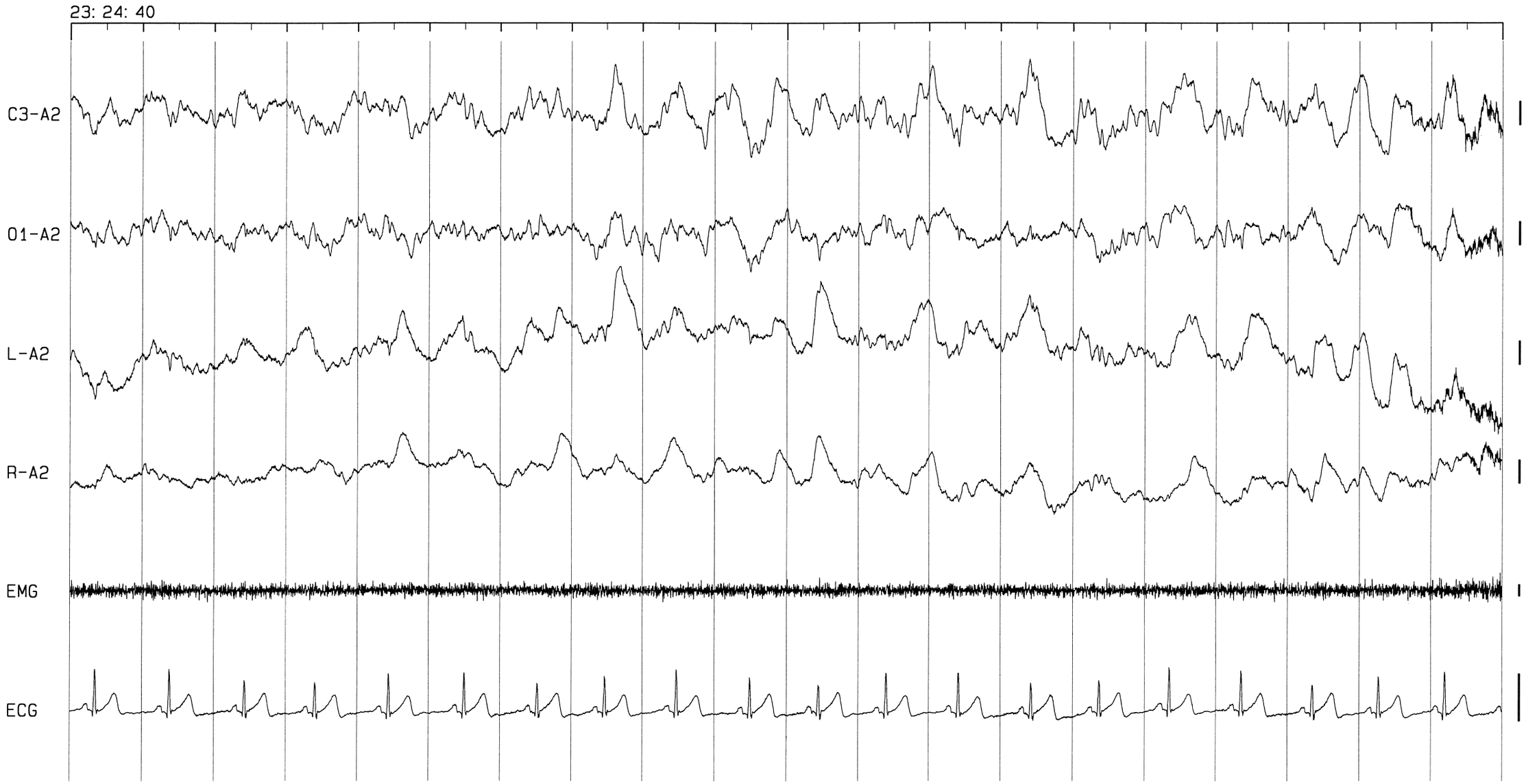


stage 1: Although K-complex-like waves appear, their amplitude is not enough for the criterion for K-complexes. Sleep spindle is only recognized in the last half of this page.

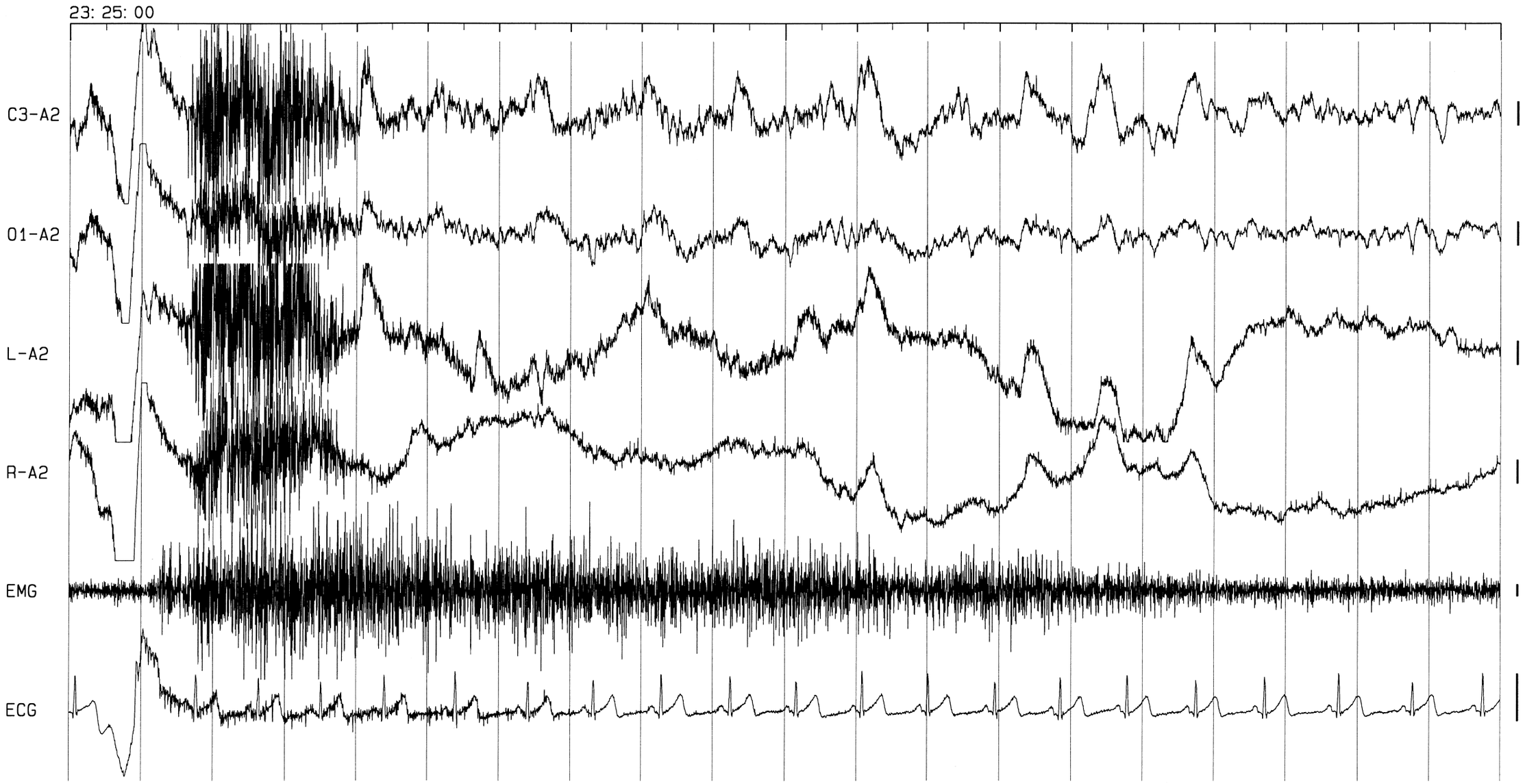
3. Scoring of NREM sleep and AR (arousal response):

Identification of arousal responses and stage scoring

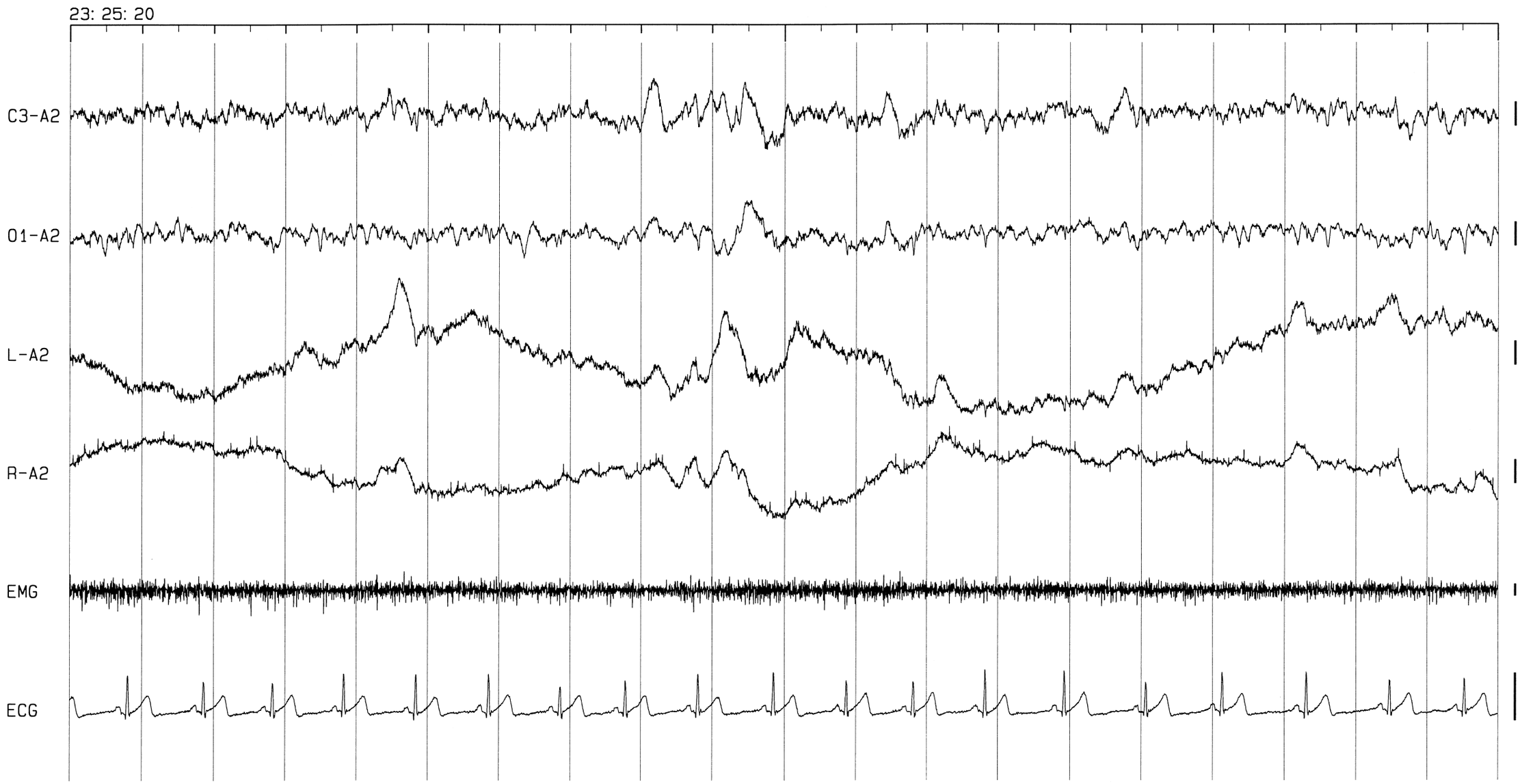
Judgment of arousal responses during the period when stages 2 and 3 appear alternately.



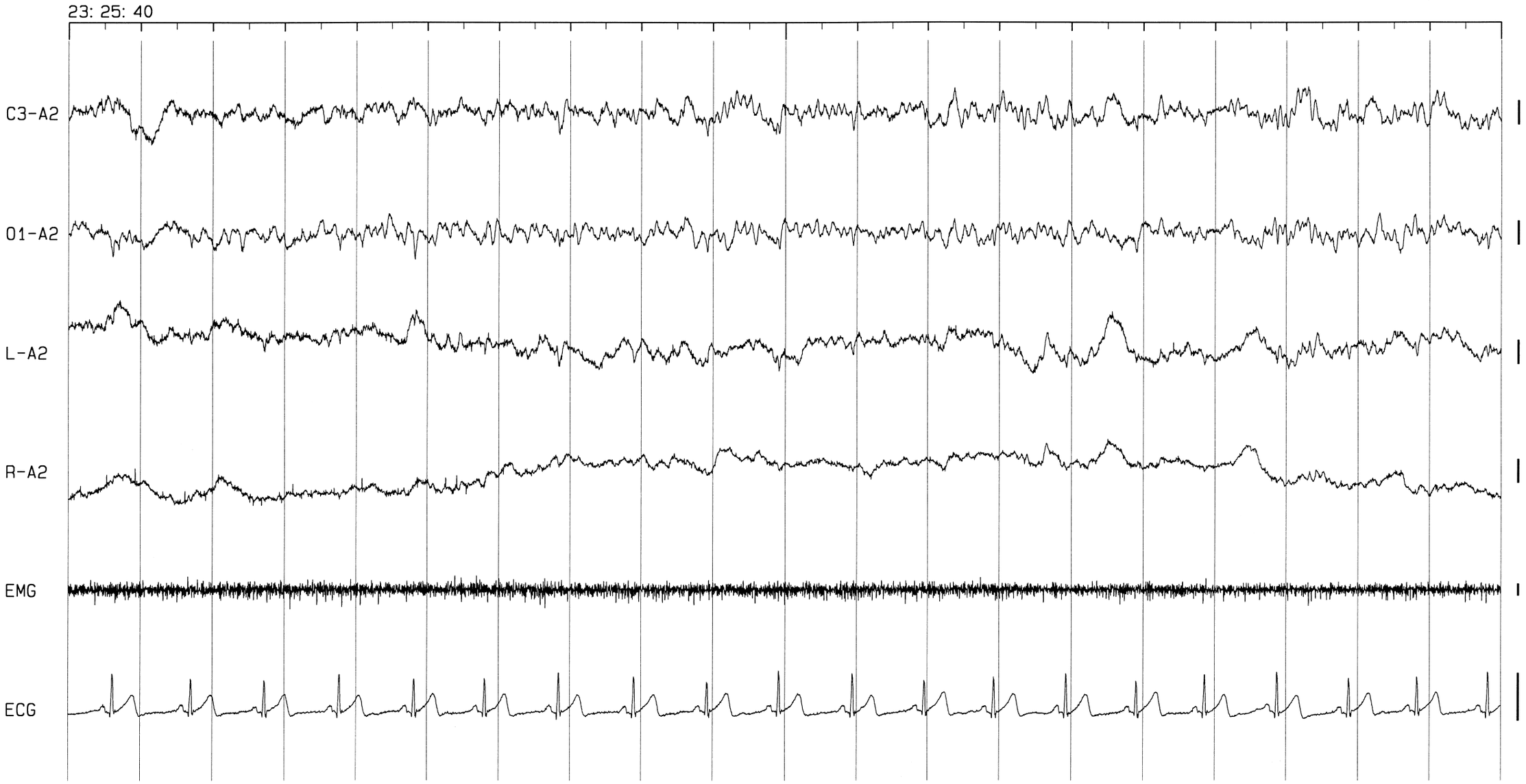
stage 3: Over 20% and less than 50% of the epoch is occupied by high amplitude slow wave activities.



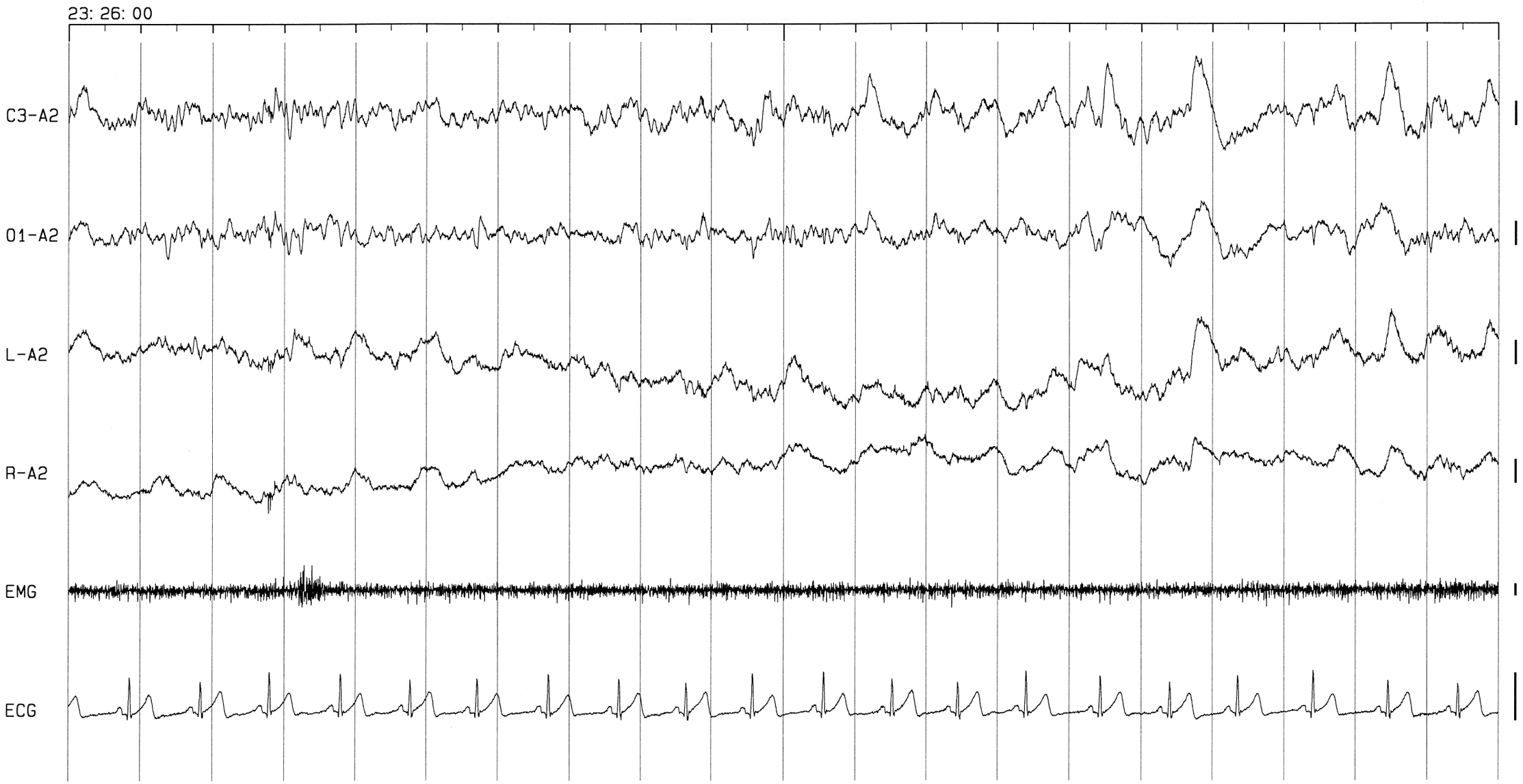
stage 1: A movement arousal can be seen in the first half of this page. The sleep stage changes from stage 3 to 1 by the movement arousal. EMG increased. Although slow wave burst is observed, these slow wave activities should be regarded as a part of the arousal responses rather than slow wave activities which represent slow wave sleep. As there are no appearance of activities which define stage 2 sleep, the sleep stage of this epoch should be scored based on the next succeeding epoch.



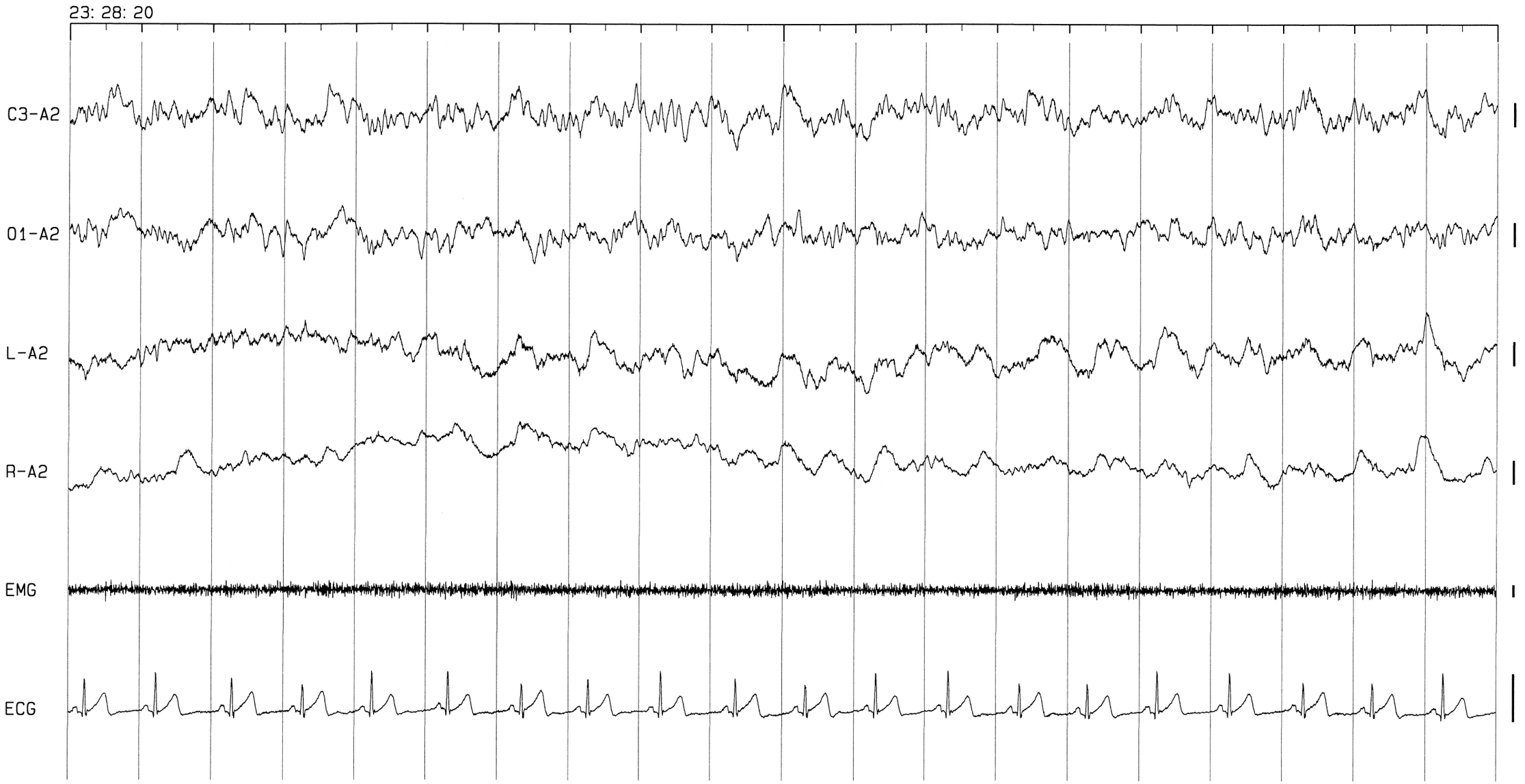
stage 1: There is no sleep spindle. This page shows typical EEG pattern of stage 1.



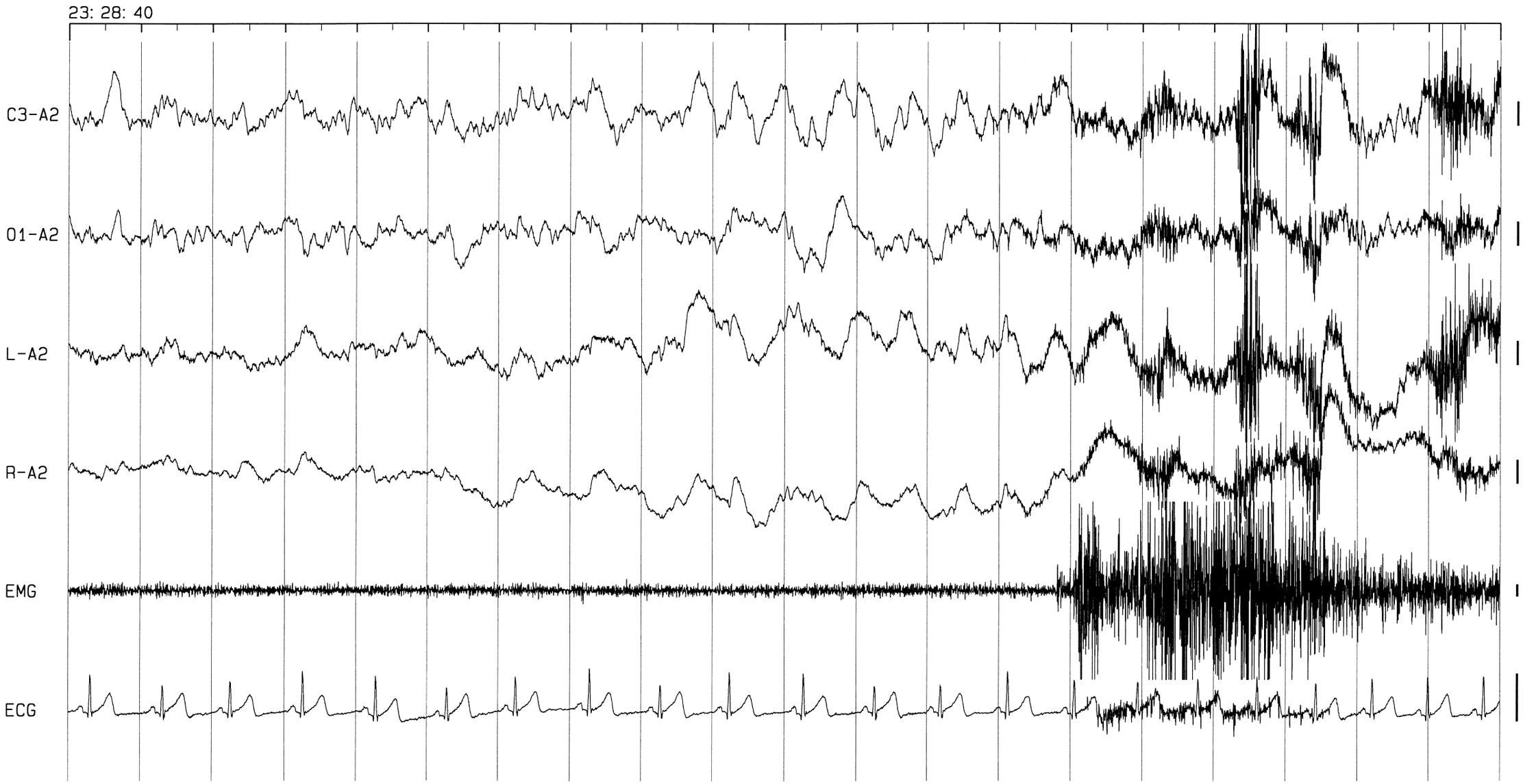
stage 1: Sleep spindles can only be seen in the last half of this page, the major EEG characteristics of this page is that of stage 1 sleep.



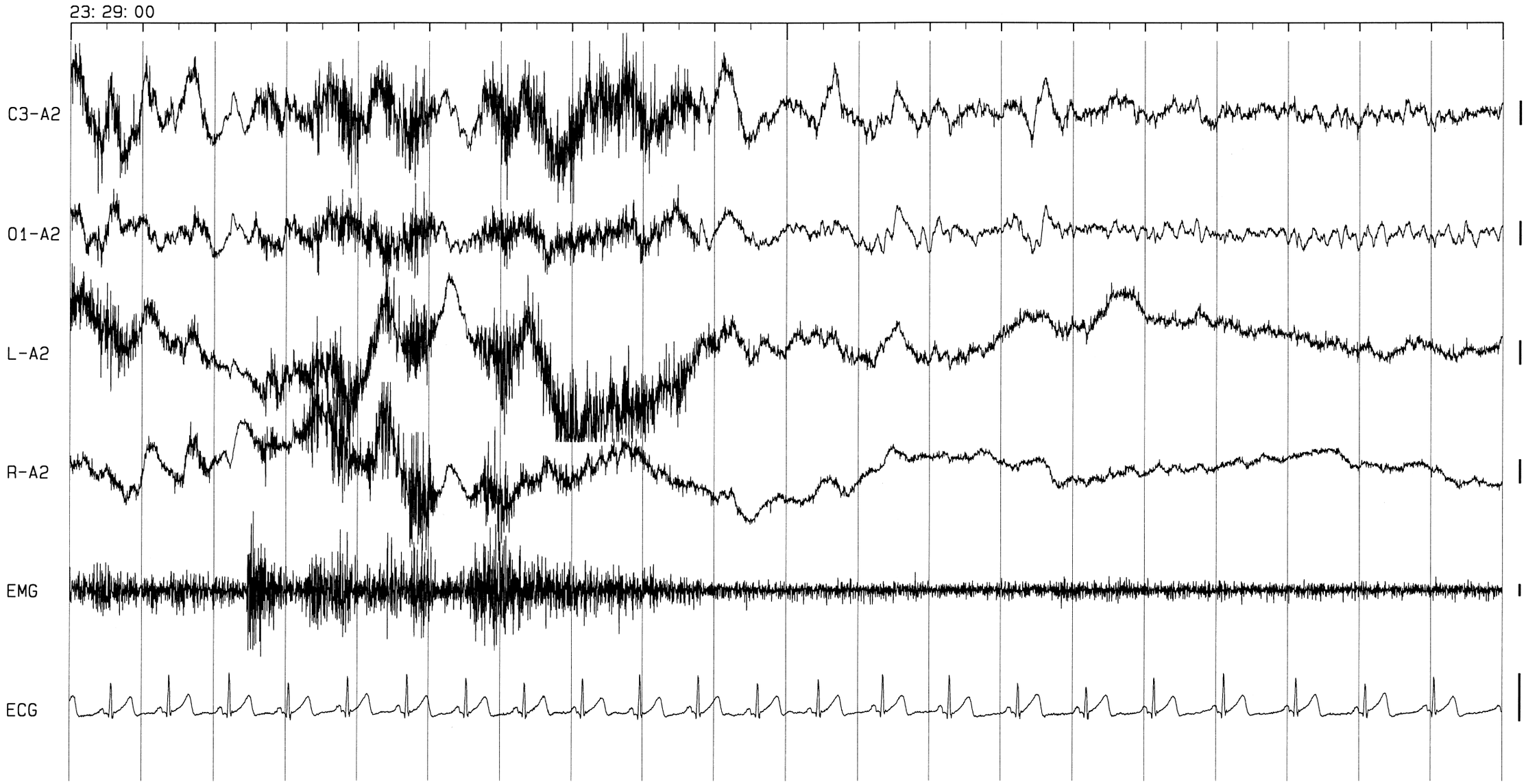
stage 2: This page is scored as stage 2, based on the appearance of sleep spindles in the previous page.



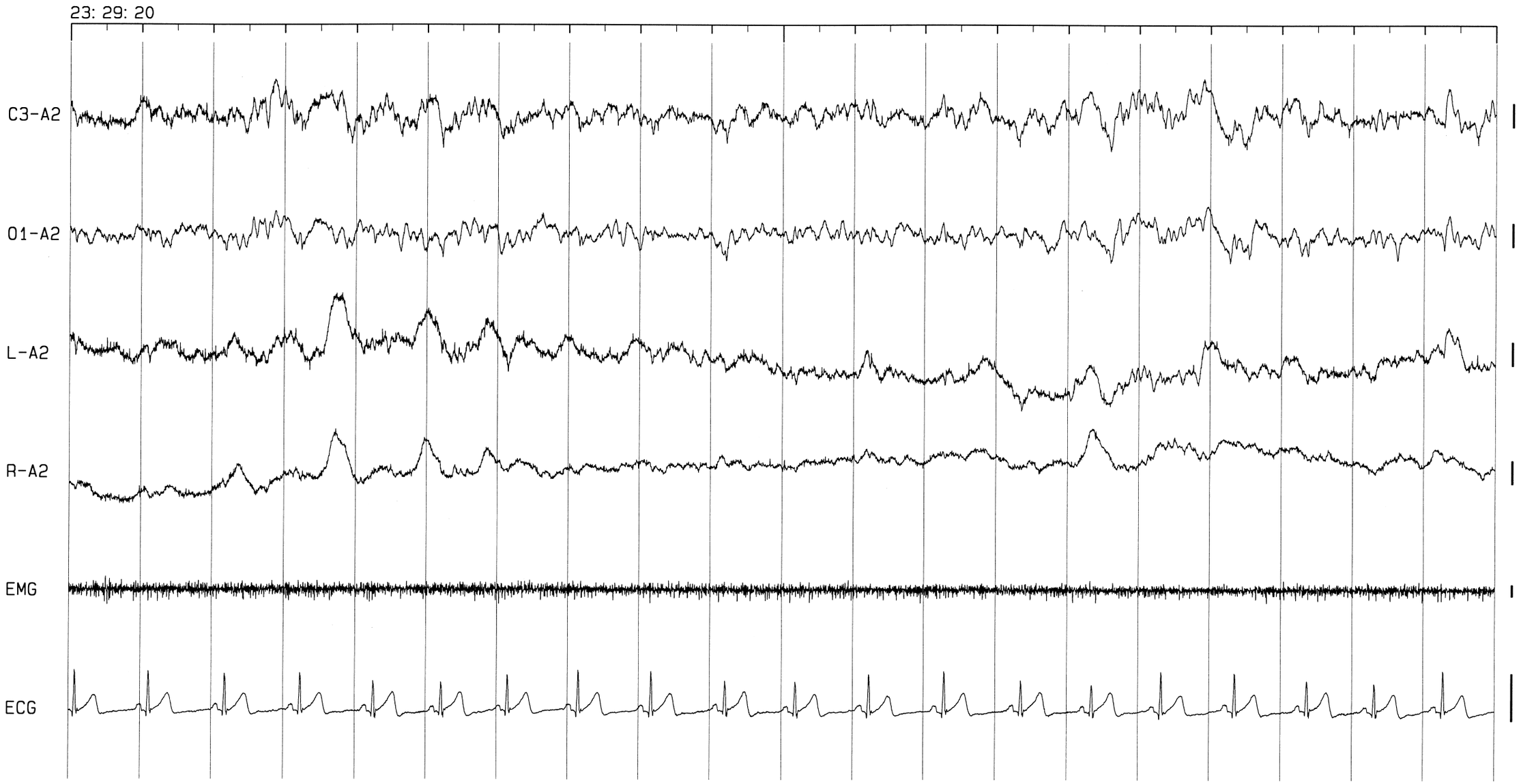
stage 2: Sleep spindles appear and only less than 20% of the epoch is occupied by high amplitude slow wave activities.



stage 3: Over 20% and less than 50% of the epoch is occupied by high amplitude slow wave activities. As a movement arousal in the last half of this page occupies only less than 50% of the epoch, this page is scored as stage 3.



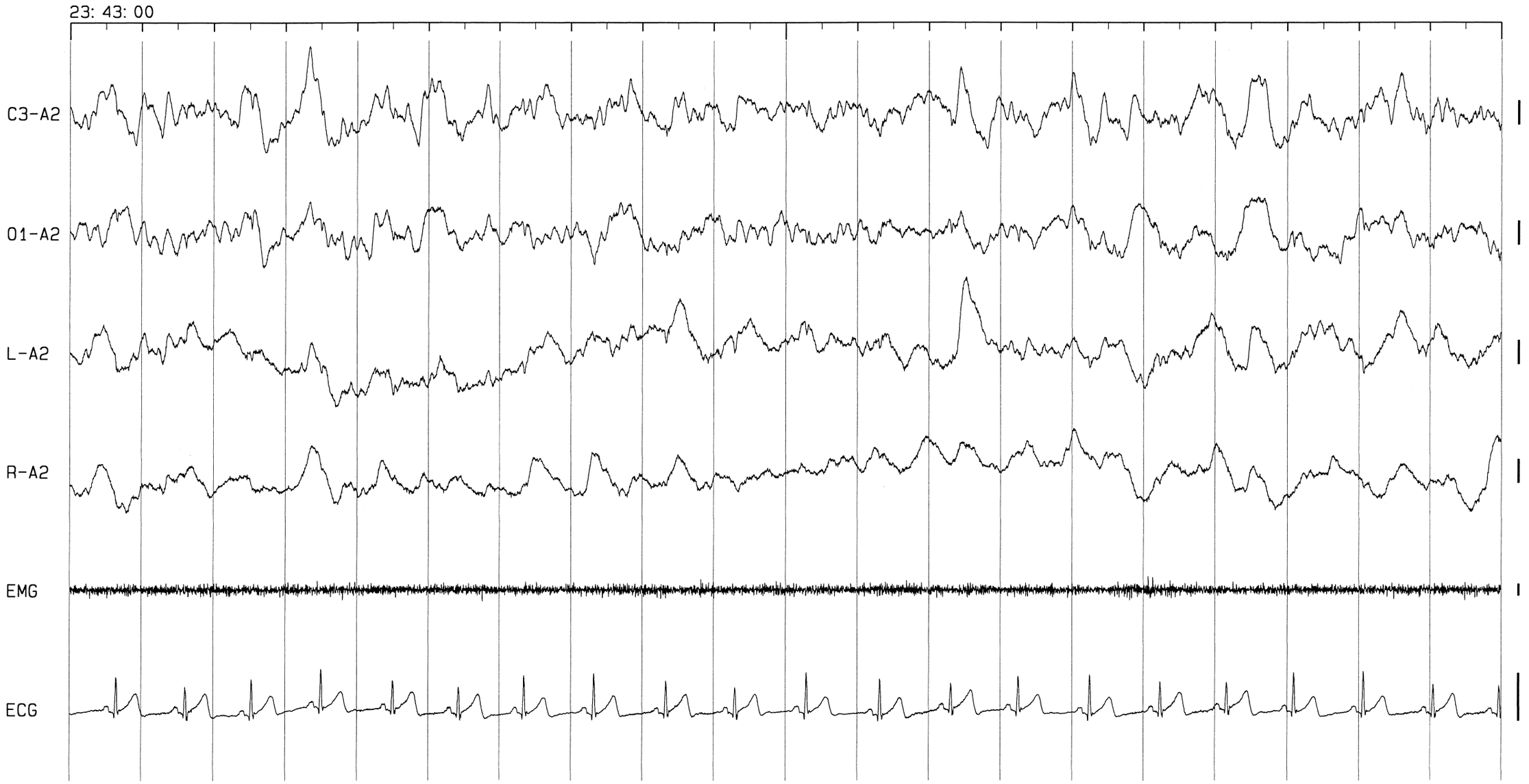
stage 1: The sleep stage changes from stage 3 to 1 by a movement arousal. EEG characteristics typical of stage 2 are not observed. Sleep stage should be scored, based on the next page. EMG increased. Although slow wave burst was observed, these slow wave activities should be regarded as a part of the arousal responses rather than slow wave activities which represent slow wave sleep.



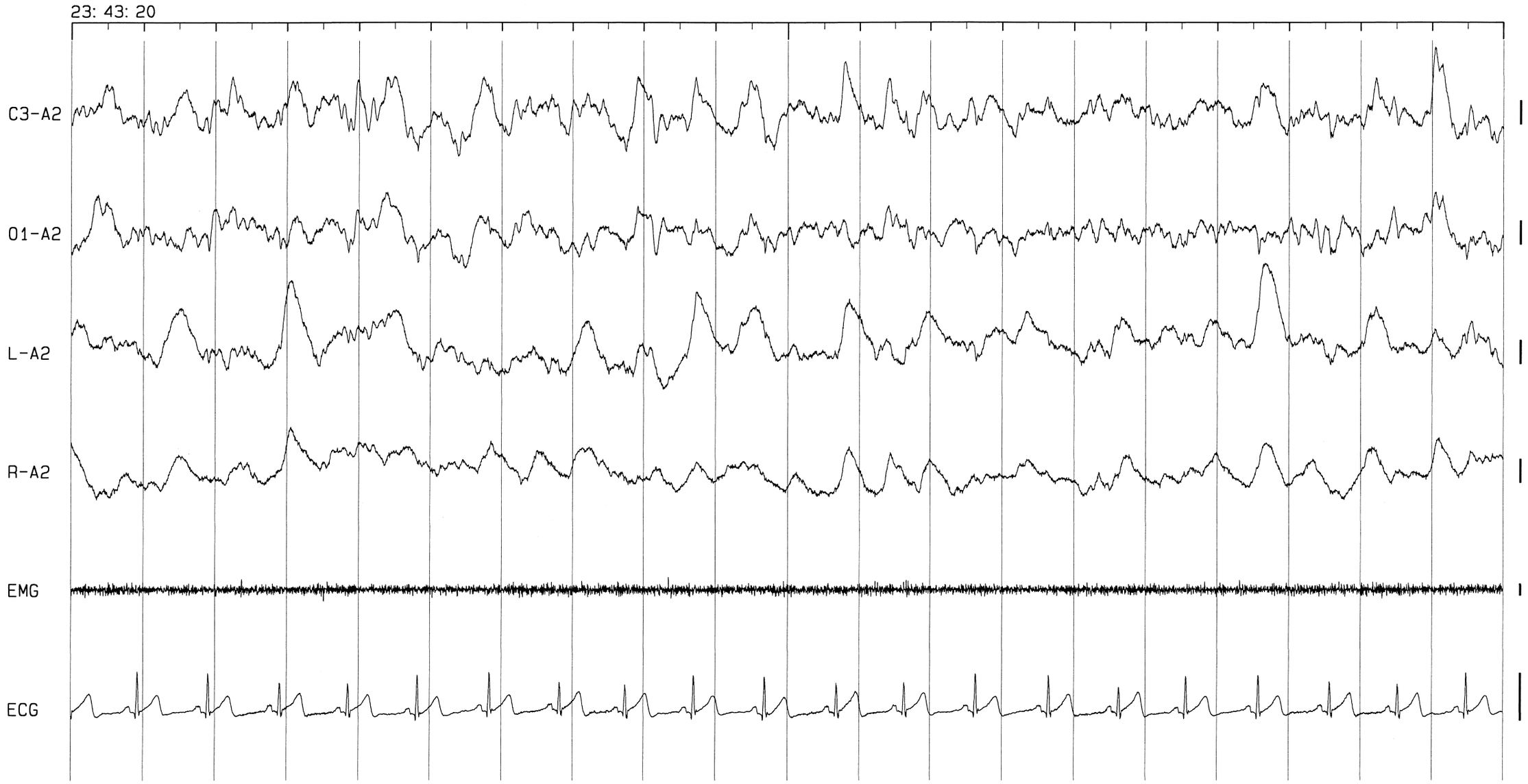
stage 1: A sleep spindle is observed only in the last half of this page.

4. Scoring of NREM sleep (stage 3 and 4):

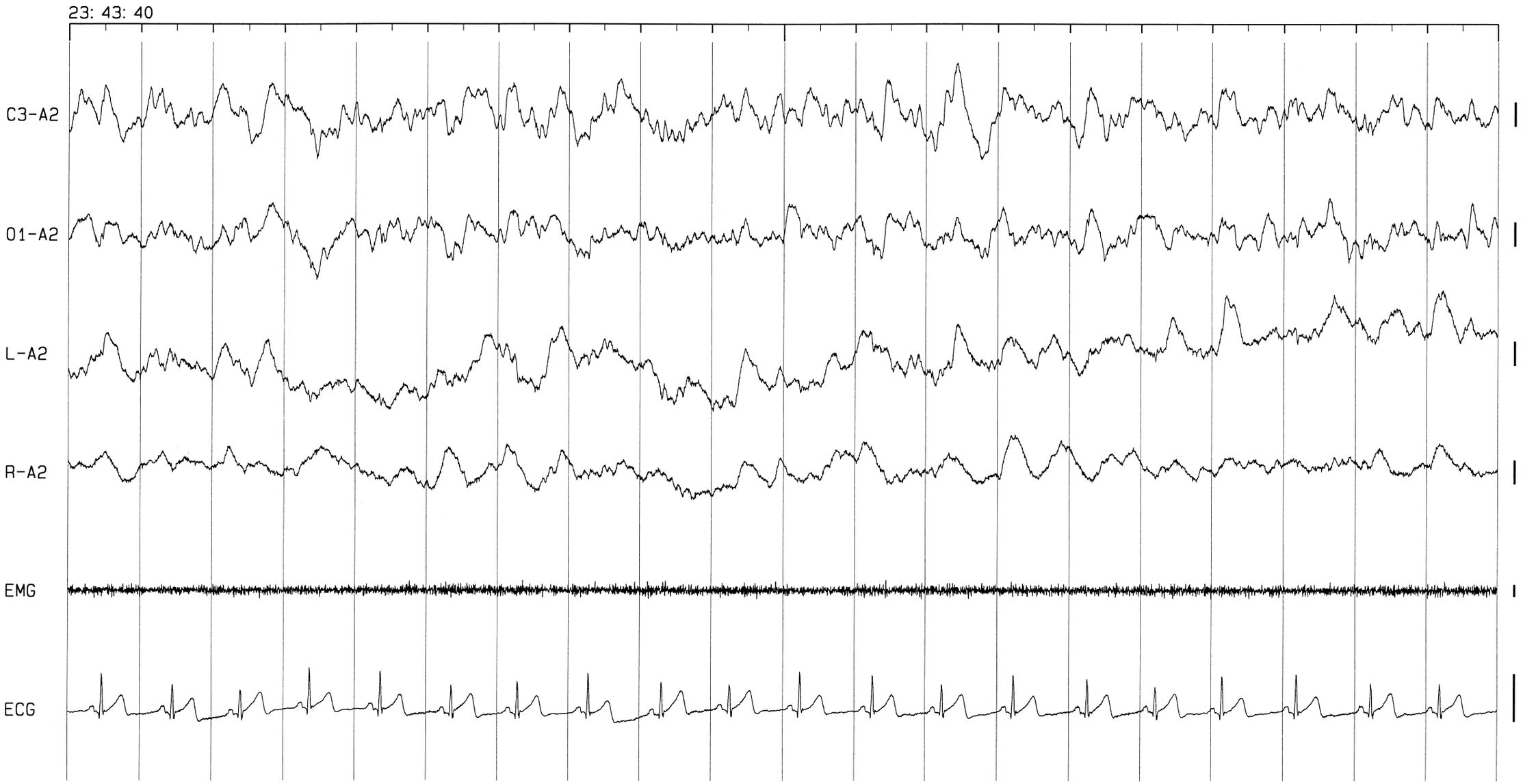
Identification of high amplitude slow wave activities (delta waves) and measurement of their duration.



stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.

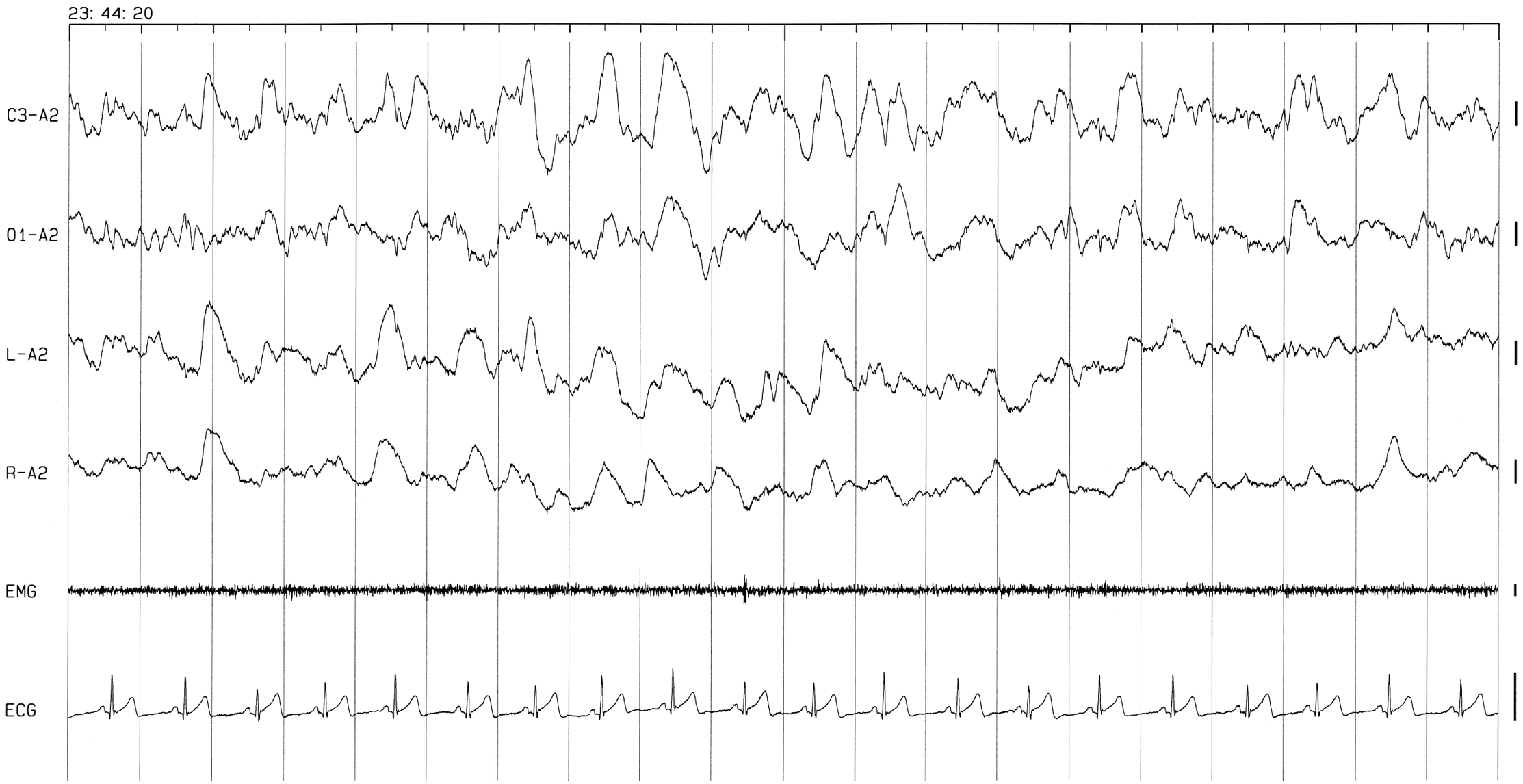


stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.



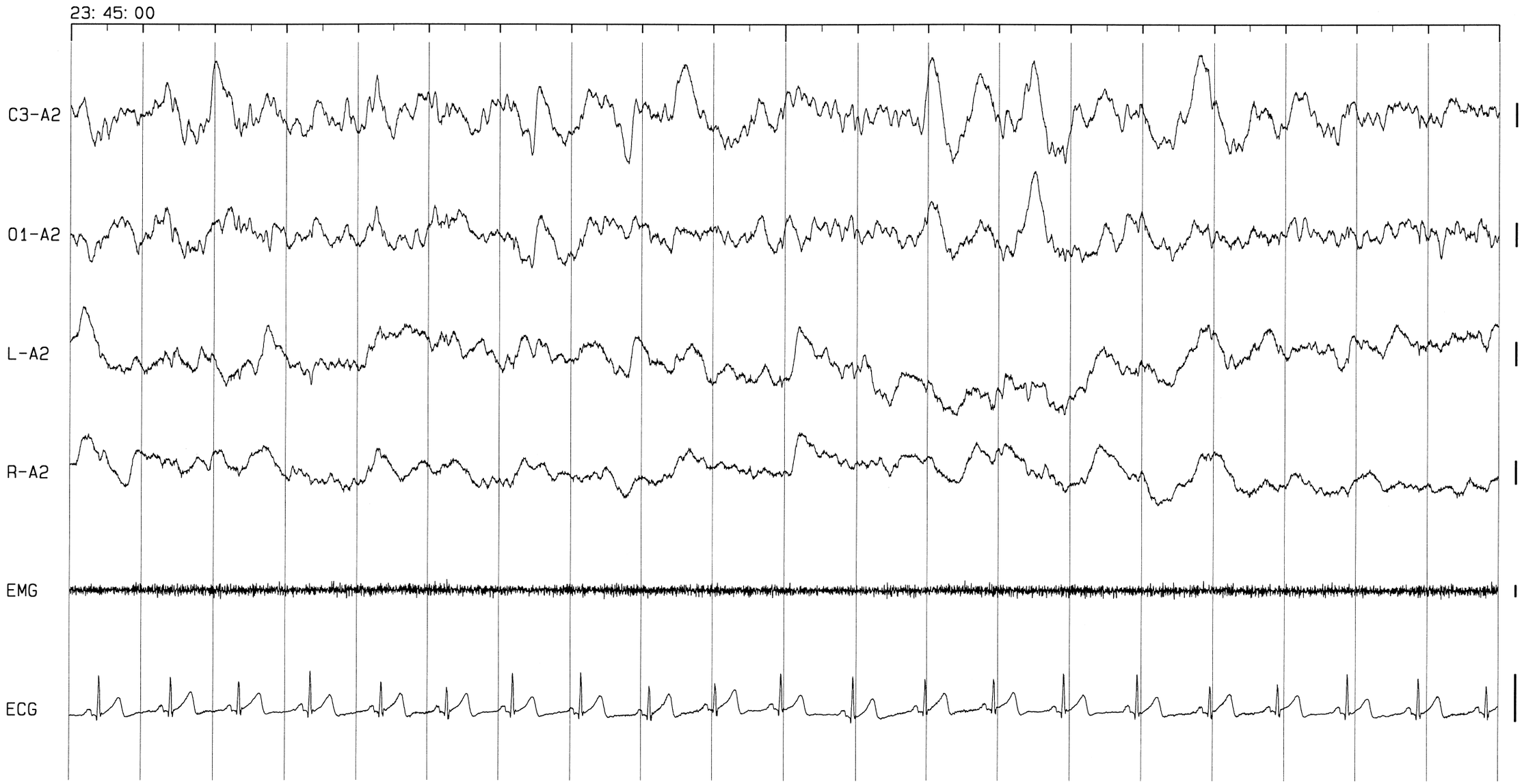
stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.

stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.

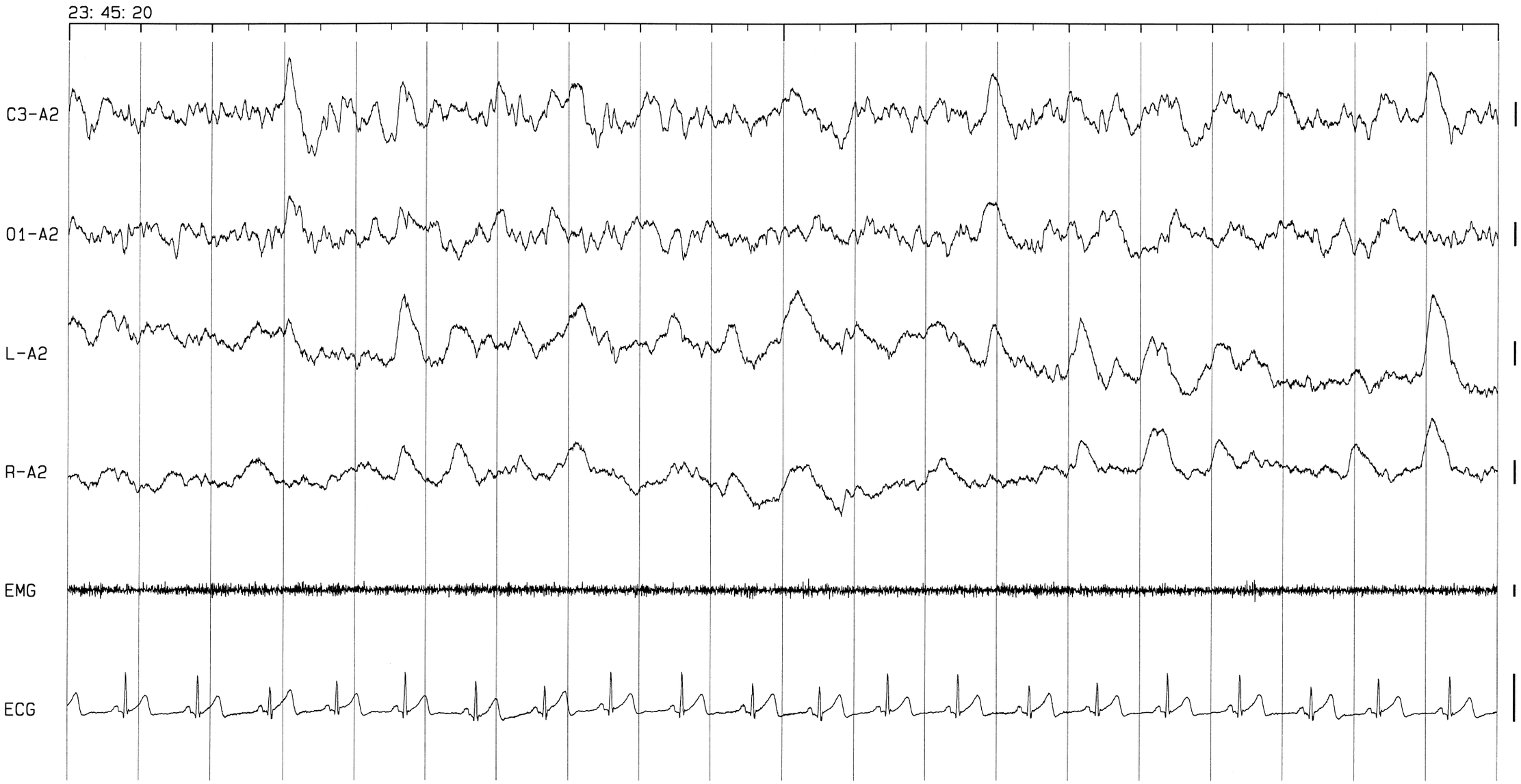


stage 4: High amplitude slow wave activity occupies more than 50% of this page.

stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.



stage 4: High amplitude slow wave activity occupies more than 50% of this page.

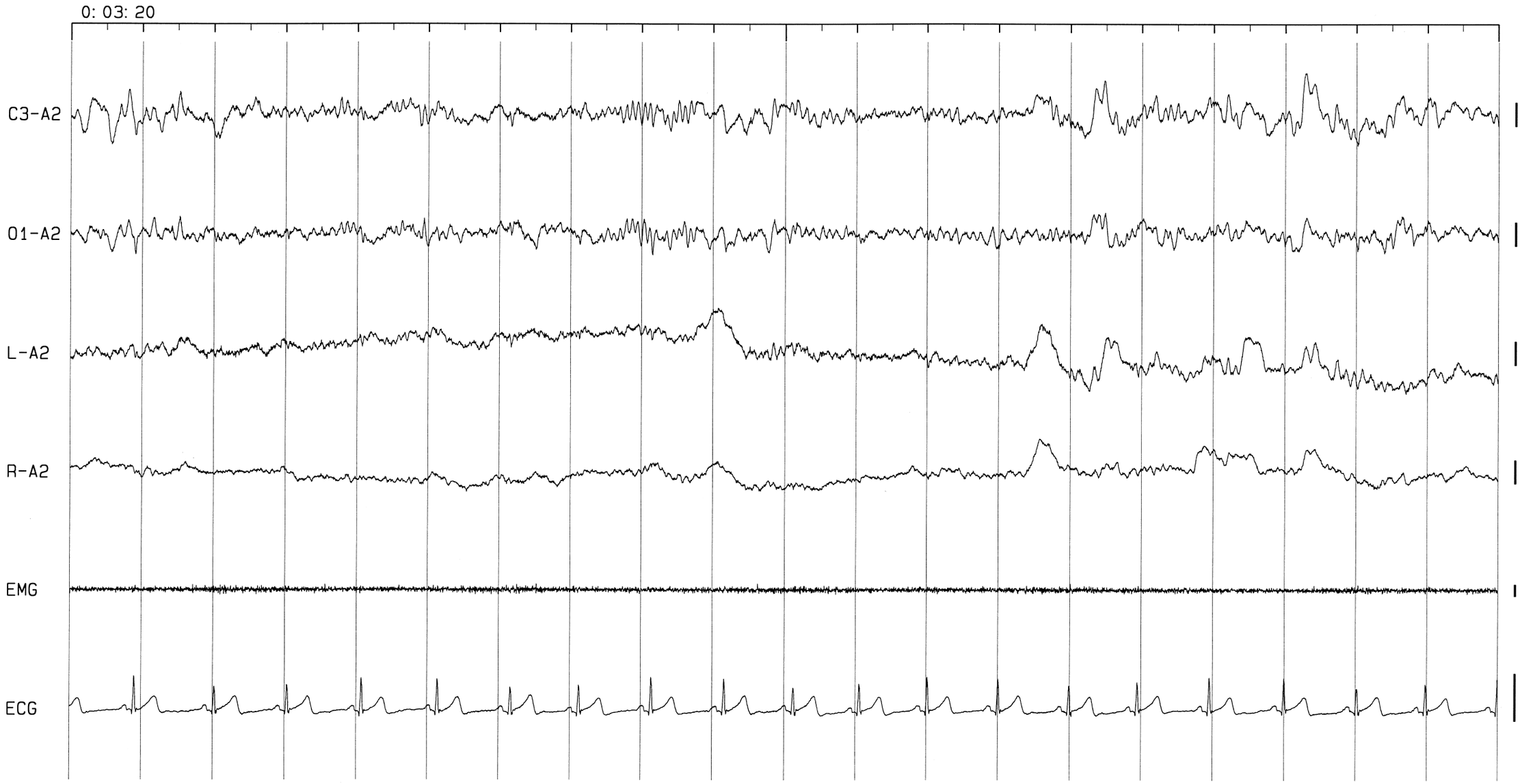


stage 3: High amplitude slow wave activity occupies more than 20% and less than 50% of this page.

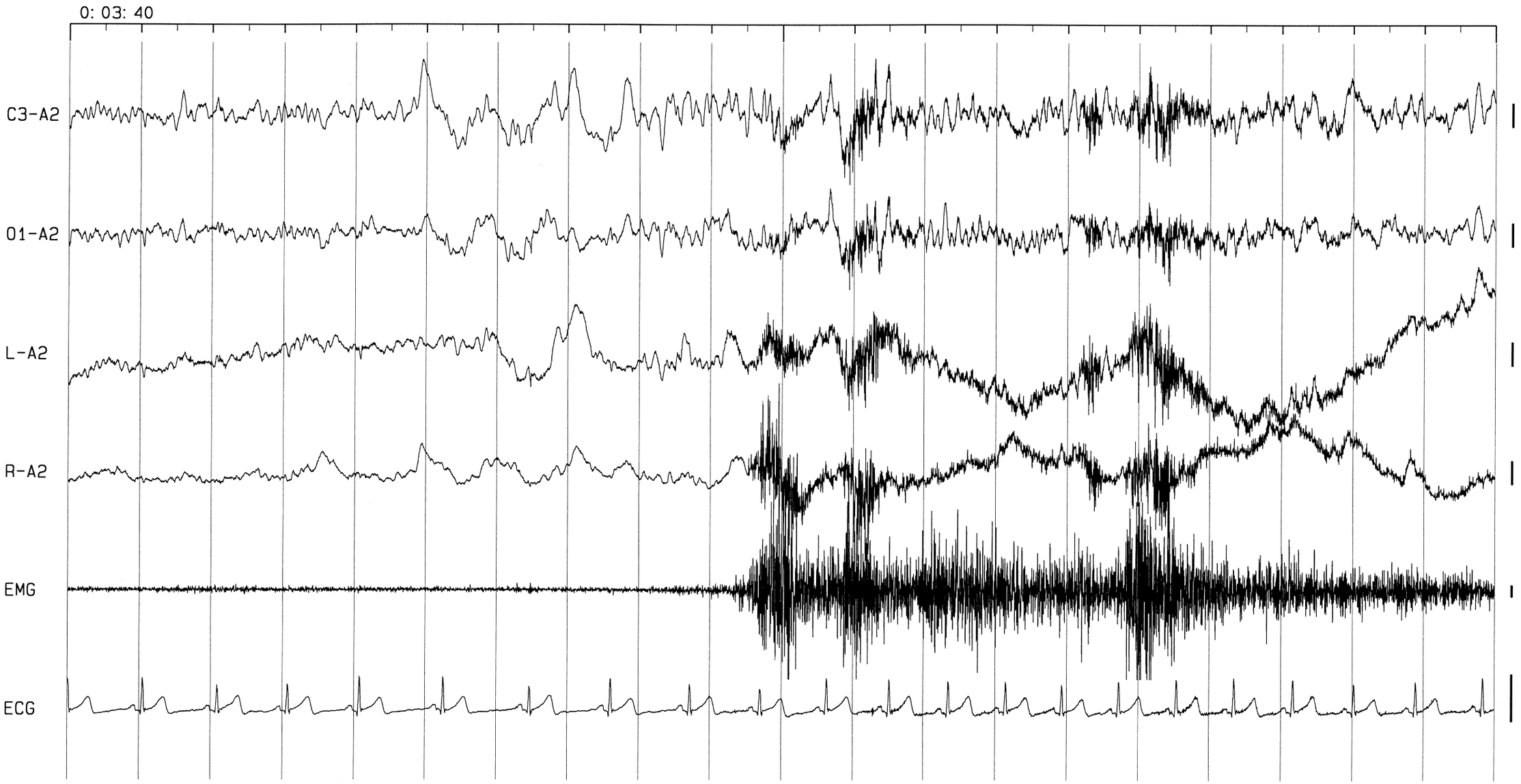
5. Stage scoring in transitional periods:

Stage scoring of the periods before the consistent appearance of sleep spindles.

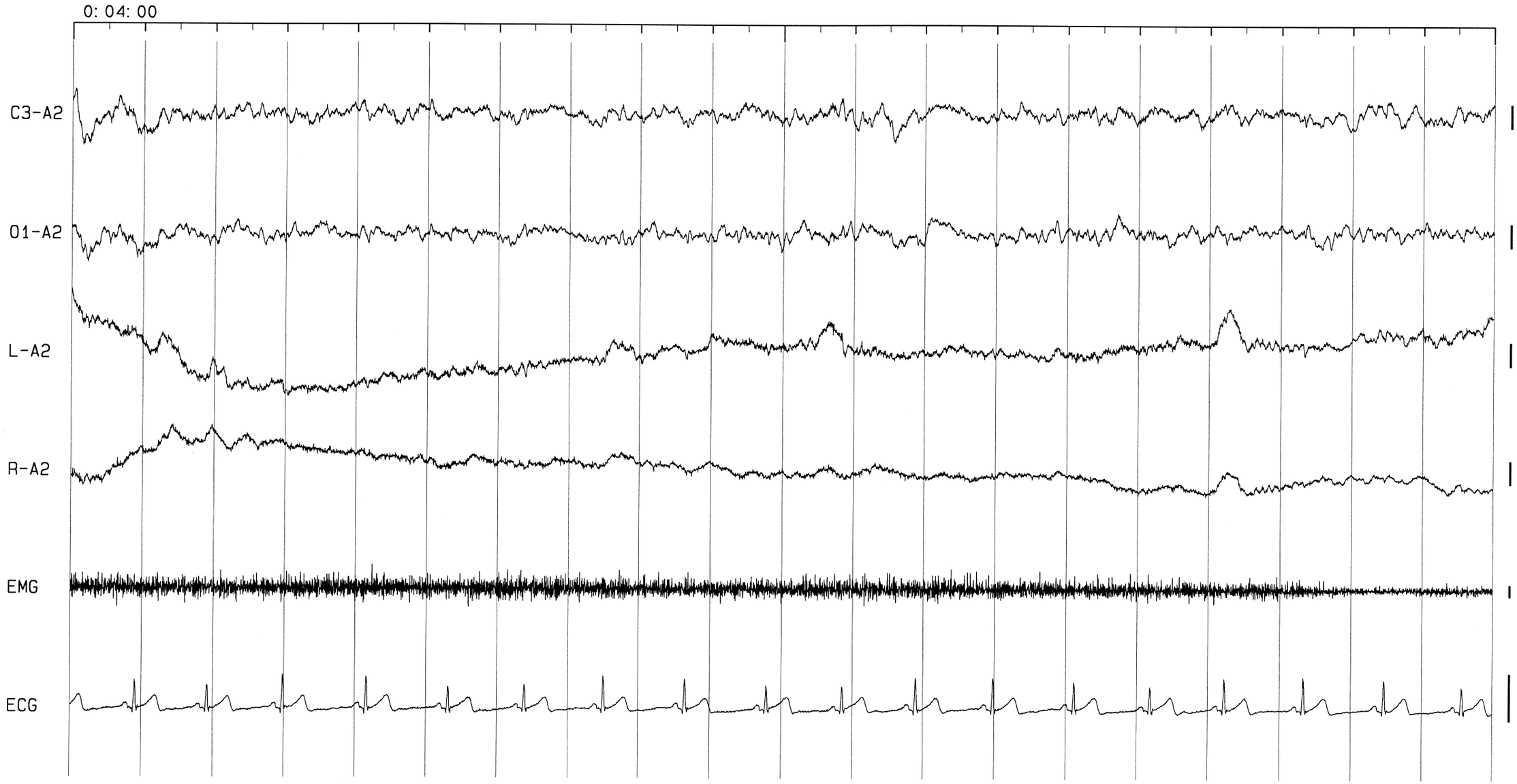
stage 2: There is a sleep spindle.



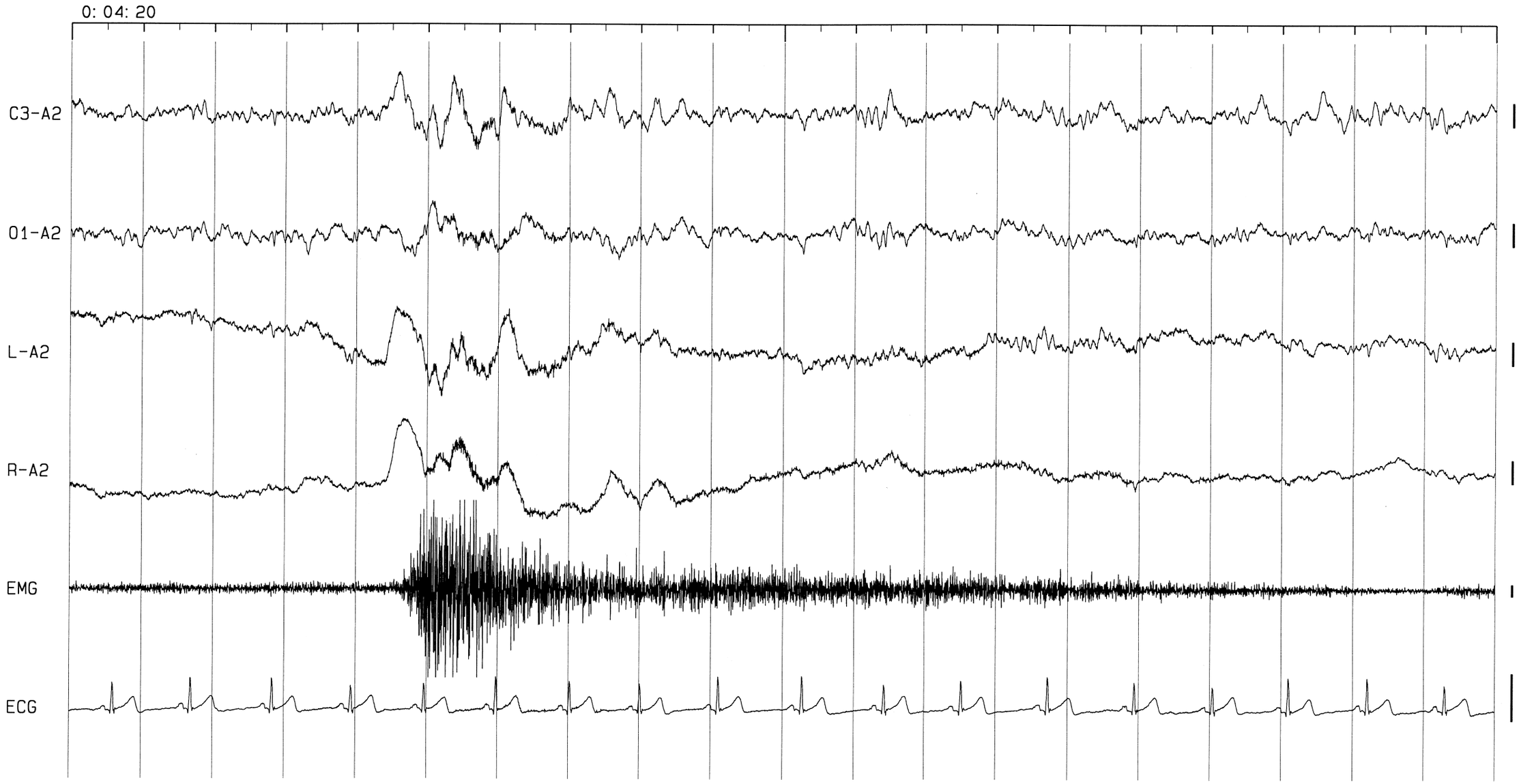
stage 2: There are sleep spindles.



stage 1: Portion after a movement arousal is scored as stage 1, which occupies more than 50% of this page.

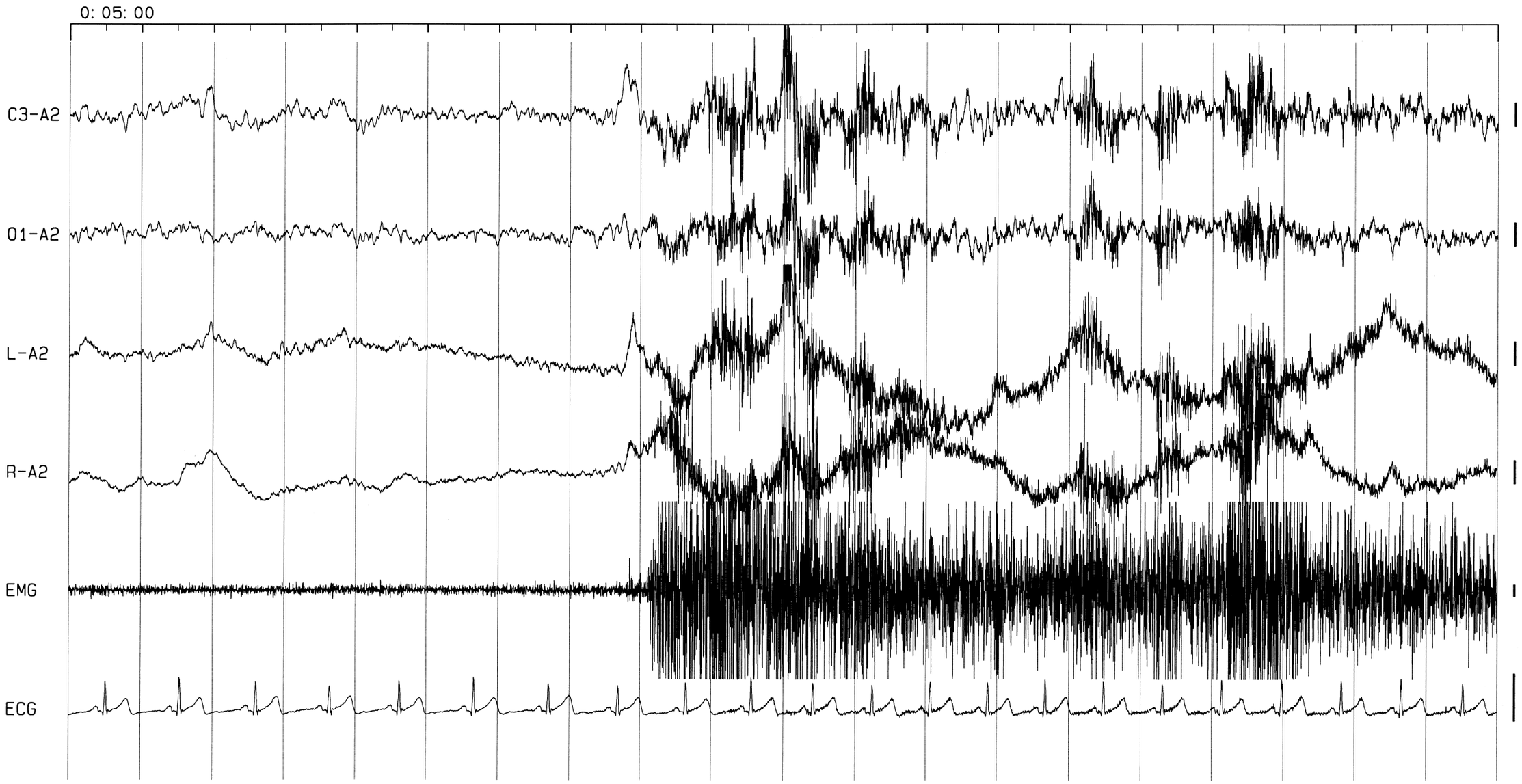


stage 1: Typical EEG pattern of stage 1 and tonic EMG increase are observed.

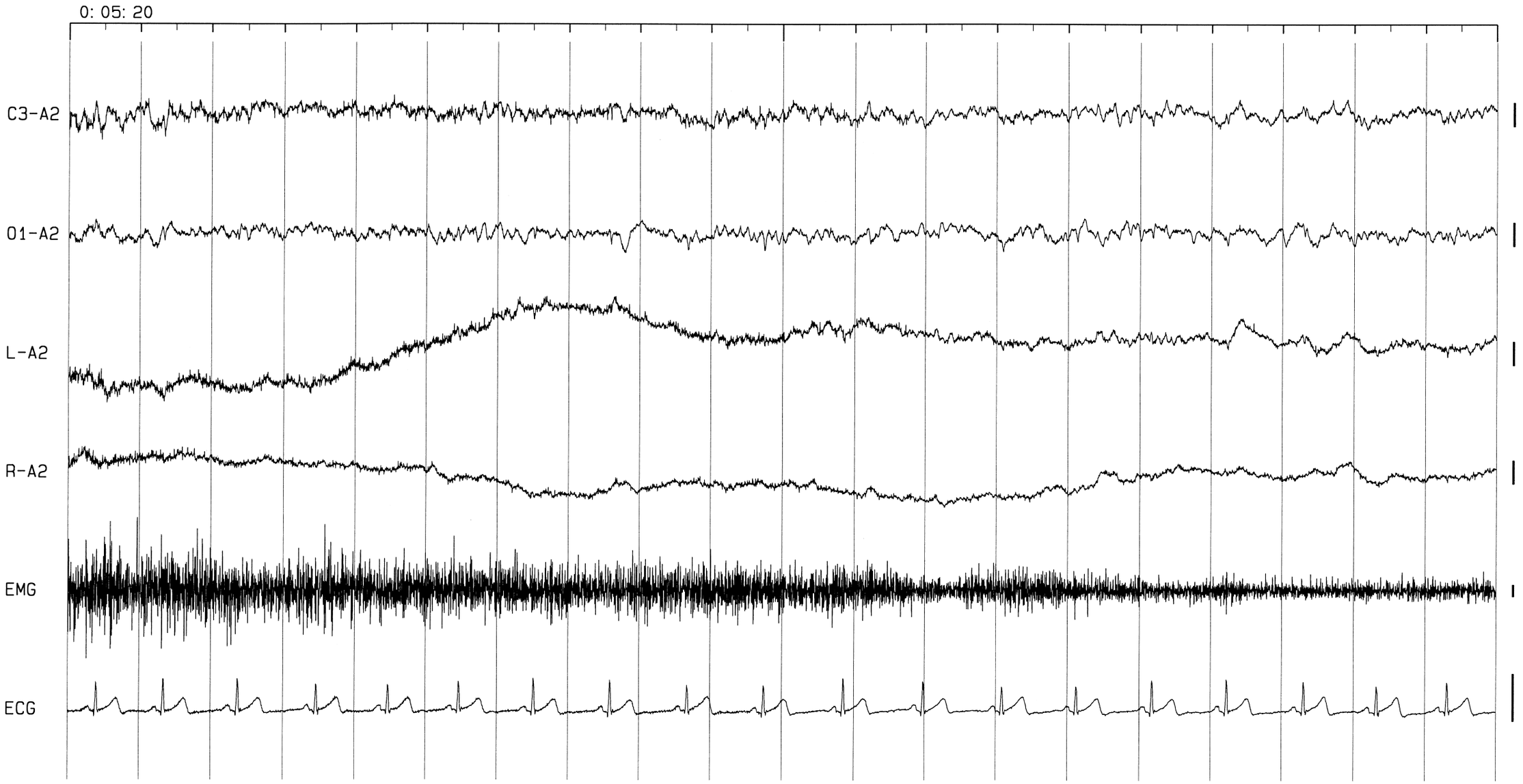


stage 1: EMG increase is observed after a movement arousal, and no sleep spindle is observed. The sleep stage on this page is determined by the result of next page.

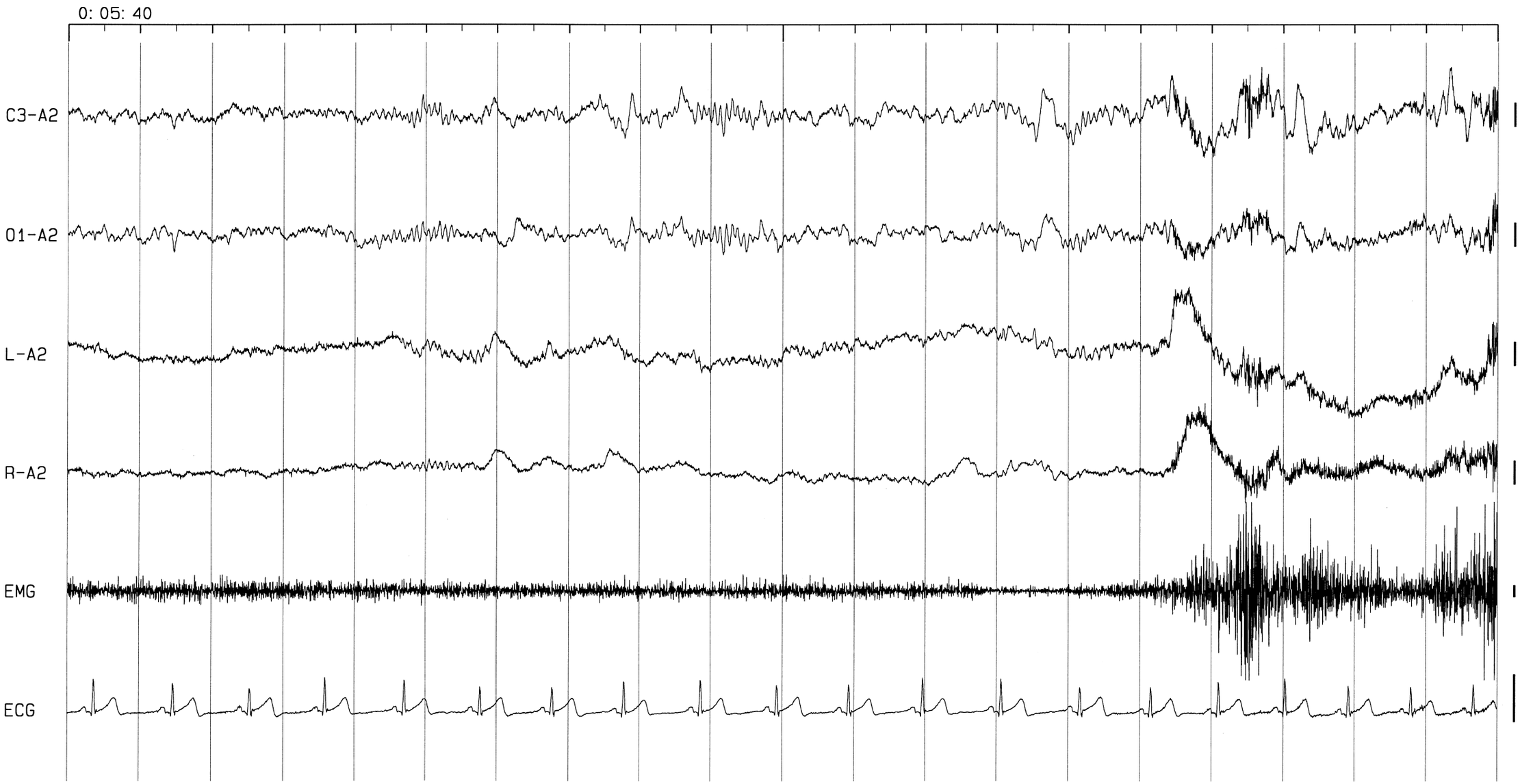
stage 1: Since a sleep spindle can be seen only at the end of this page, this page is scored as stage 1.



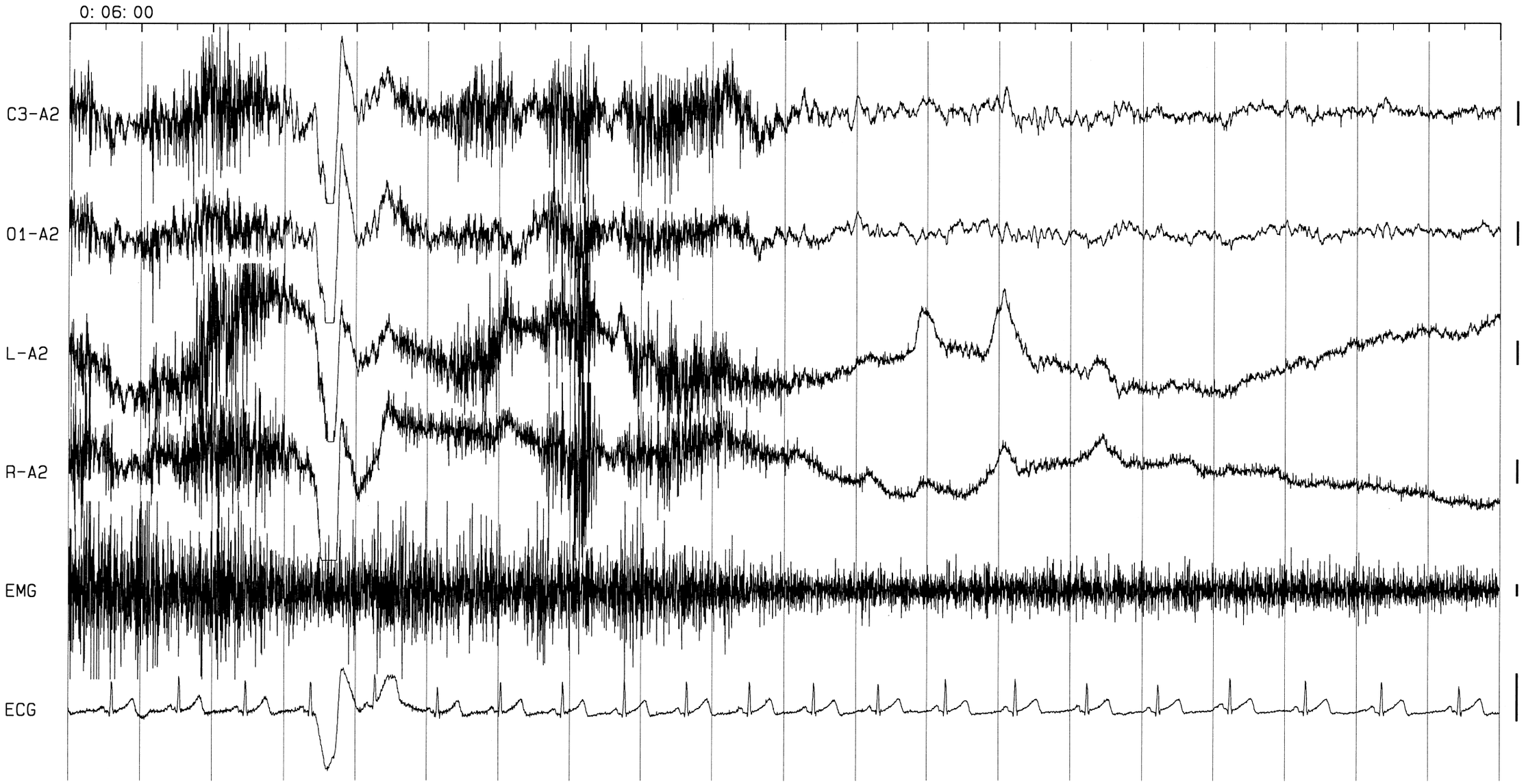
MT Prominent increase of EMG and the EMG artifacts on EEG and EOG recordings are observed in more than 50% of the data on this page. This page is scored as MT.



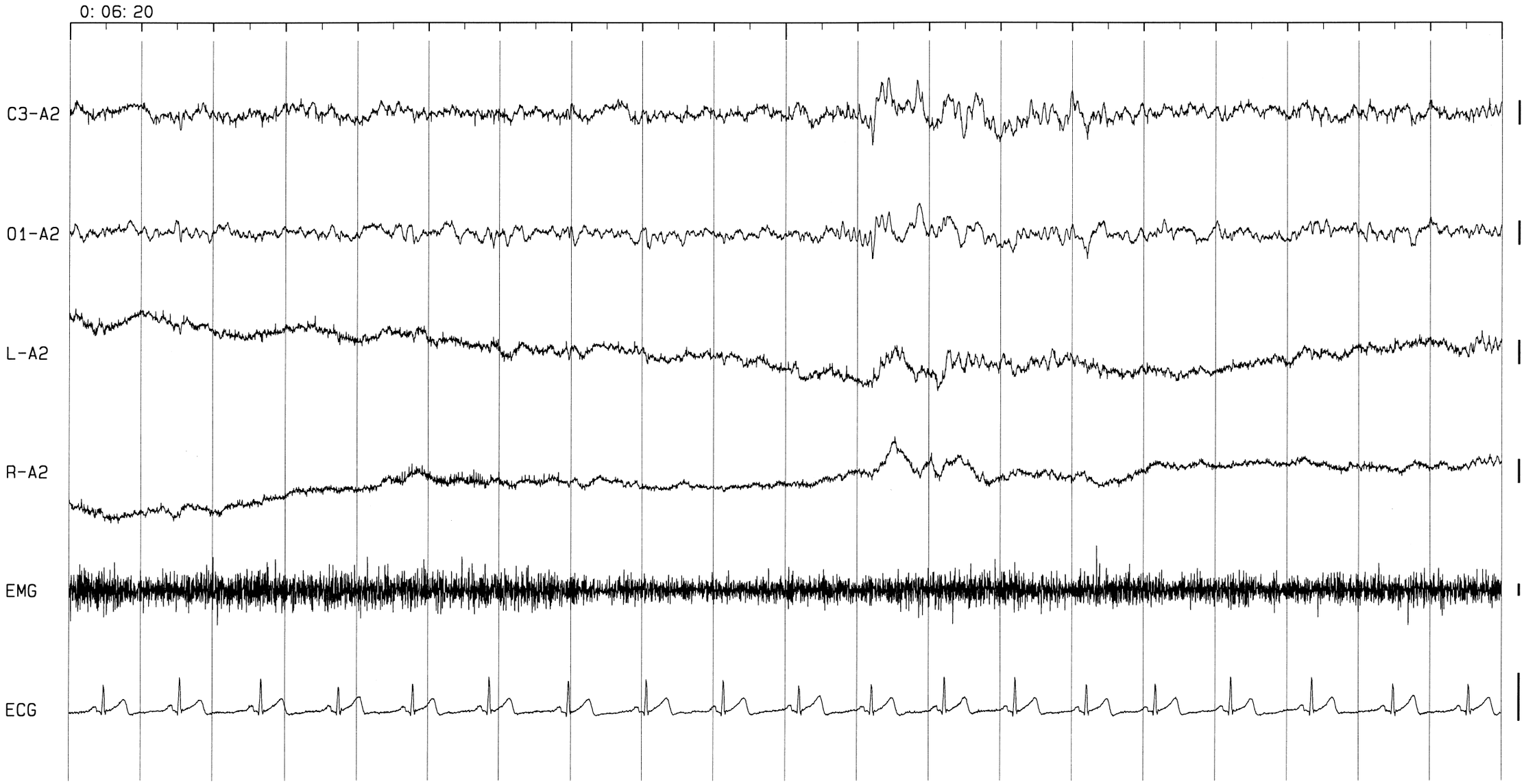
stage 1: EMG increase and the typical EEG pattern of stage 1 are observed.



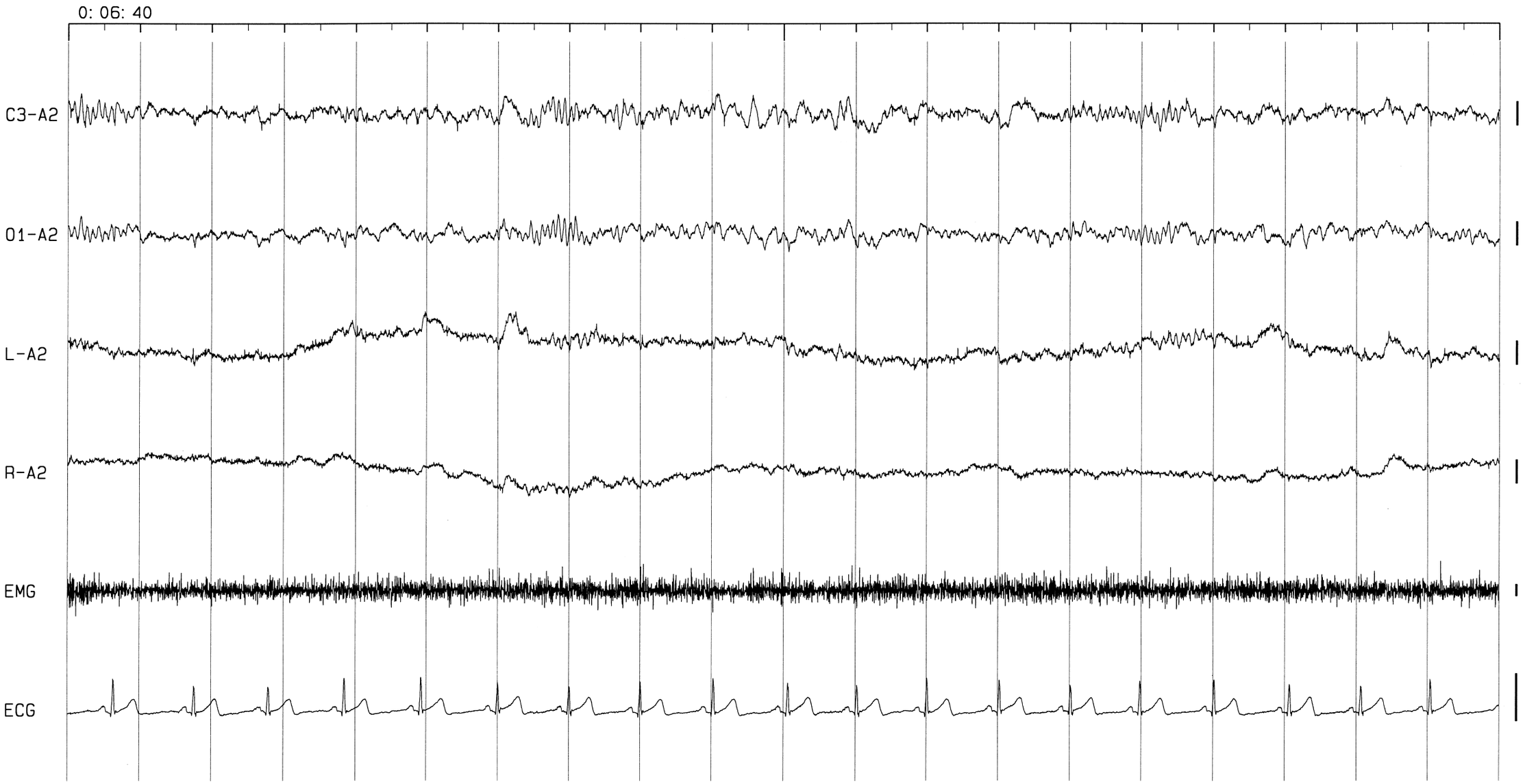
stage 2: Three sleep spindles are observed. While a movement arousal appears in the last half of this page, it occupies less than 50%.



stage 1: The sleep state changes from stage 2 to stage 1 with a movement arousal. The portion scored as stage 1 is more than 50%.

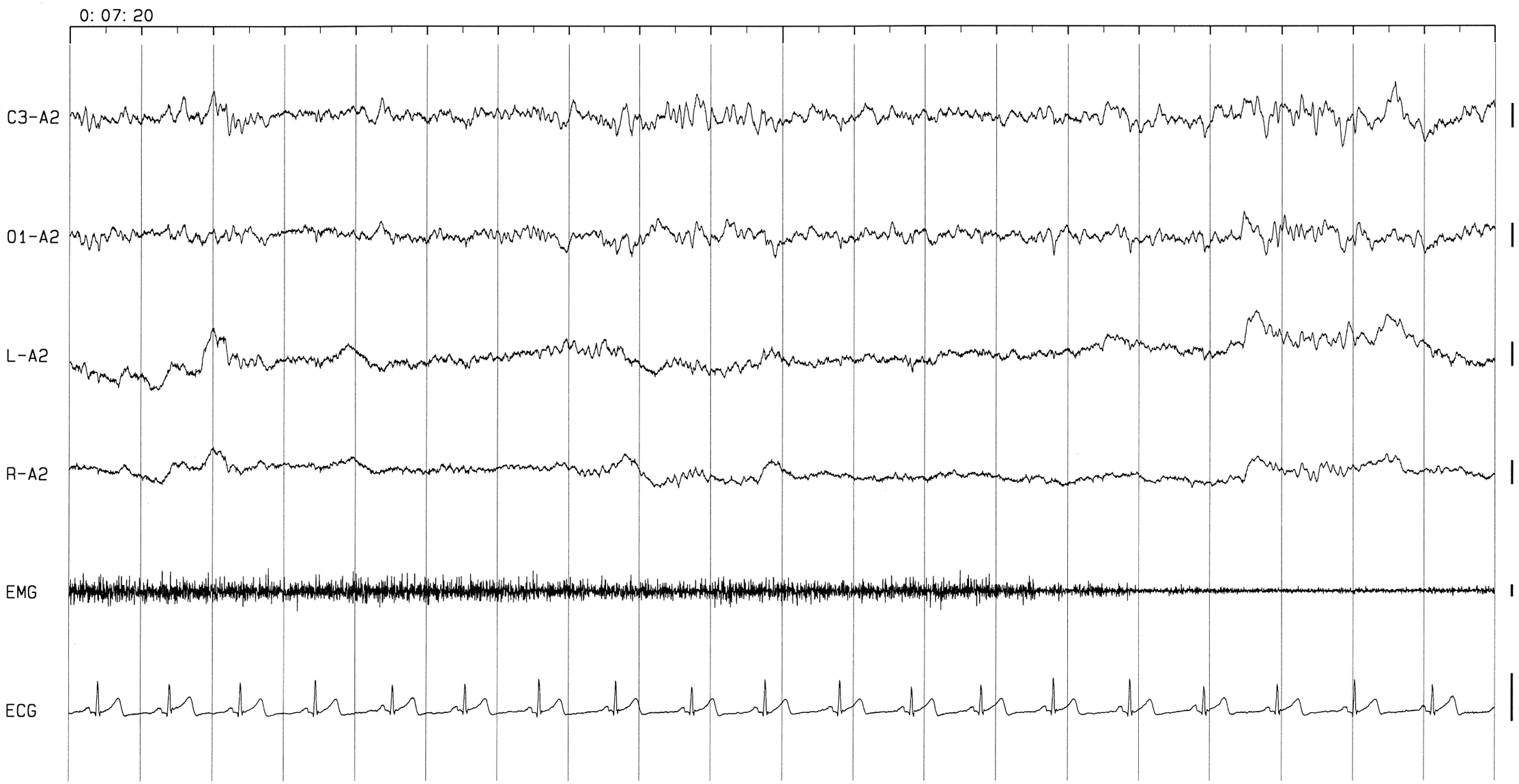


stage 1: EMG increase and the typical stage 1 EEG are observed.

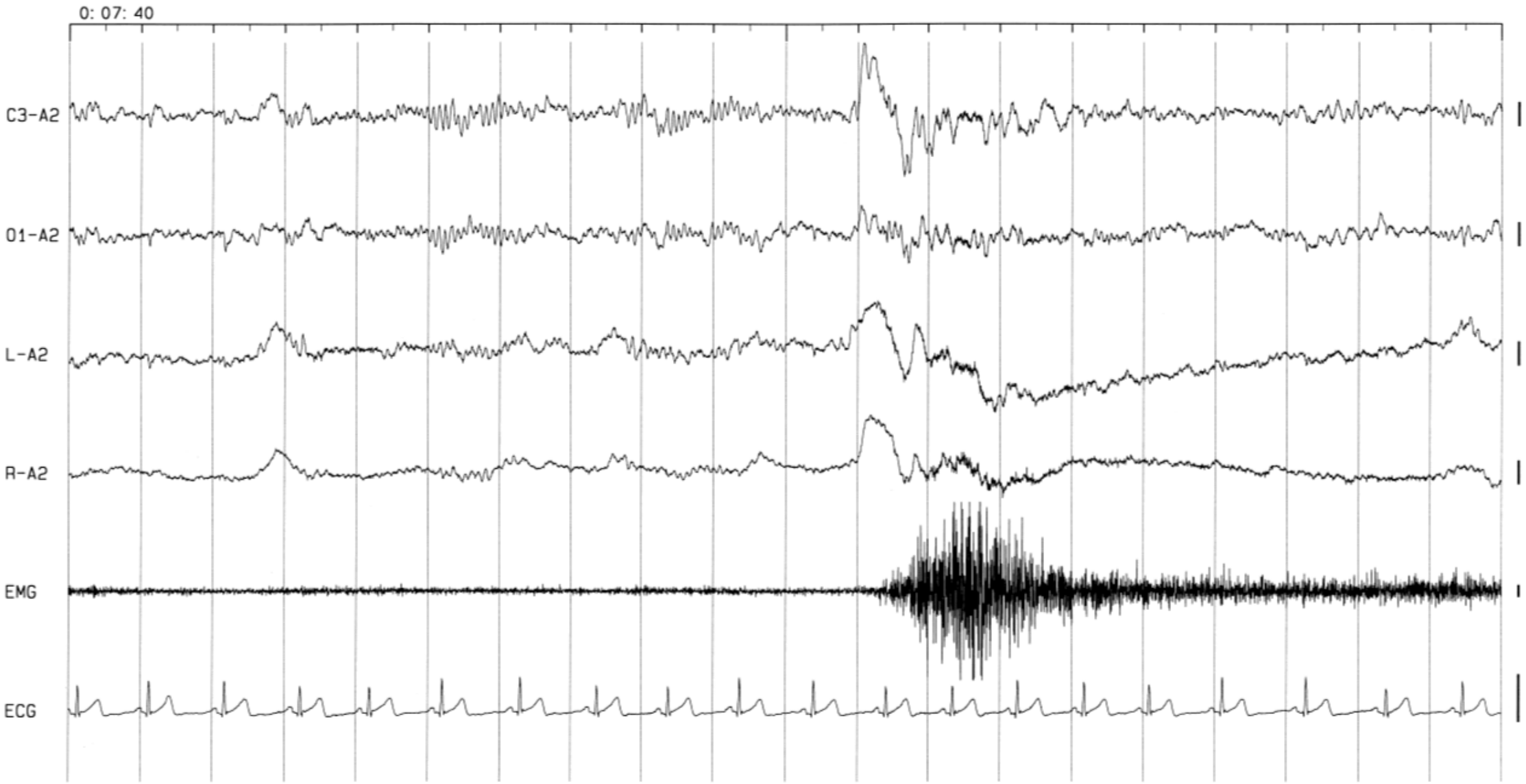


stage 2: Sleep spindles are recognized.

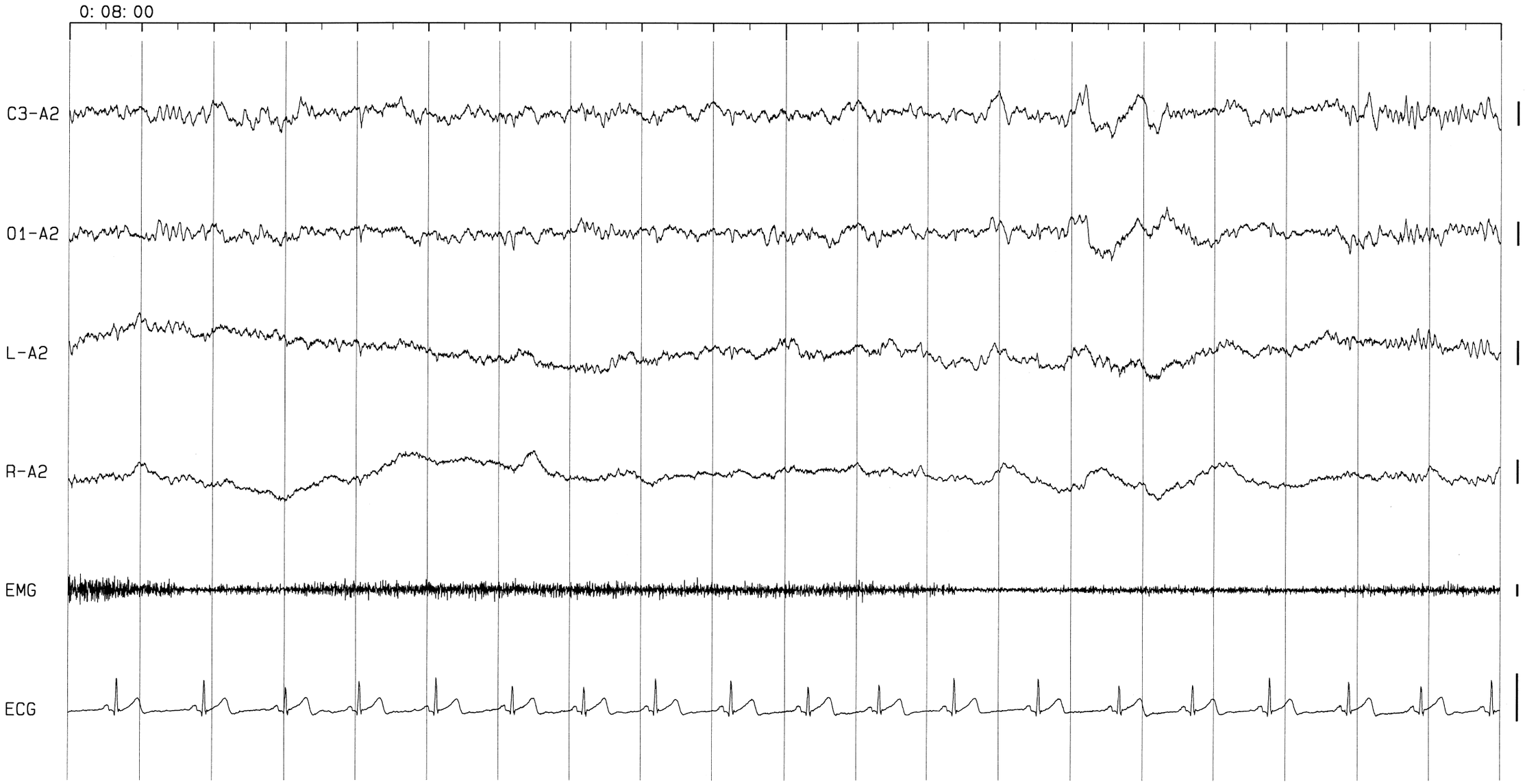
stage 2: Sleep spindles are recognized.



stage 2: While no sleep spindle is observed on this page, there is no movement arousal. This page is scored as stage 2, based on sleep spindles in the first half of the next page.



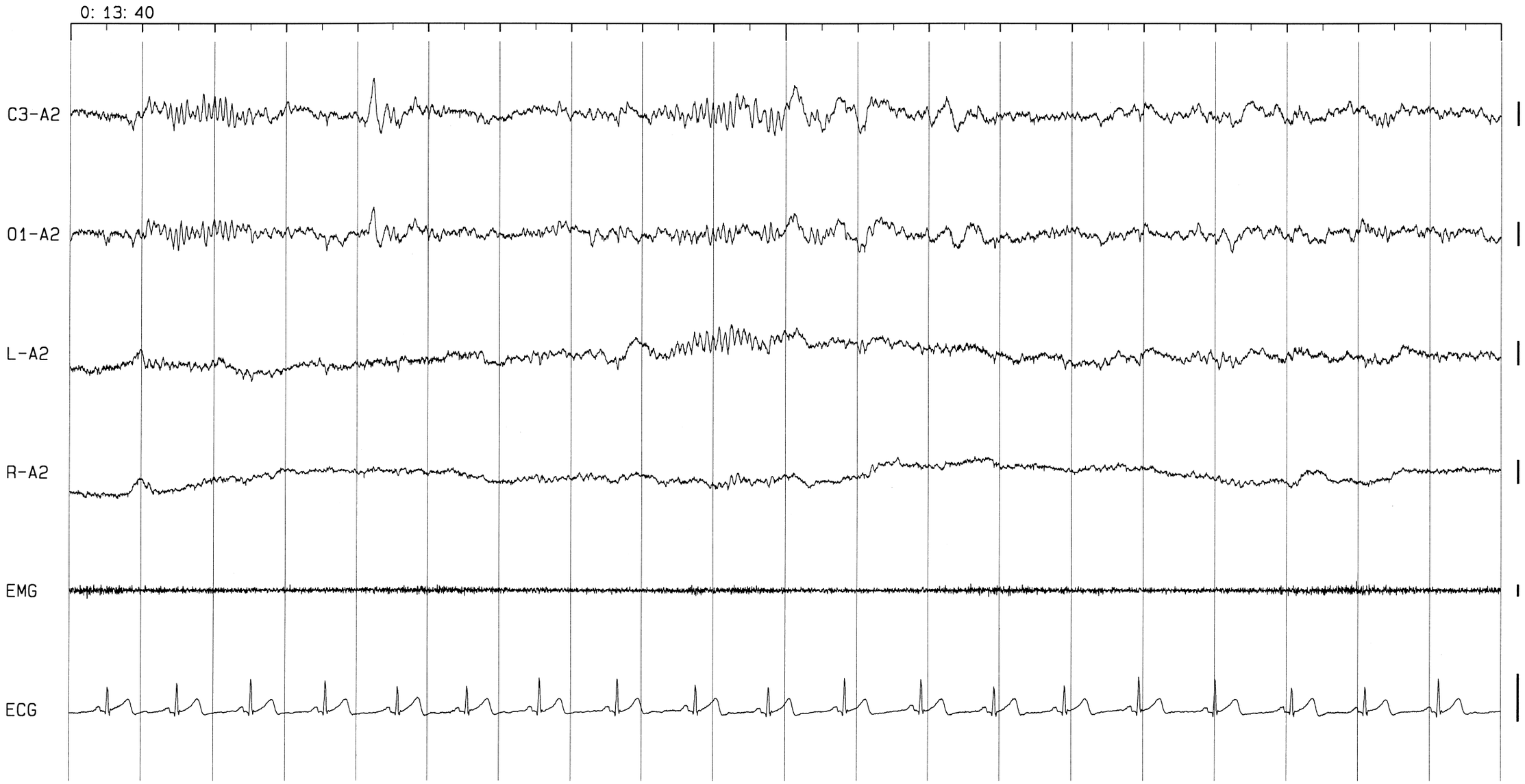
stage 2: Sleep spindles are observed in the first half. In the last half, a movement arousal is recognized, however, the portion after the movement arousal is less than 50% of this page.



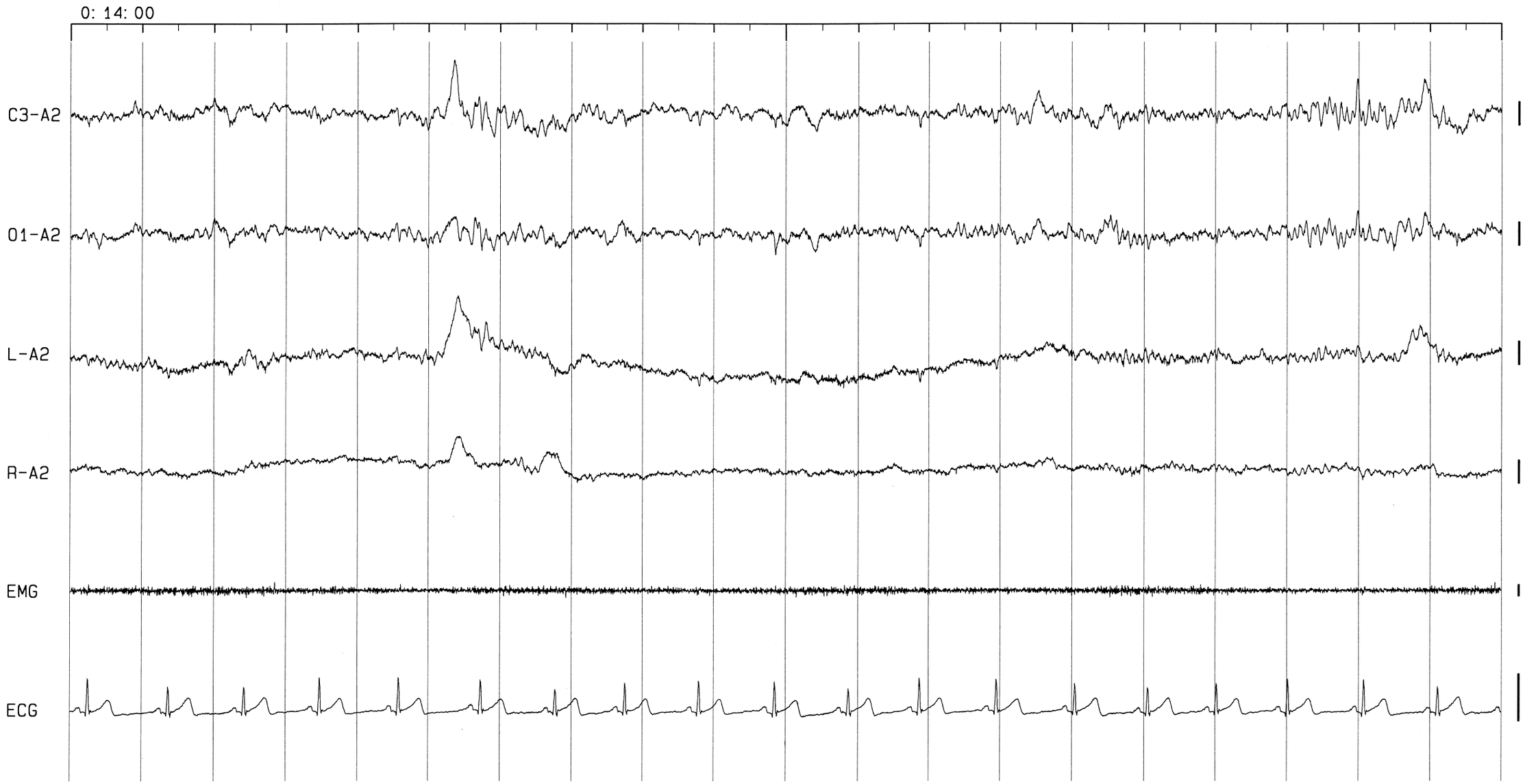
stage 1: A sleep spindle is recognized at the end of this page, however, sleep state changes from stage 2 to stage 1 with a movement arousal in the first half of the page. The portion scored as stage 1 is more than 50% of this page.

6. Judgment of movement arousals (MA) and stage scoring:

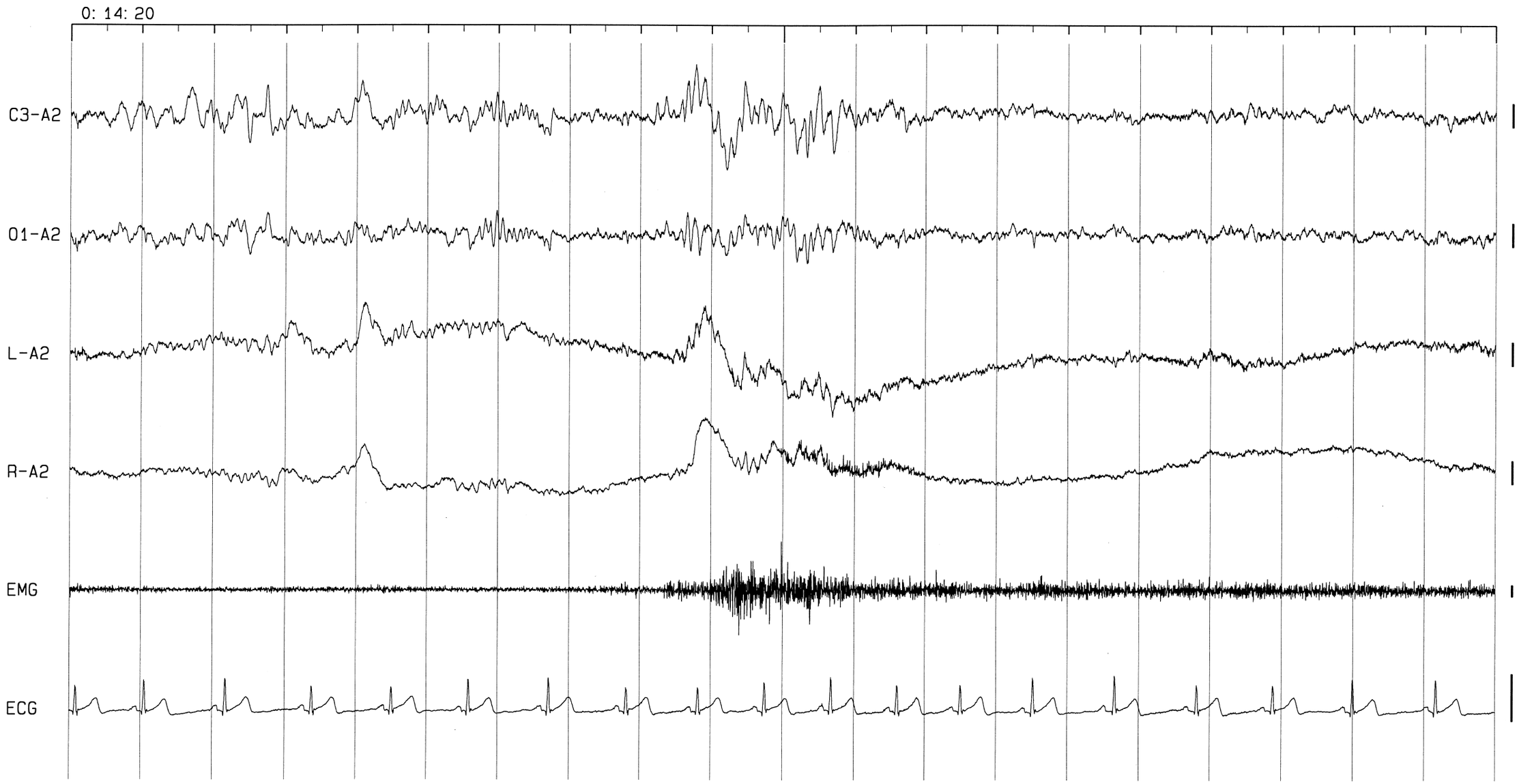
Sleep stage scoring of epochs with MA.



stage 2: Sleep spindles are observed in the first half of this page.

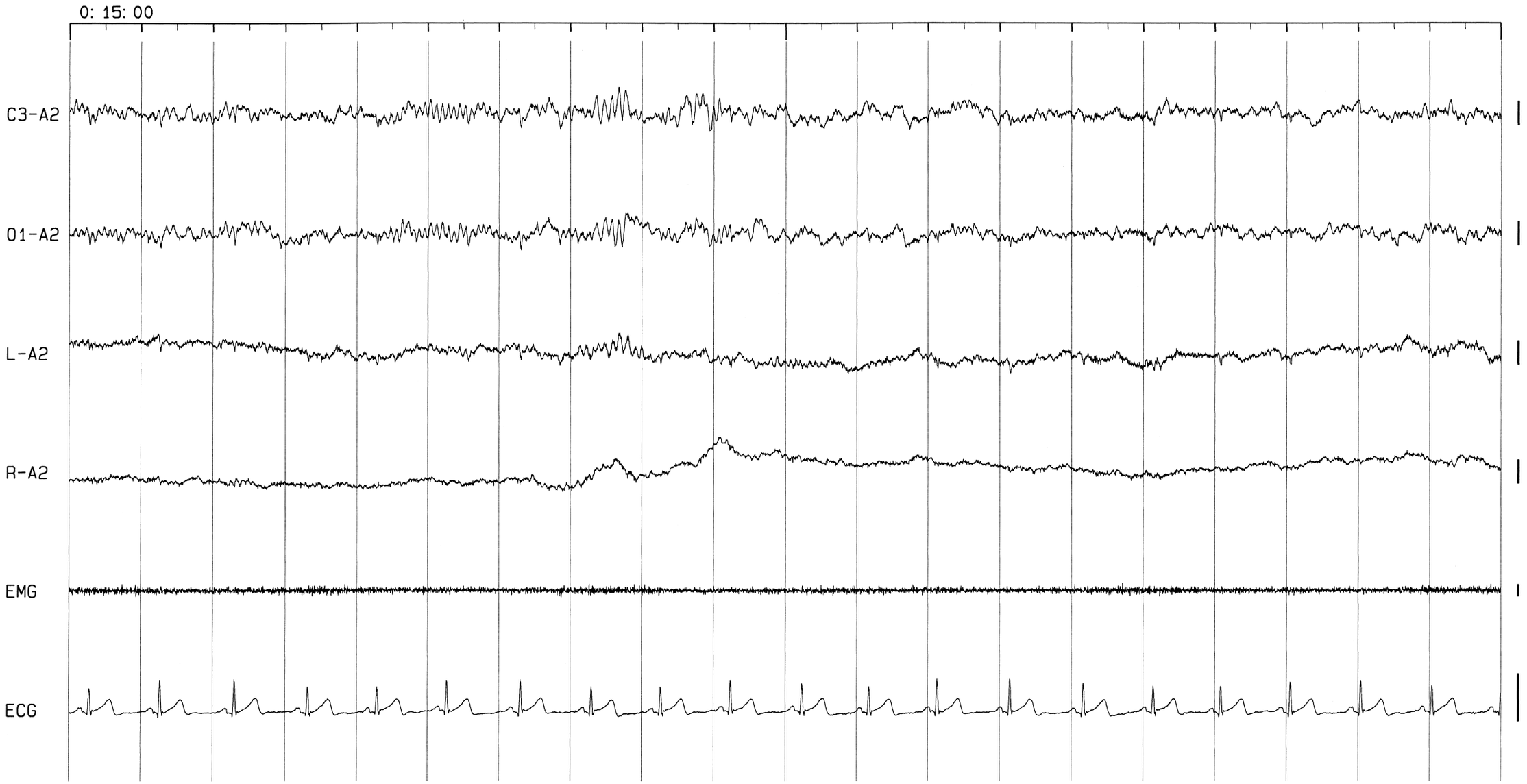


stage 2: No movement arousals are observed, and a sleep spindle is found in the last half.

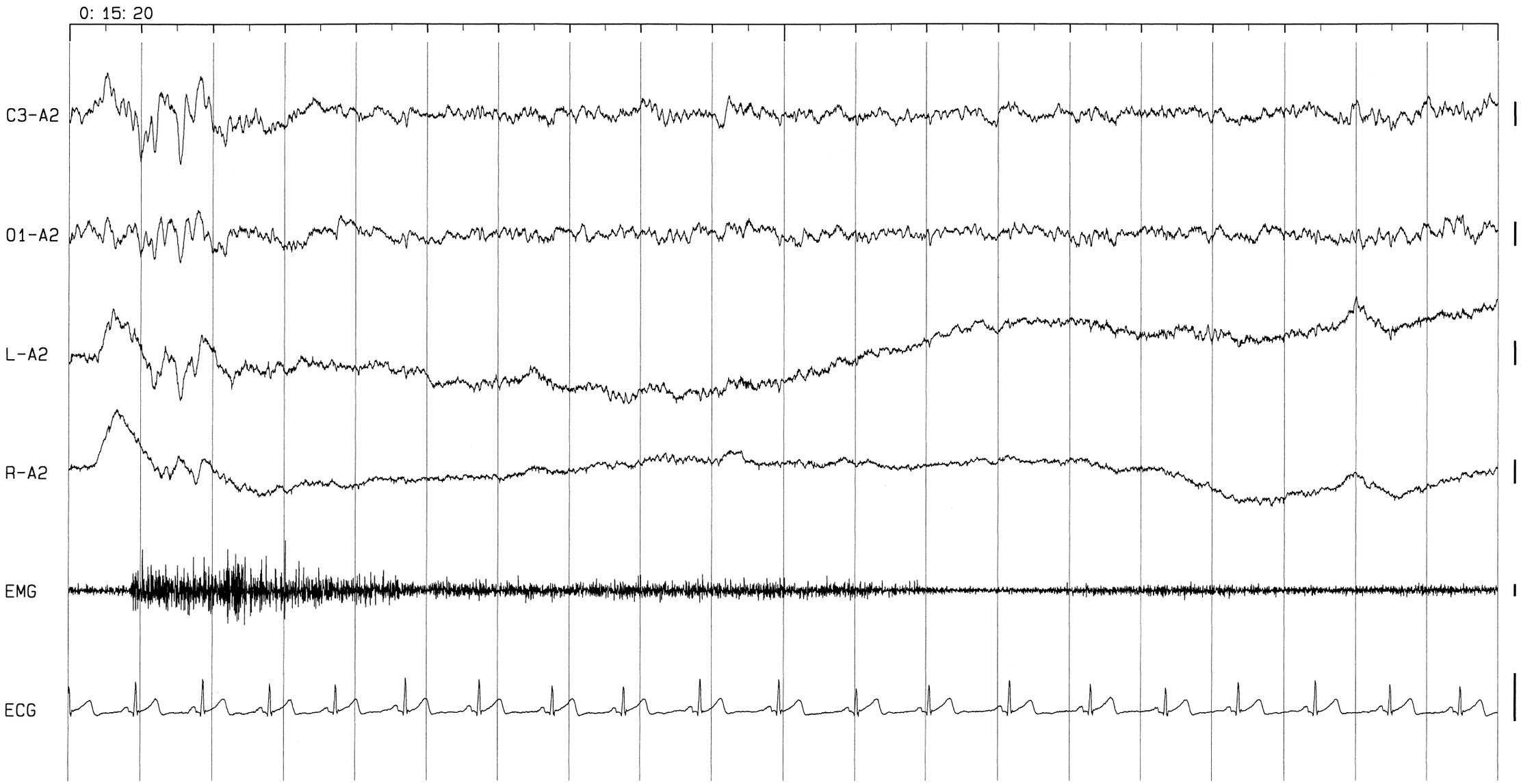


stage 1: A movement arousal with EMG increase is observed. The portion scored as stage 1 after the movement arousal is more than 50% of this page.

stage 1: Typical EEG pattern of stage 1 is observed.



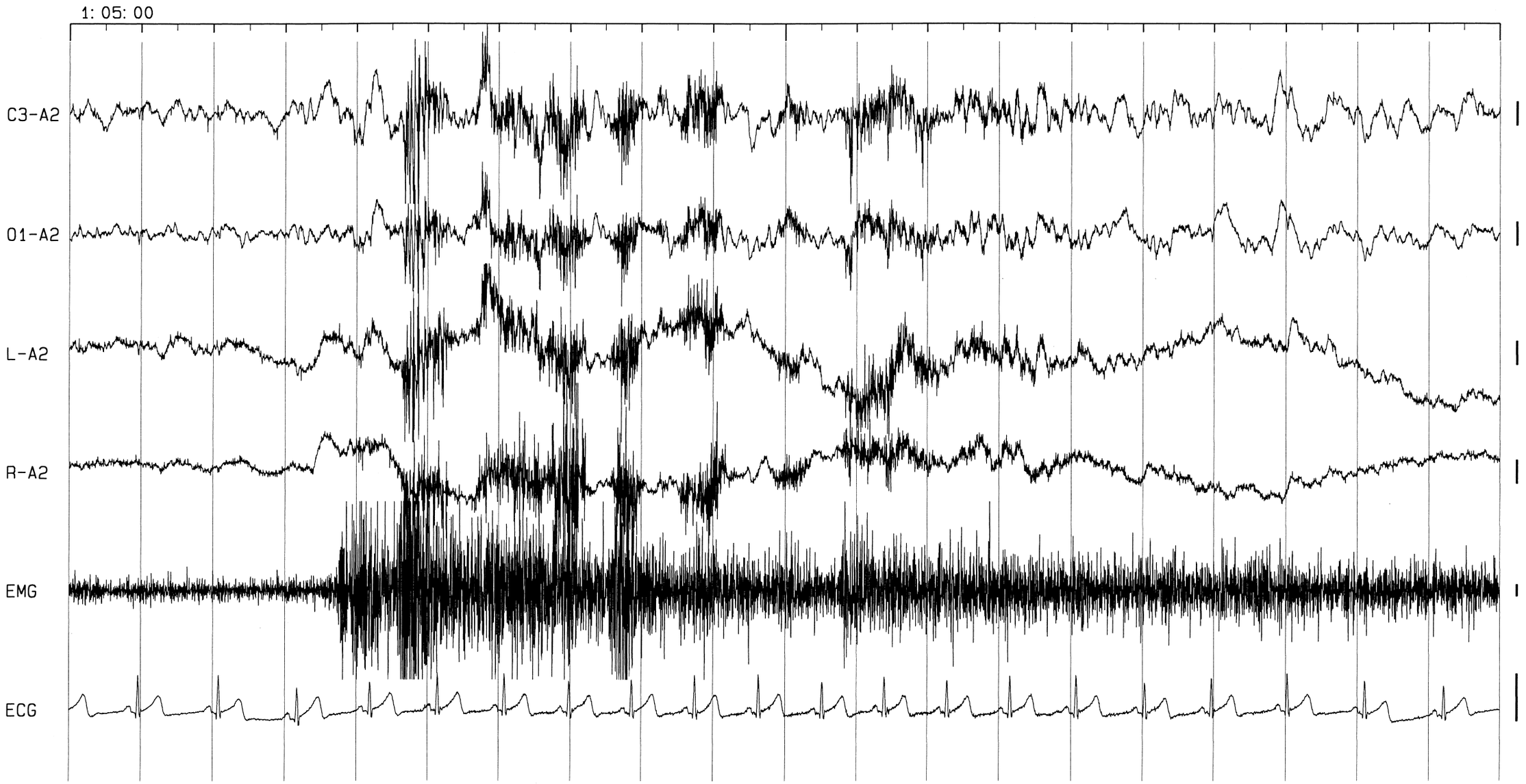
stage 2: A sleep spindle is recognized in the first half of this page.



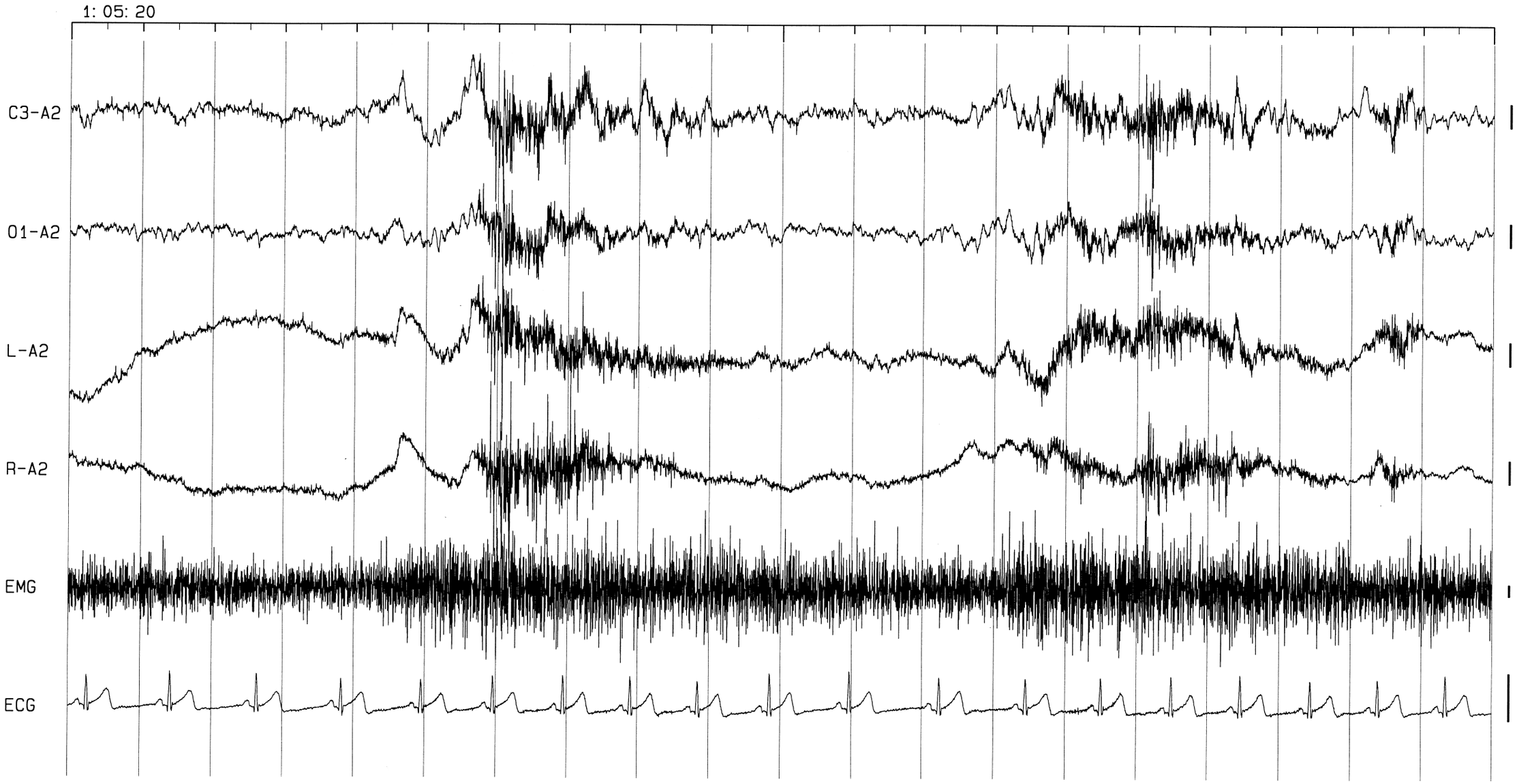
stage 1: A movement arousal with EMG increase is observed in the first half. Typical EEG pattern of stage 1 is observed.

7. Movement time (MT) and scoring of stage 1.

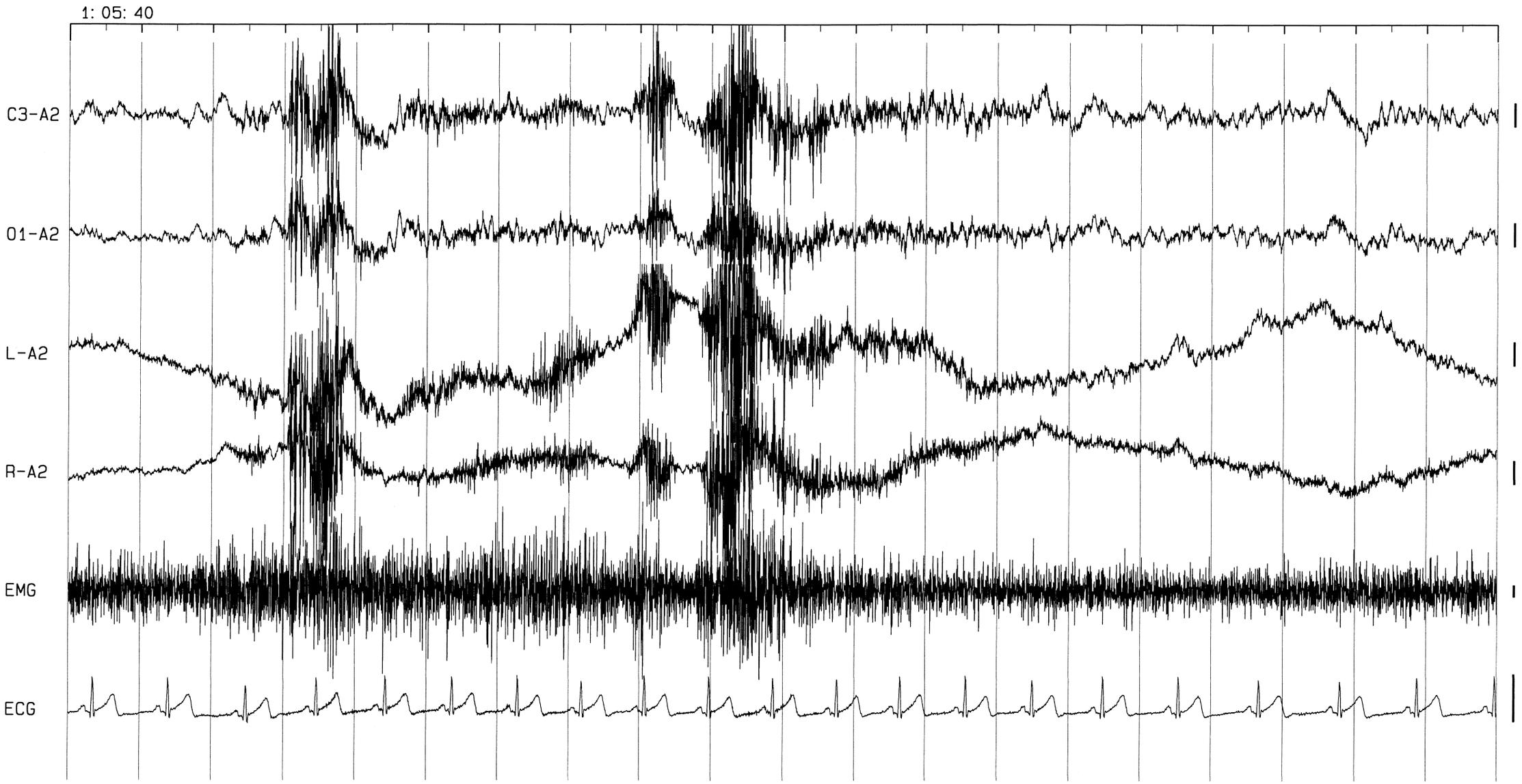
stage 2: A sleep spindle is recognized in the first half of this page.



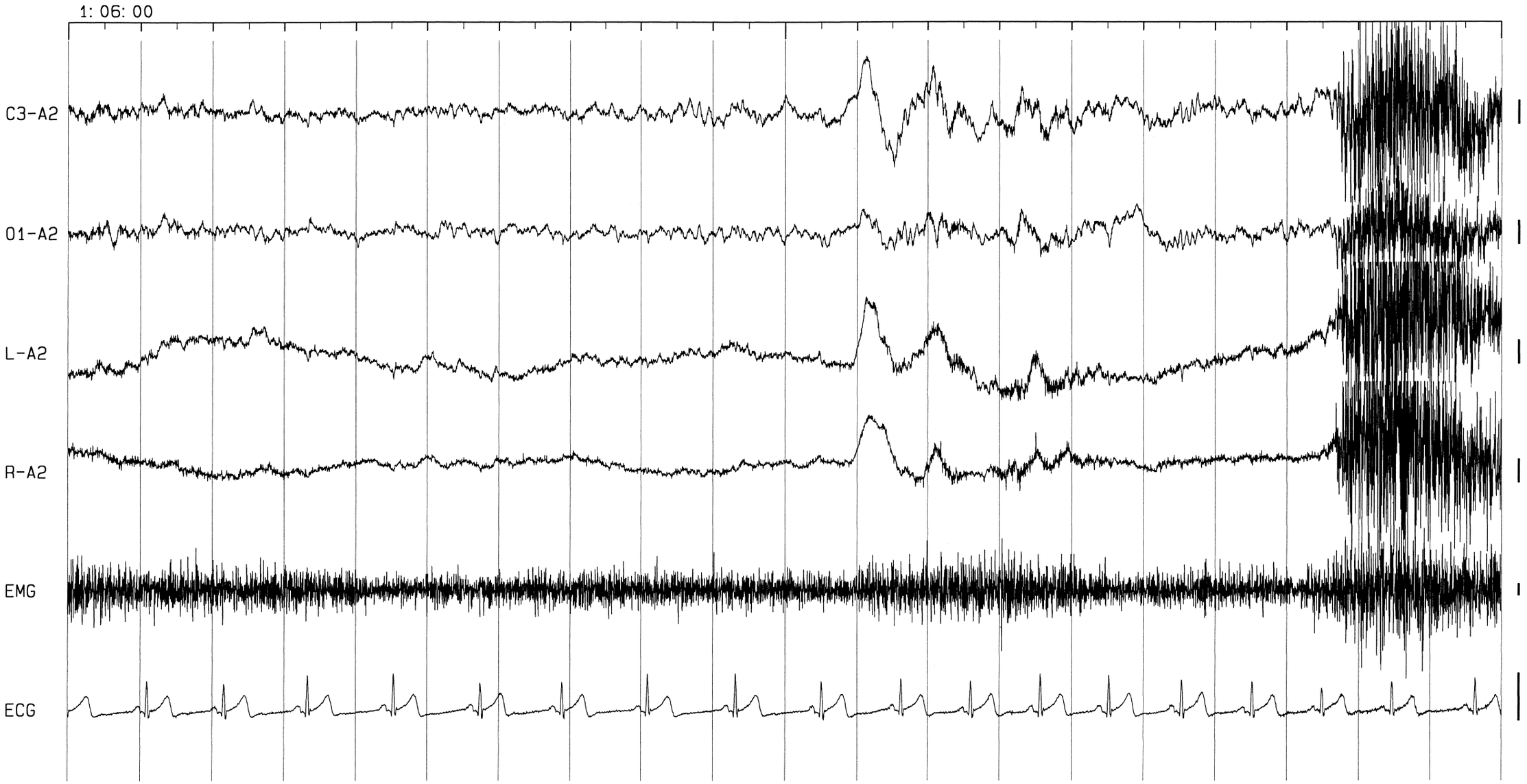
stage 1: A movement arousal is recognized in the first half. Typical EEG pattern of stage 1 is observed.



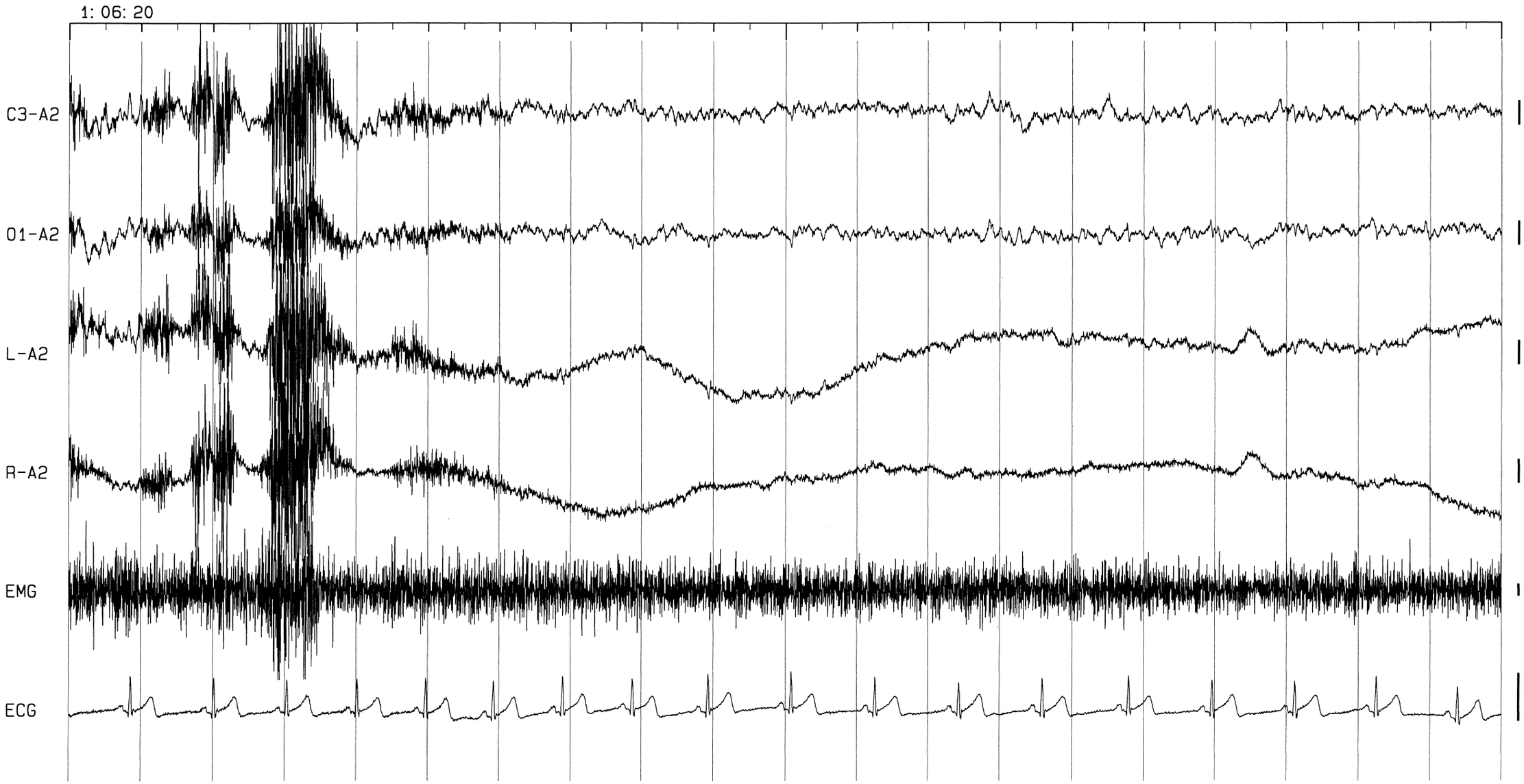
stage 1: A movement arousal is recognized in the first half. Typical EEG pattern of stage 1 is observed.



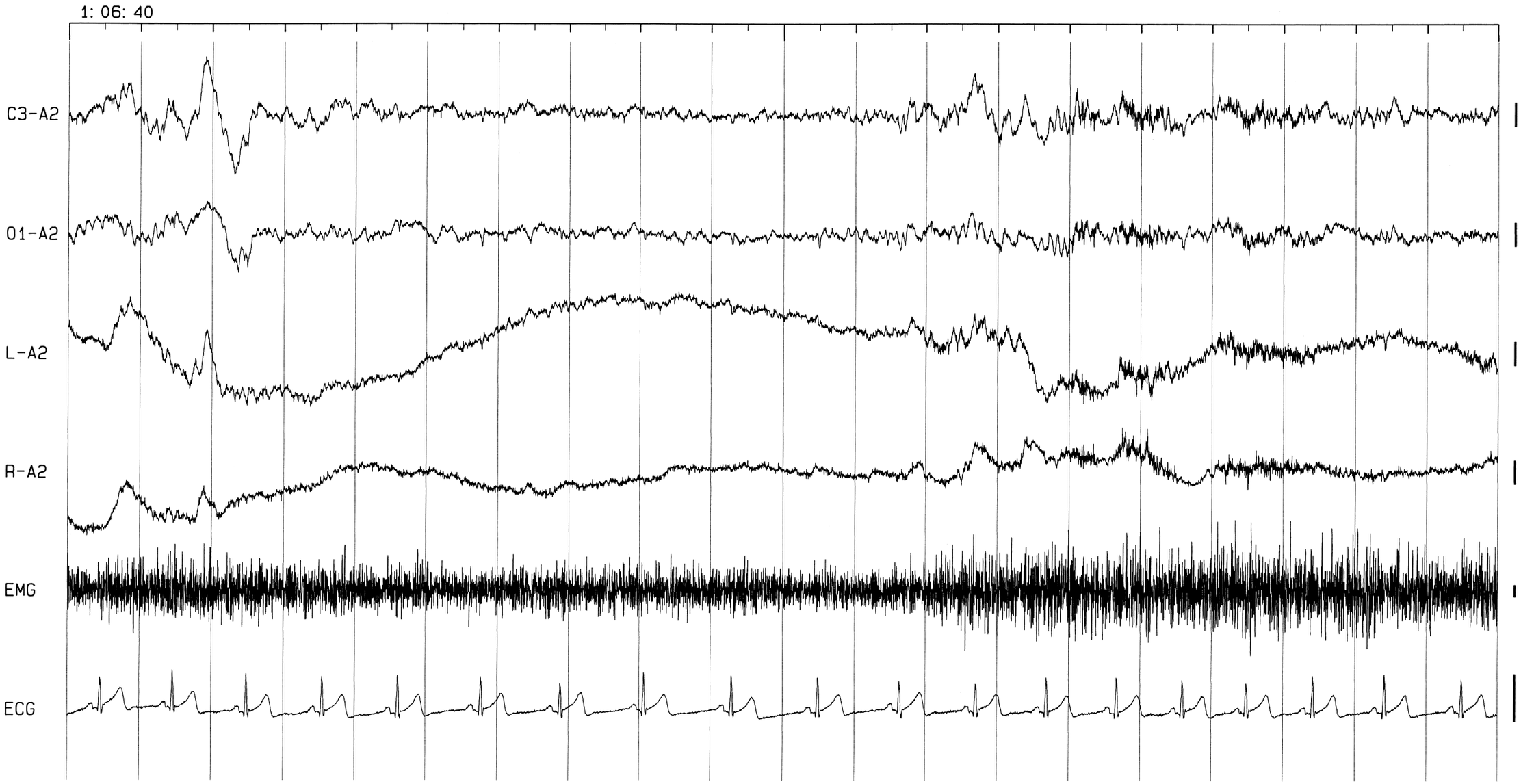
MT Prominent increase of EMG and the EMG artifacts on EEG and EOG recordings are observed in more than 50%. This page is scored as MT.



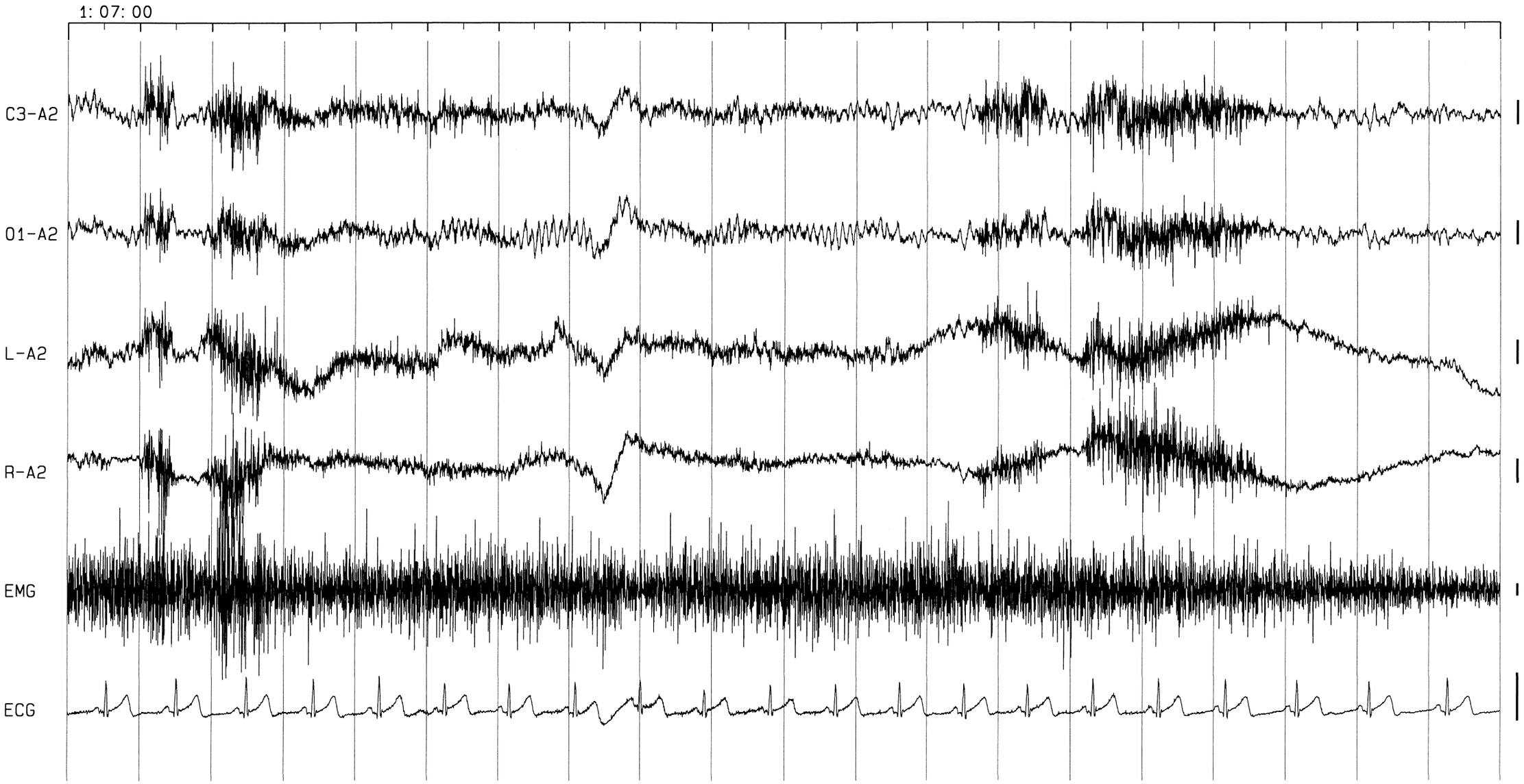
stage 1: While a movement arousal is observed in the last half, the portion with typical EEG pattern of stage 1 occupies more than 50%.



stage 1: While a movement arousal is observed in the first half, the portion with typical EEG pattern of stage 1 occupies more than 50%.



stage 2: A K-complex is observed in the beginning of this page, and a movement arousal is recognized in the last half. The portion between the K-complex and the movement arousal occupies more than 50% of this page.



MT Prominent increase of EMG and the EMG artifacts on EEG and EOG recordings are observed in more than 50%. This page is scored as MT.

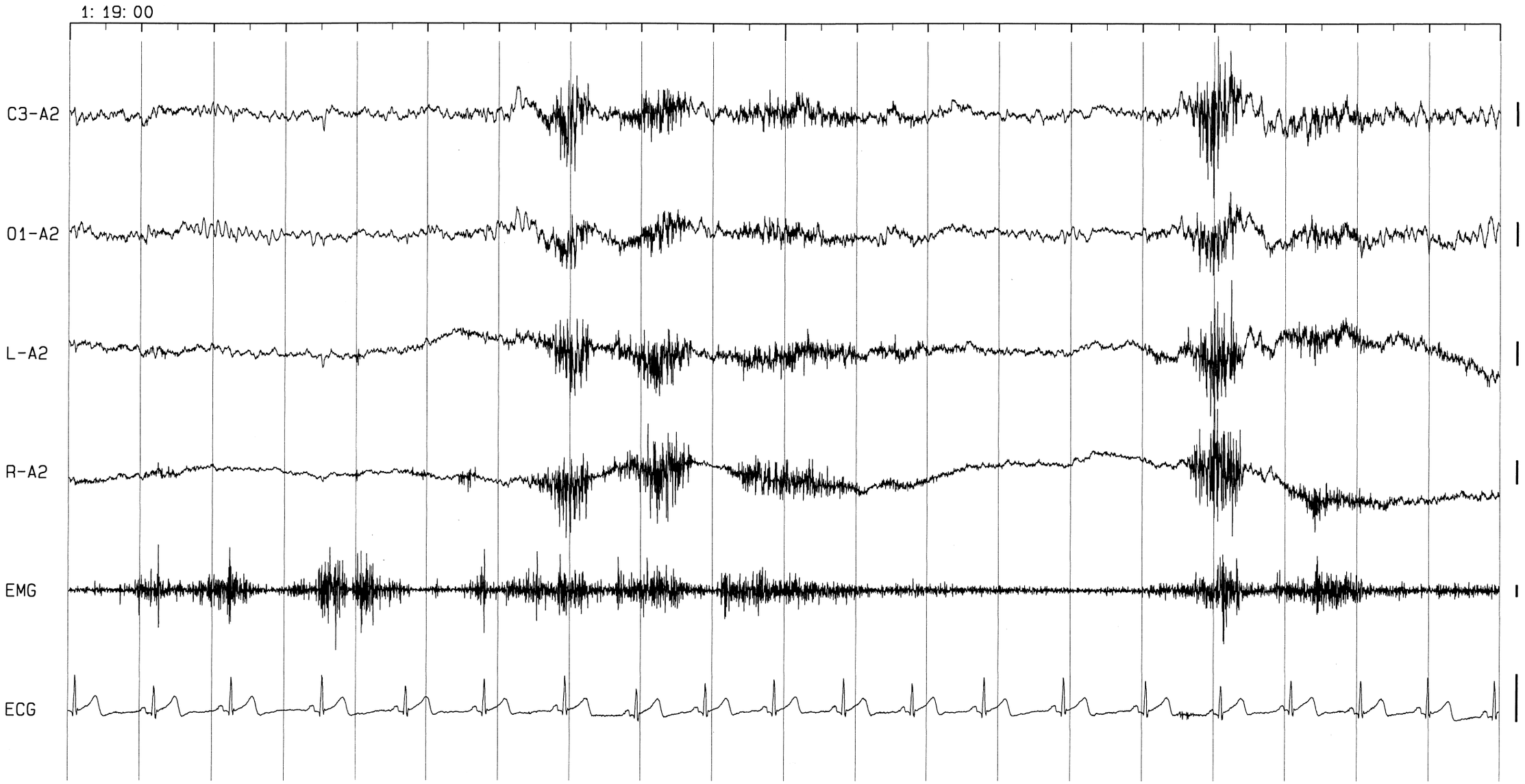
8. Scoring of REM sleep (stage REM):

Superimposition of Alpha Waves, Variation of EMG Level, Appearance of REMs, and Appearance of Twitch.

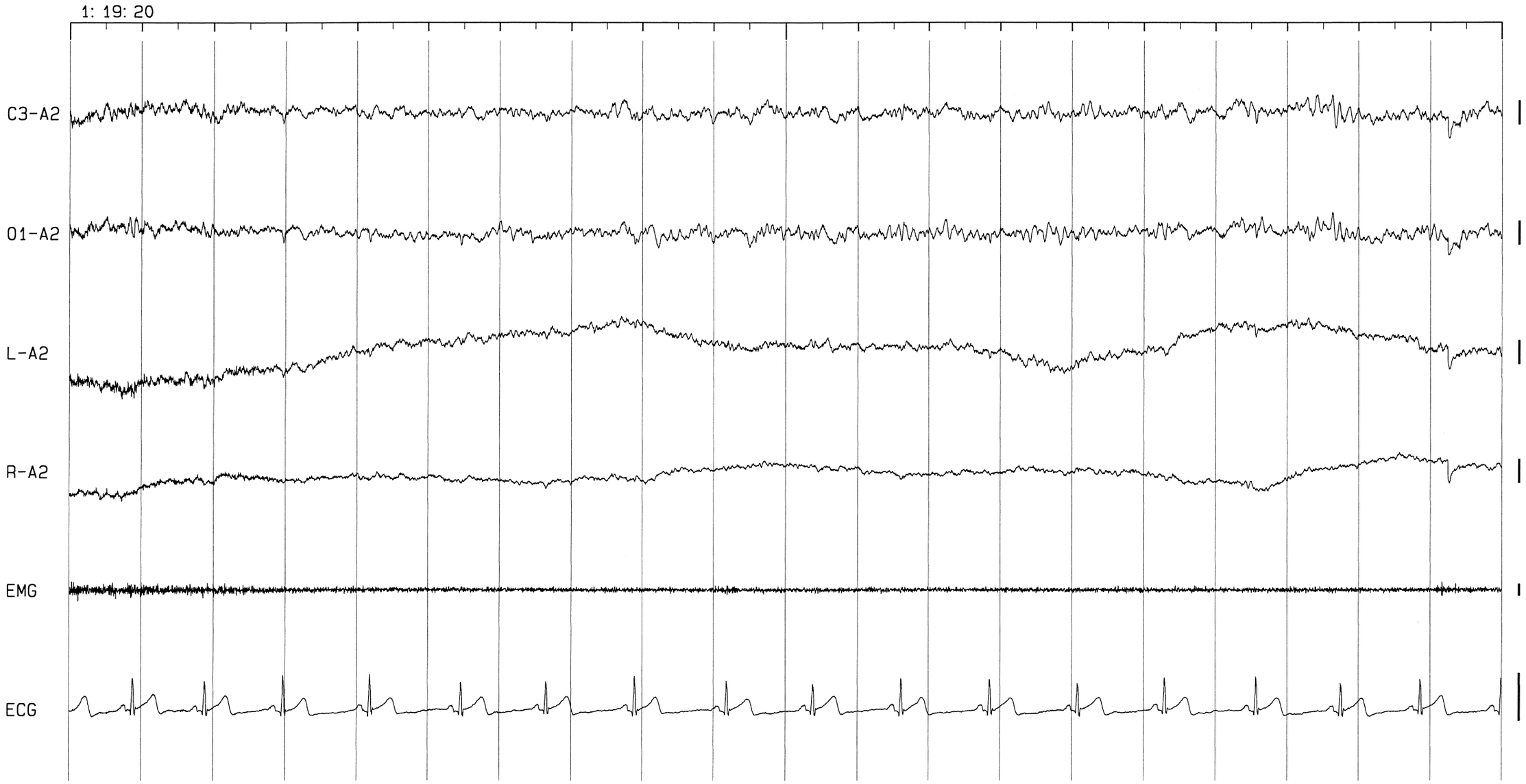
Onset of Stage REM

Continuation of Stage REM

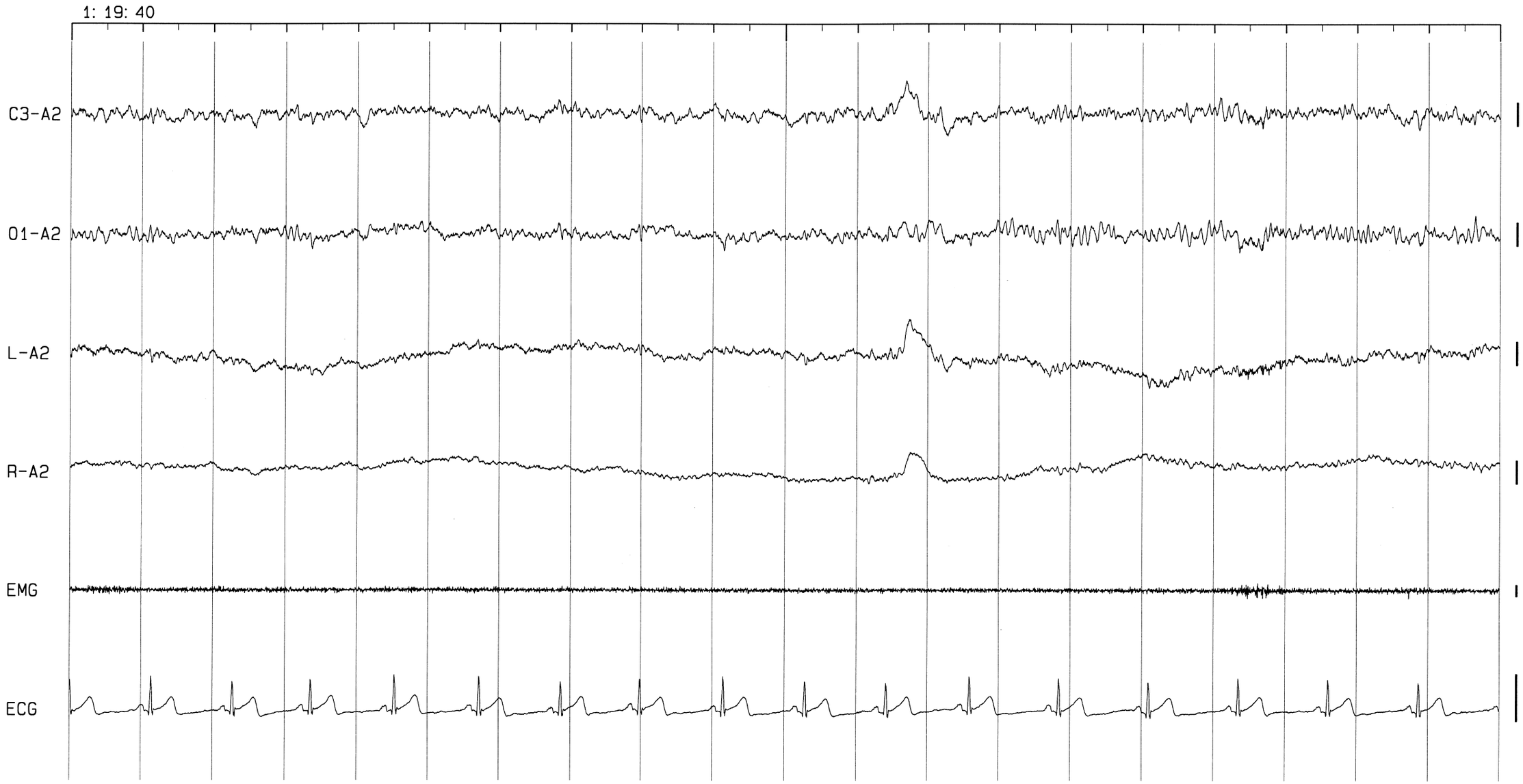
Termination of Stage REM



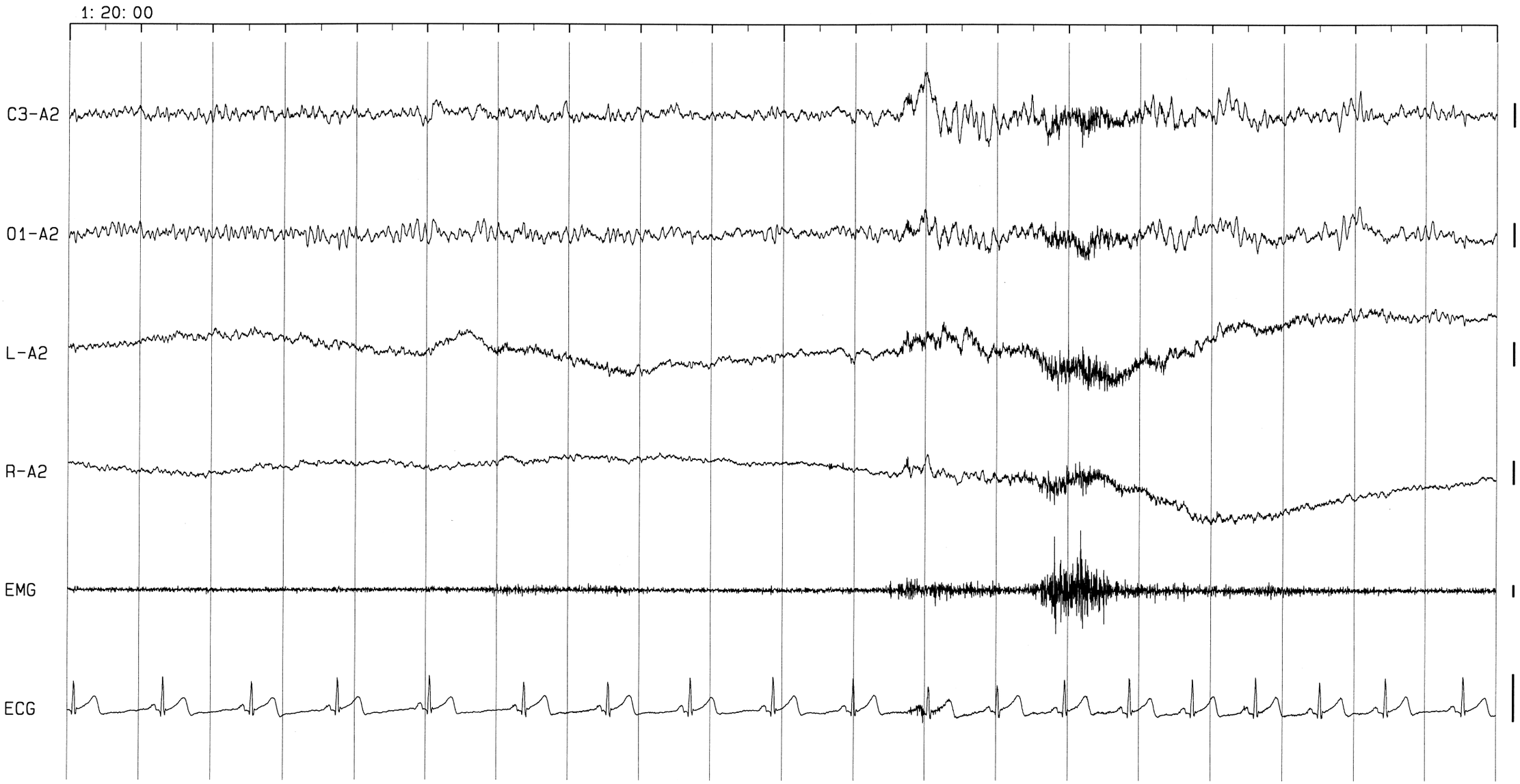
stage 1: While an increase of EMG and EMG artifacts on EEG and EOG recordings are observed, the portion of typical EEG pattern of stage 1 occupies more than 50% of this page.



stage 1: The portion of typical EEG pattern of stage 1 occupies more than 50% of this page.

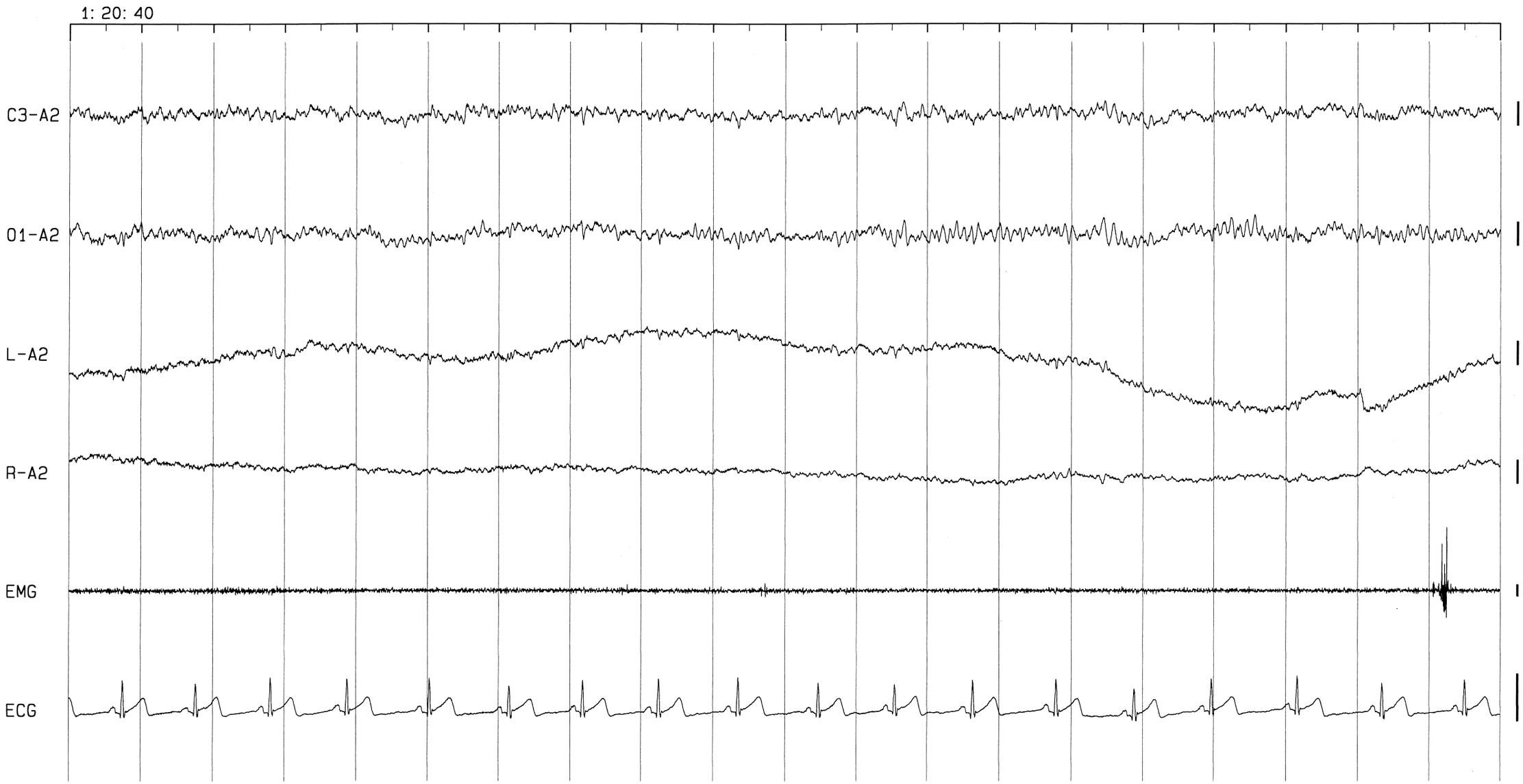


stage 1: The portion of typical EEG pattern of stage 1 occupies more than 50% of this page.

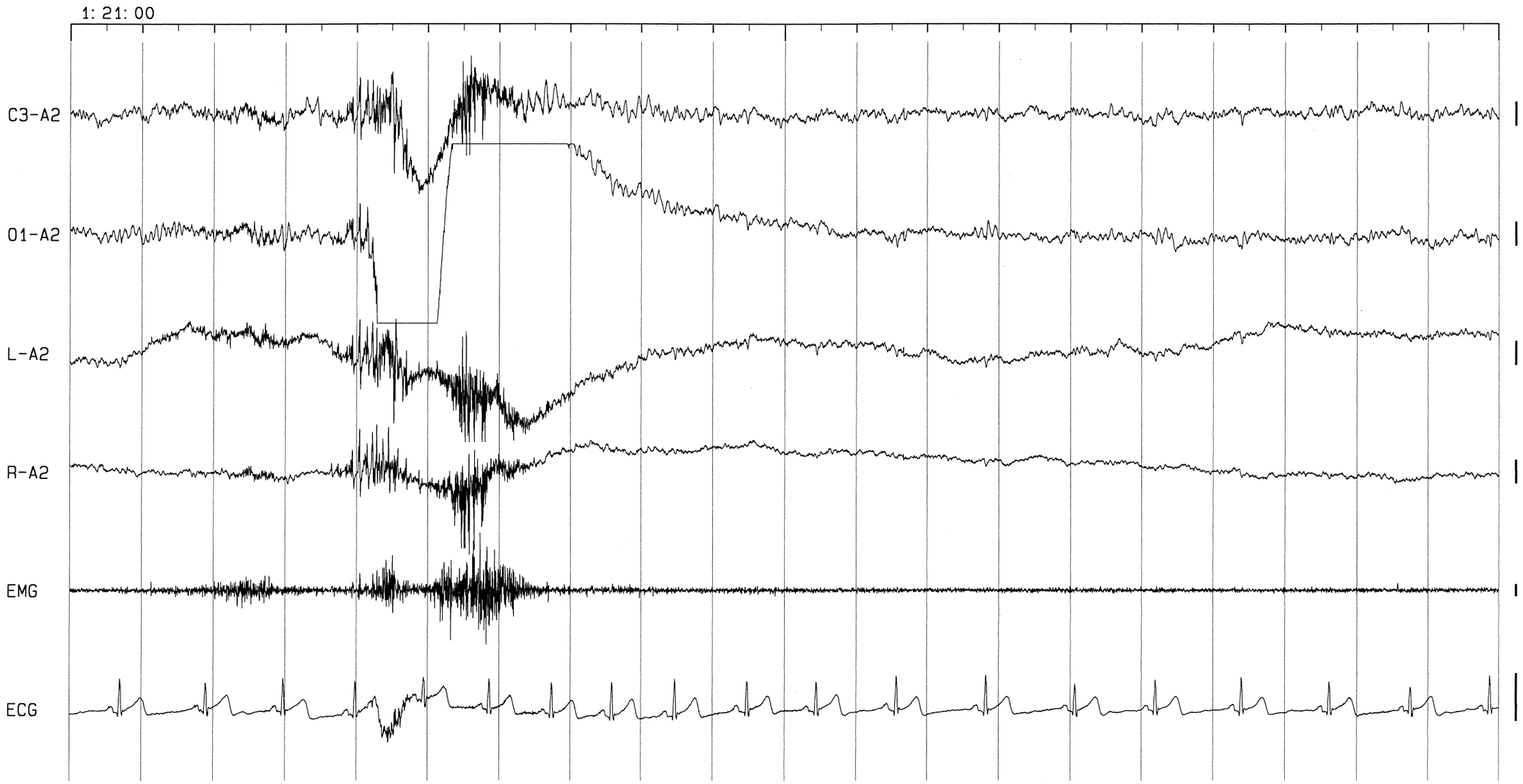


stage 1: While a movement arousal is observed in the last half, the portion of typical EEG pattern of stage 1 occupies more than 50% of this page.

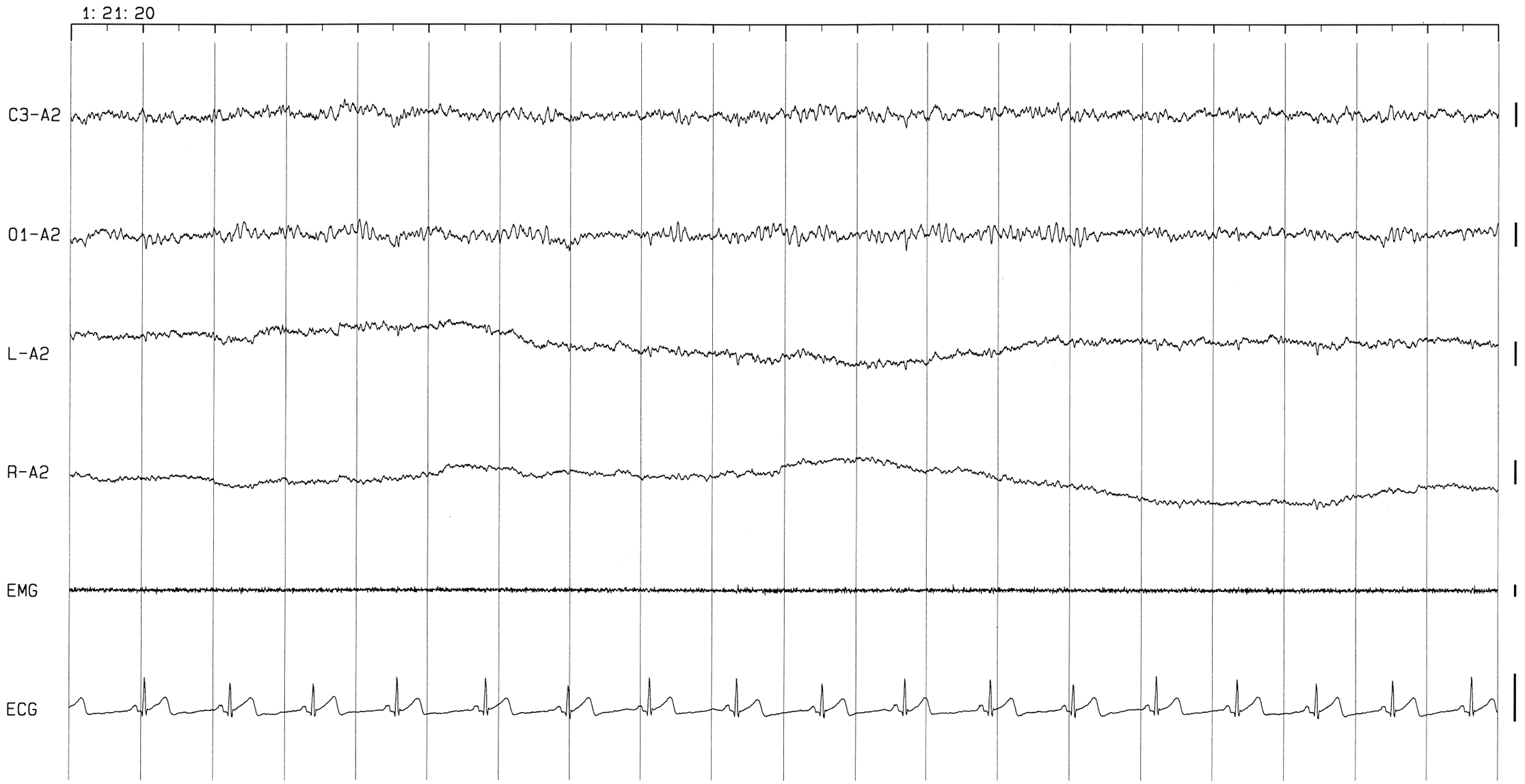
stage REM: Tonic EMG is kept at the lowest level and no movement arousal is found. This page is scored as stage REM, based on the next page where rapid eye movement is found. .



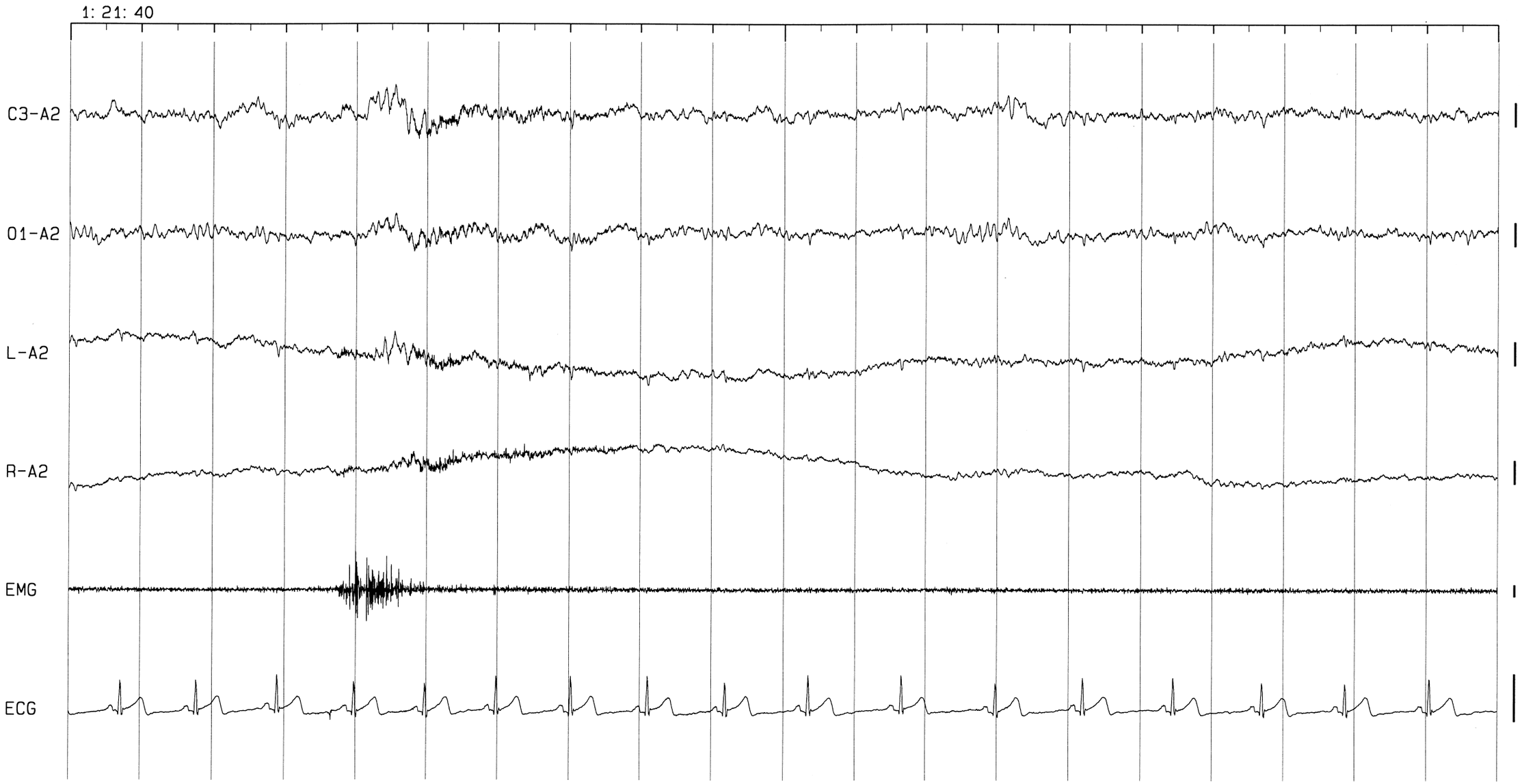
stage REM: The lowest level of tonic EMG and a rapid eye movement are recognized. A twitch is observed in the last half.



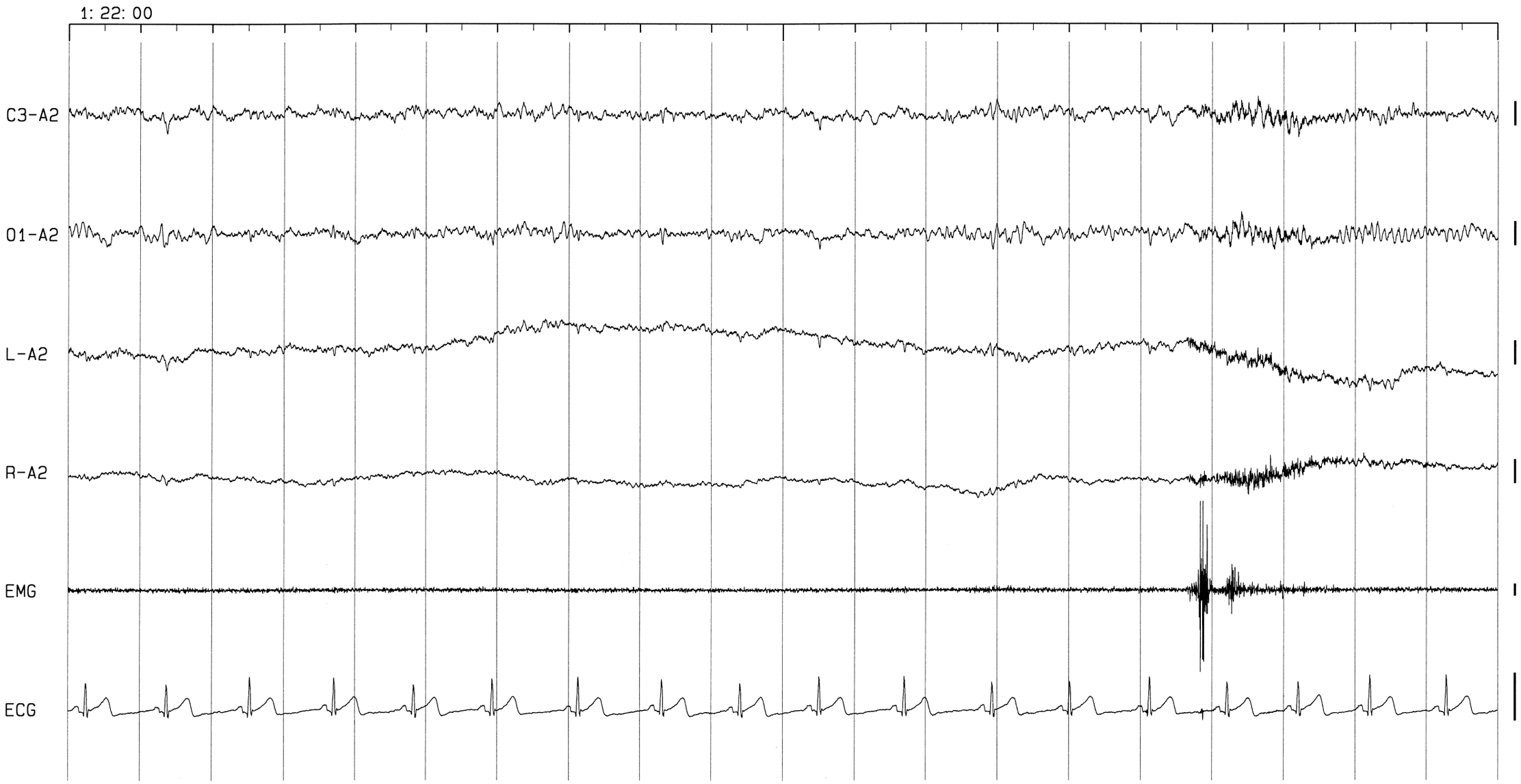
stage 1: Movement arousal is observed in the first half of this page and on page “1:21:40”. While EMG is kept at low level, as REMs are not observed between these two movement arousals, this page is scored as stage 1.



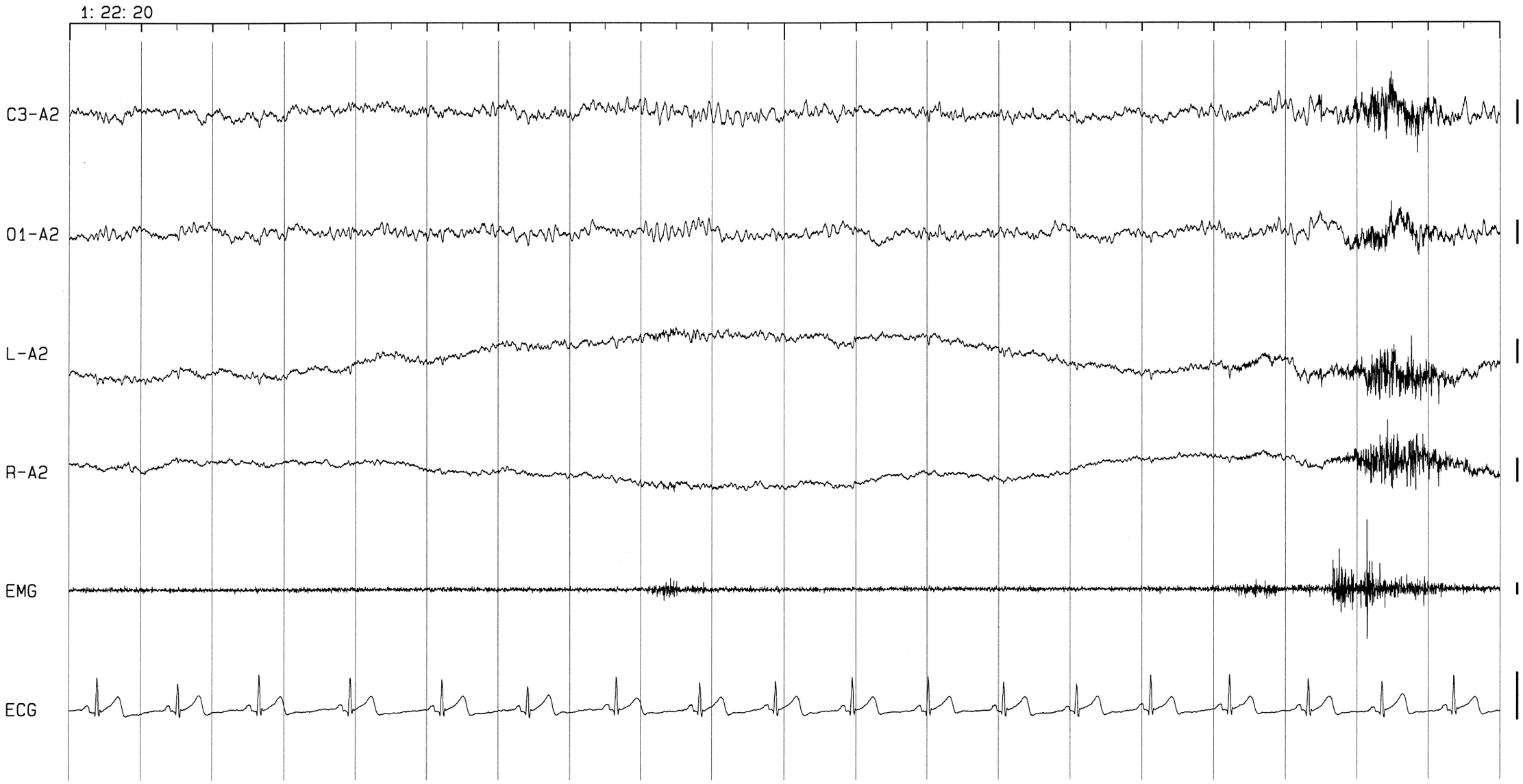
stage 1: During the period between the movement arousal in the previous page and one in the next page, EMG is kept at low level. However, because REMs are not observed in this period, this page is scored as stage 1.



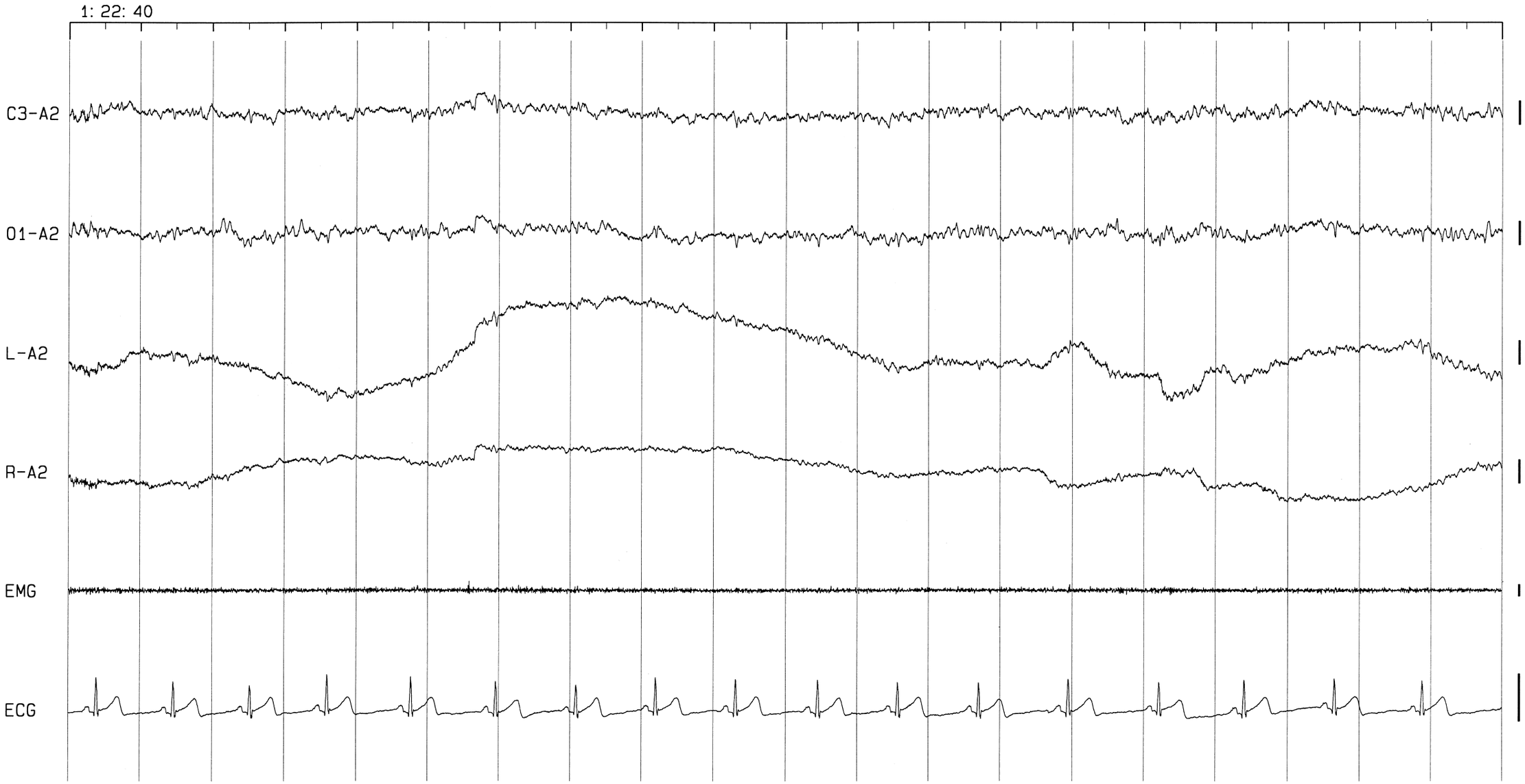
stage 1: A movement arousal is recognized in the first half. EMG is kept at low level. However, because REMs are not observed, this page is scored as stage 1.



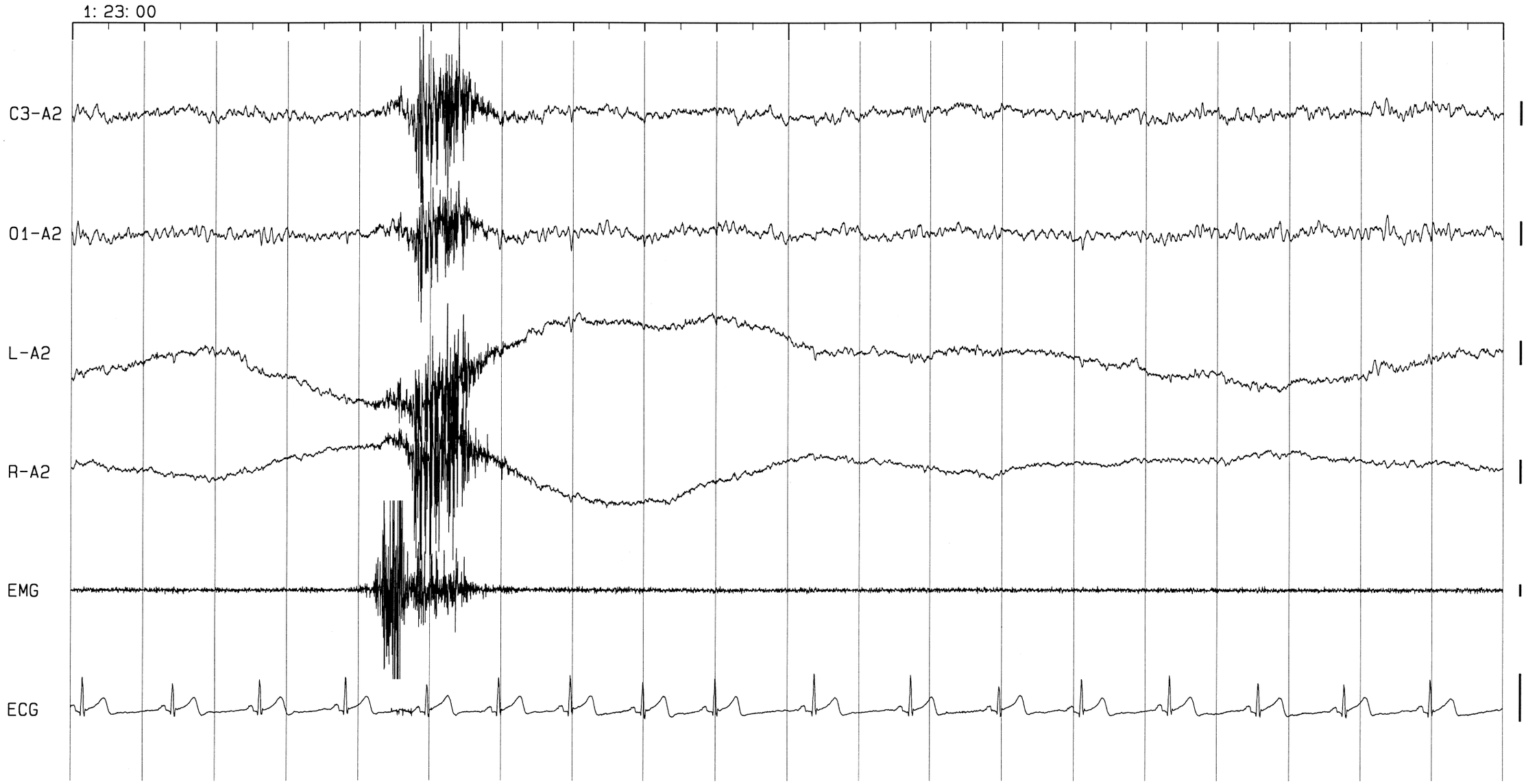
stage 1: While a movement arousal is observed in the last half, portion of typical EEG pattern of stage 1 occupies more than 50% of this page.



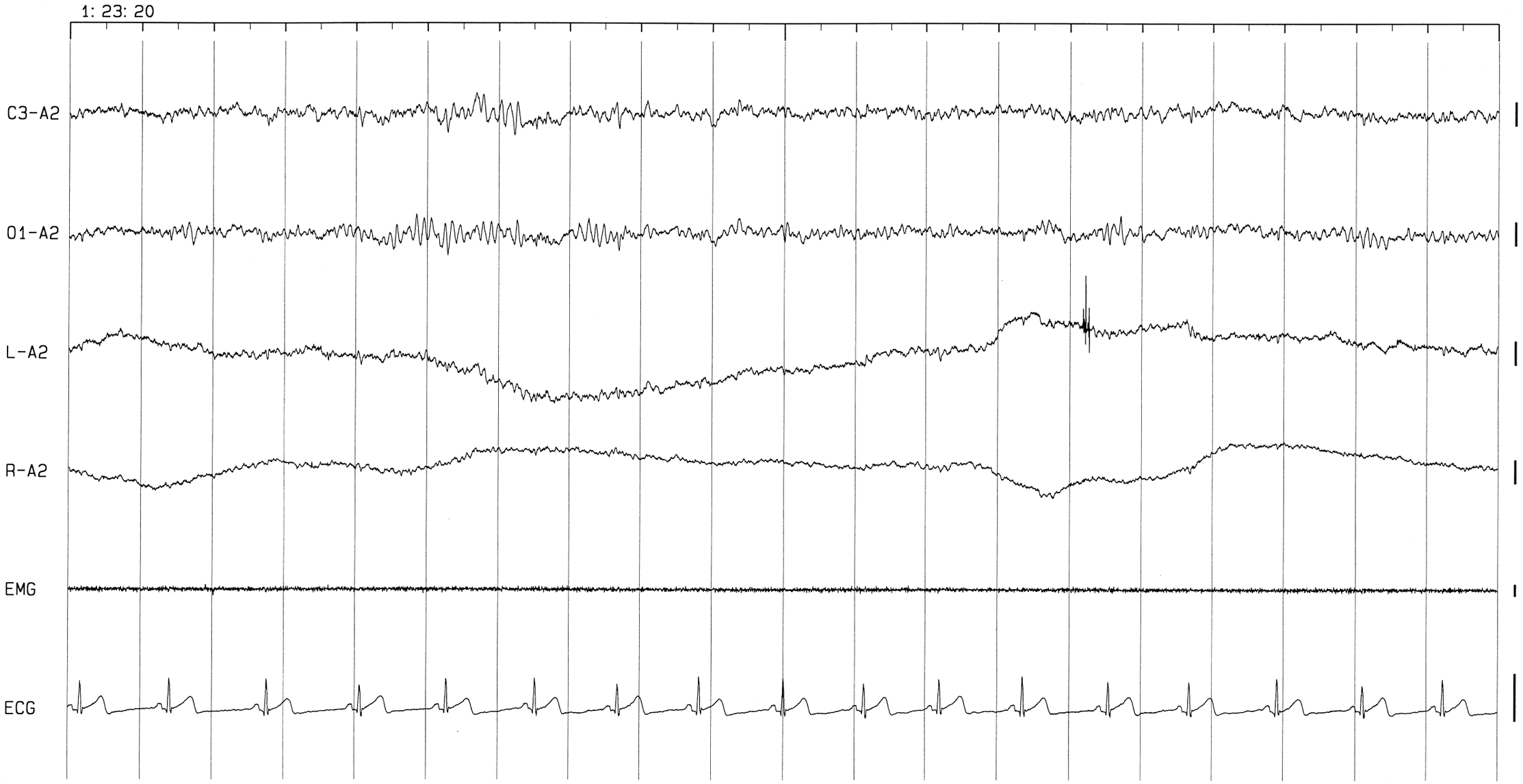
stage 1: While a movement arousal is observed in the last half, portion of typical EEG pattern of stage 1 occupies more than 50% of this page.



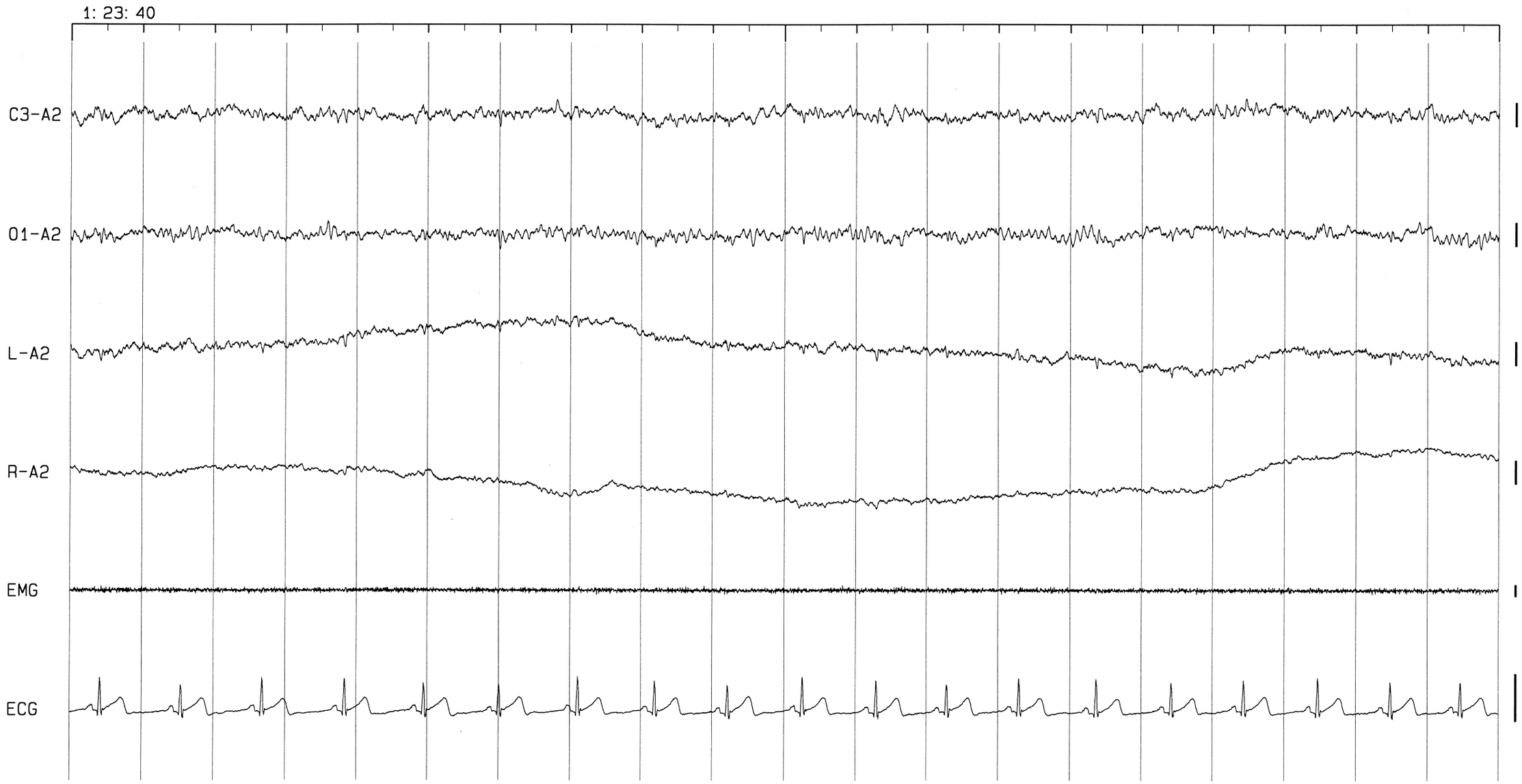
stage REM: EMG level is low and REMs are found in the last half of this page. A movement arousal preceding the REMs is found at the end of the previous page. This page is scored as stage REM.



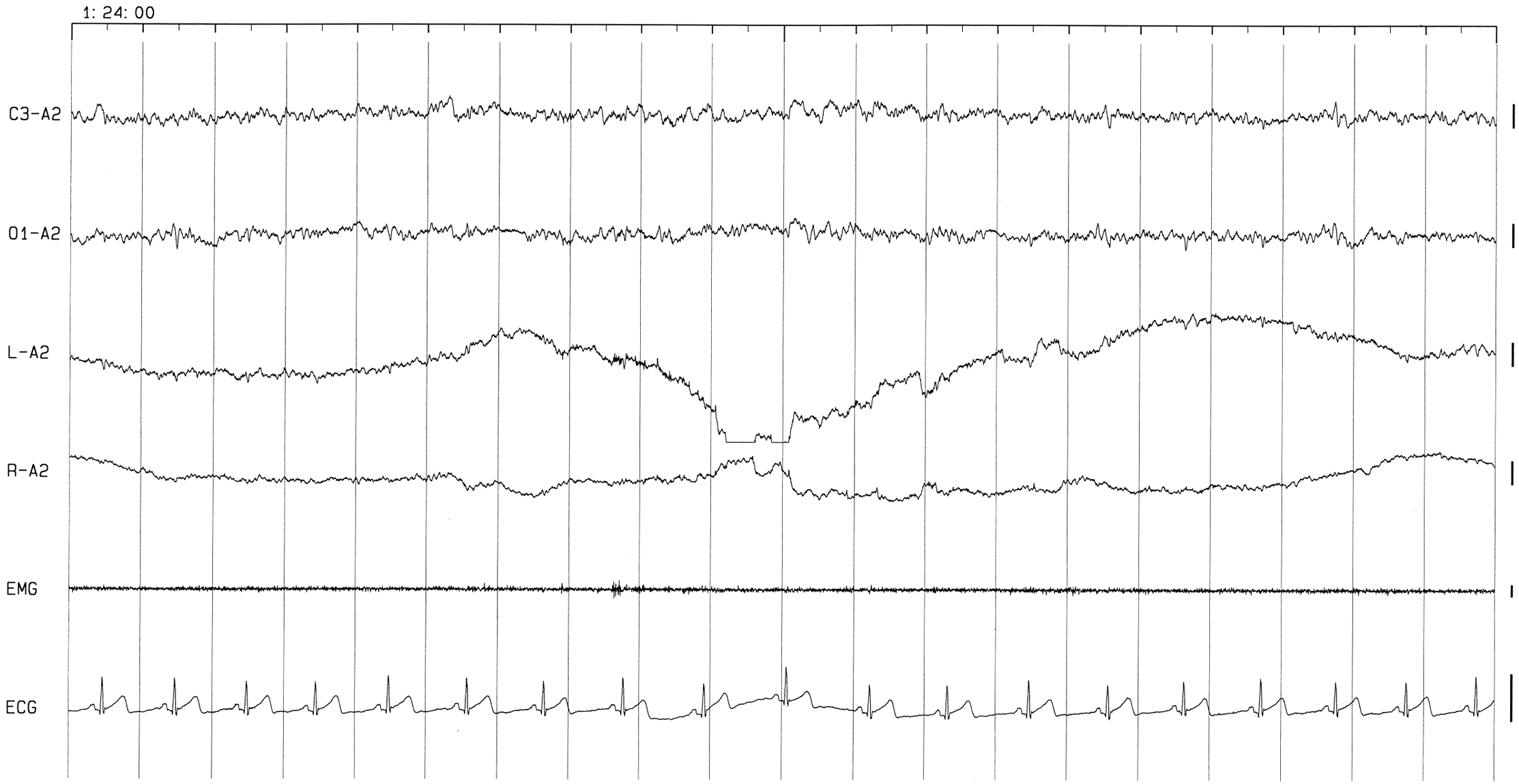
stage REM: While a movement arousal is found in the first half, EMG is kept at low level afterward, which occupies more than 50% of this page. This page is scored as stage REM, based on the REMs in the following page of "1:24:00".



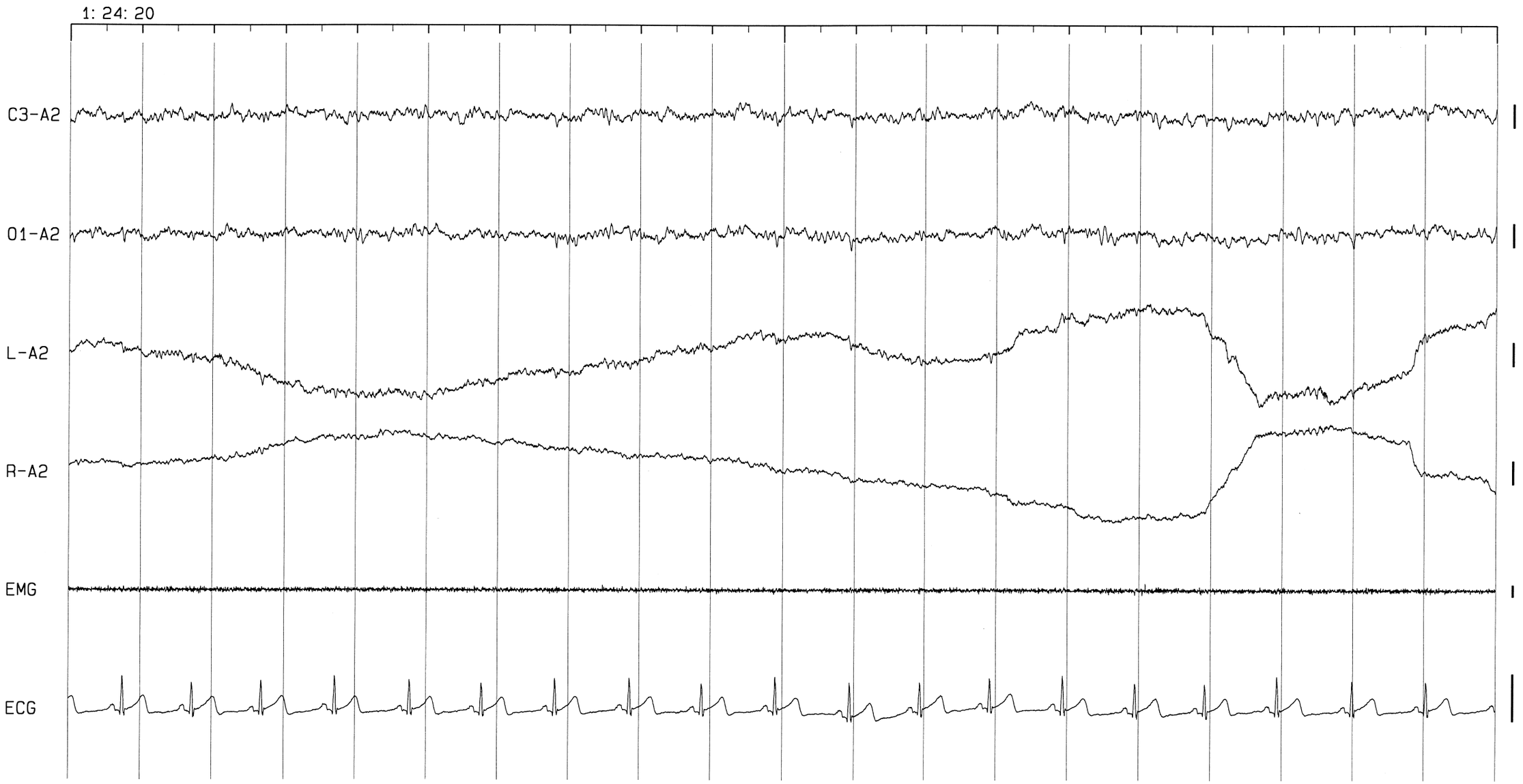
stage REM: EMG level is low. This page is scored as stage REM, based on the REMs in the following page of "1:24:00".



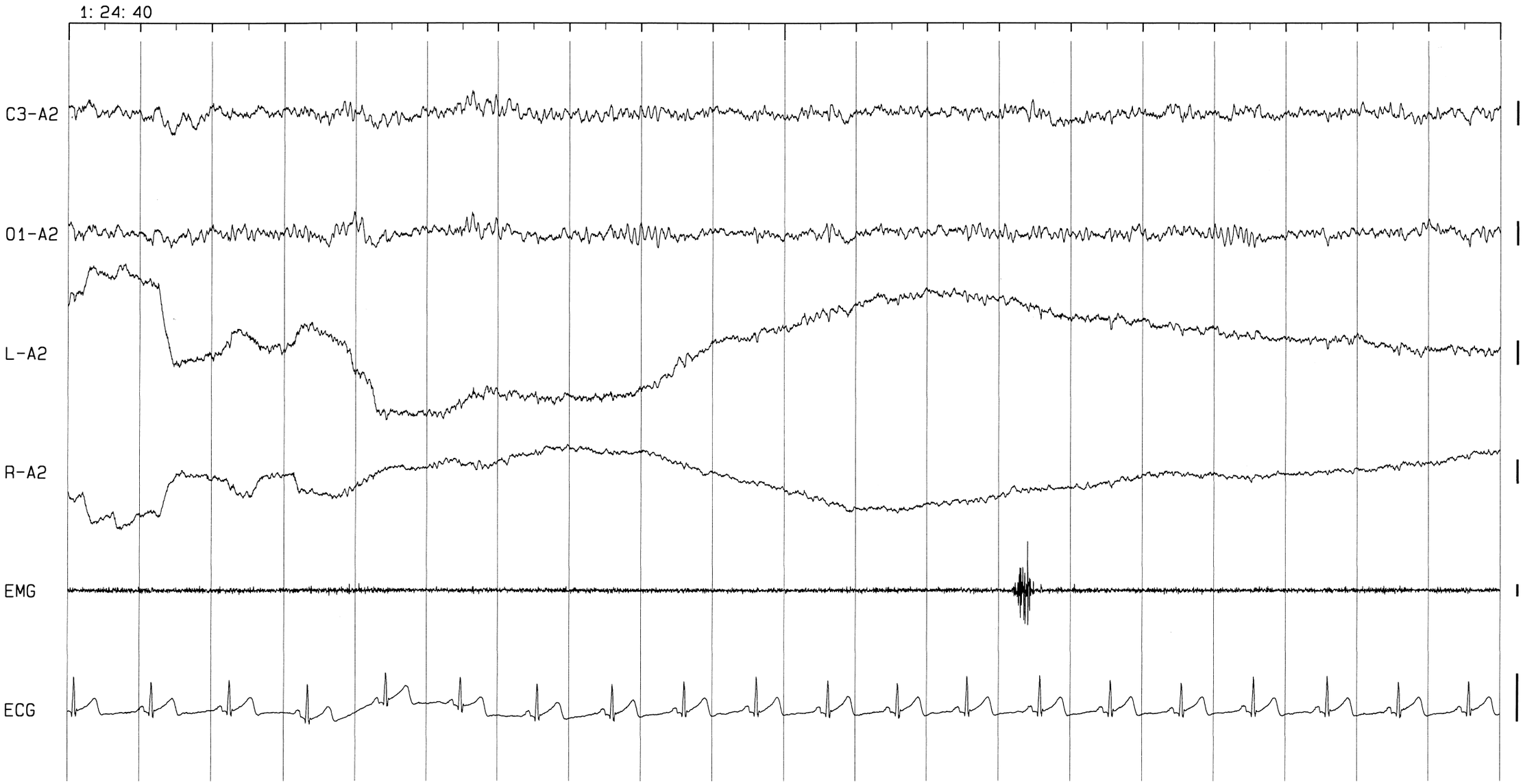
stage REM: EMG level is low. This page is scored as stage REM, based on the REMs in the following page of "1:24:00".



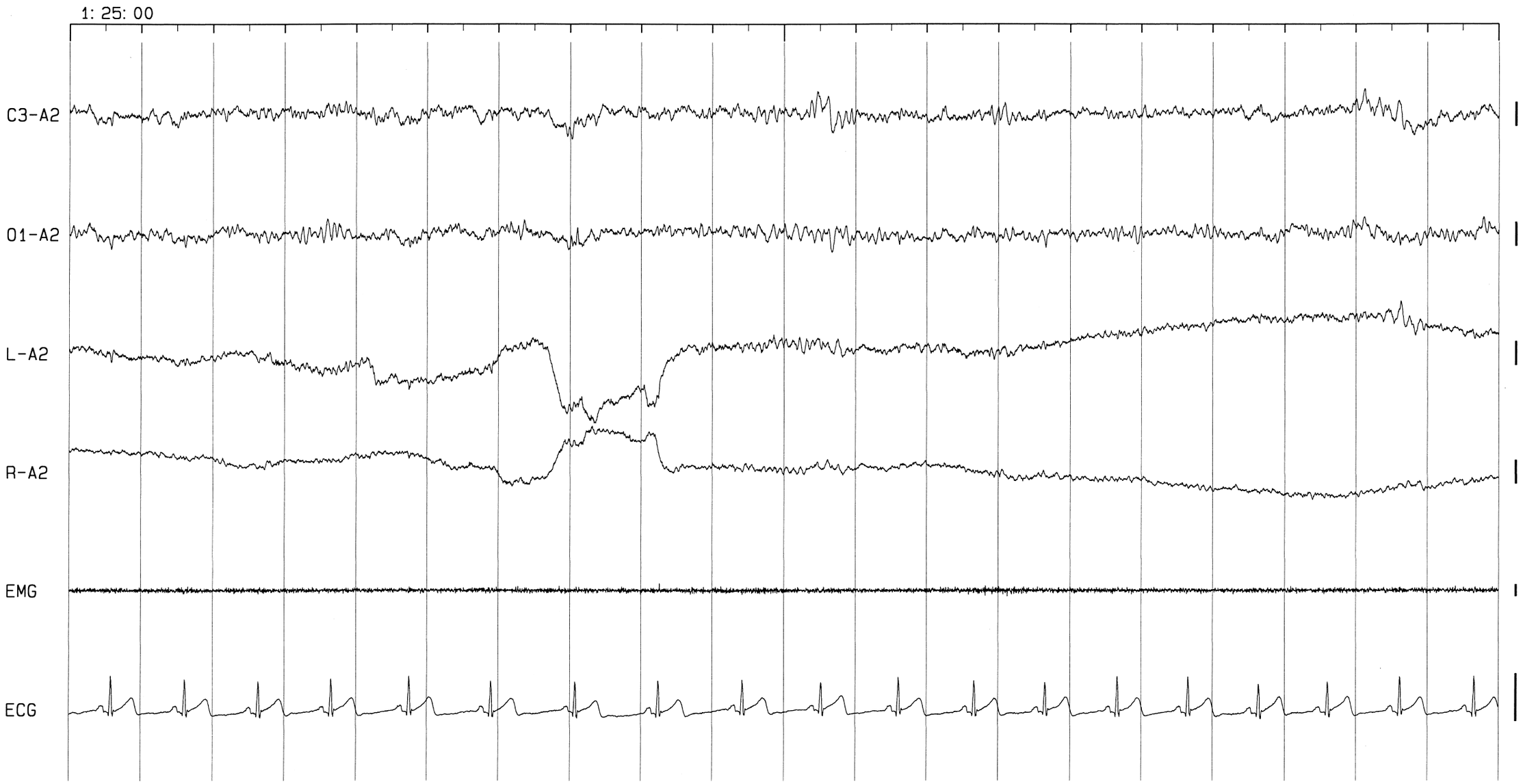
stage REM: REMs are observed and EMG level is low.



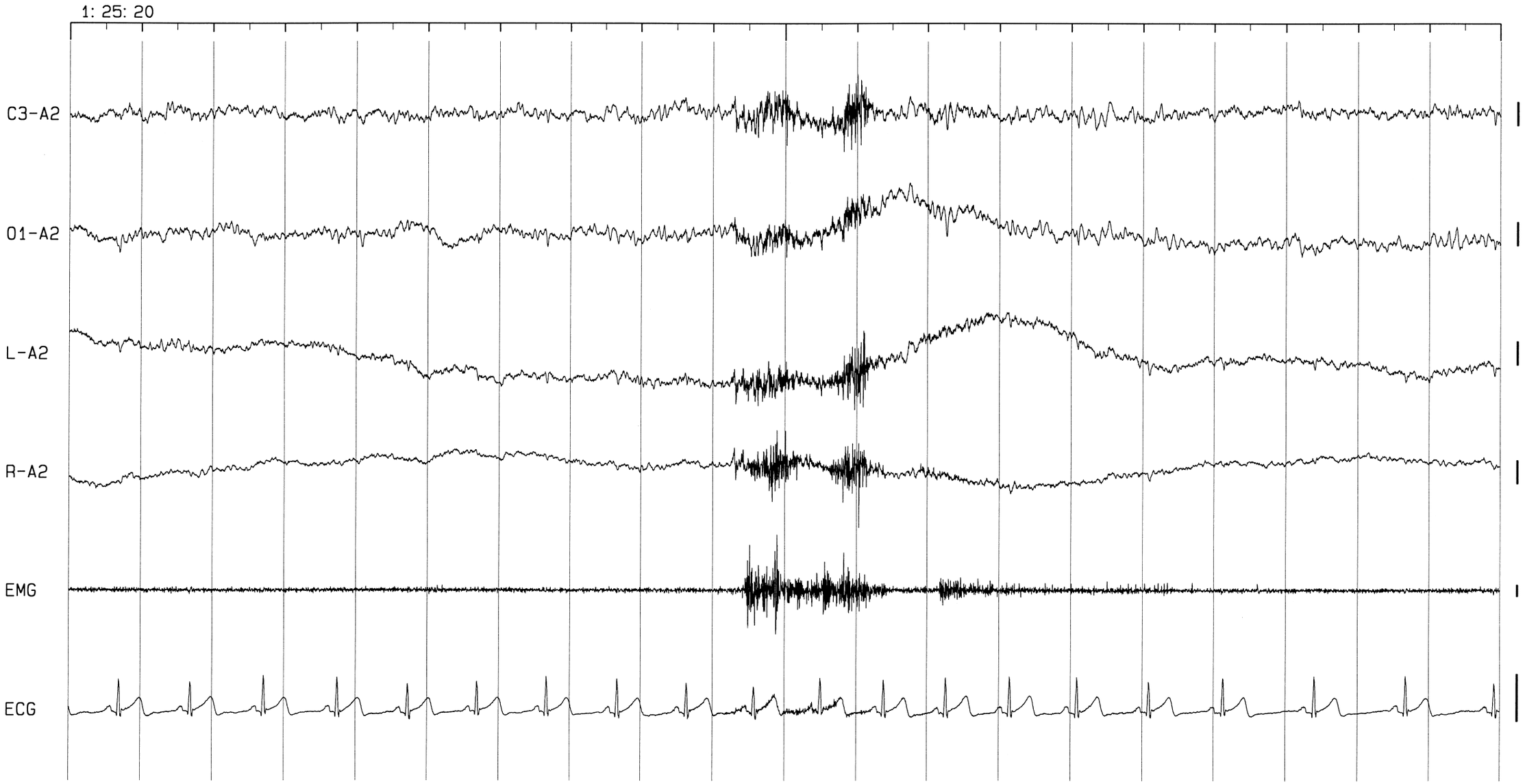
stage REM: REMs are observed and EMG level is low.



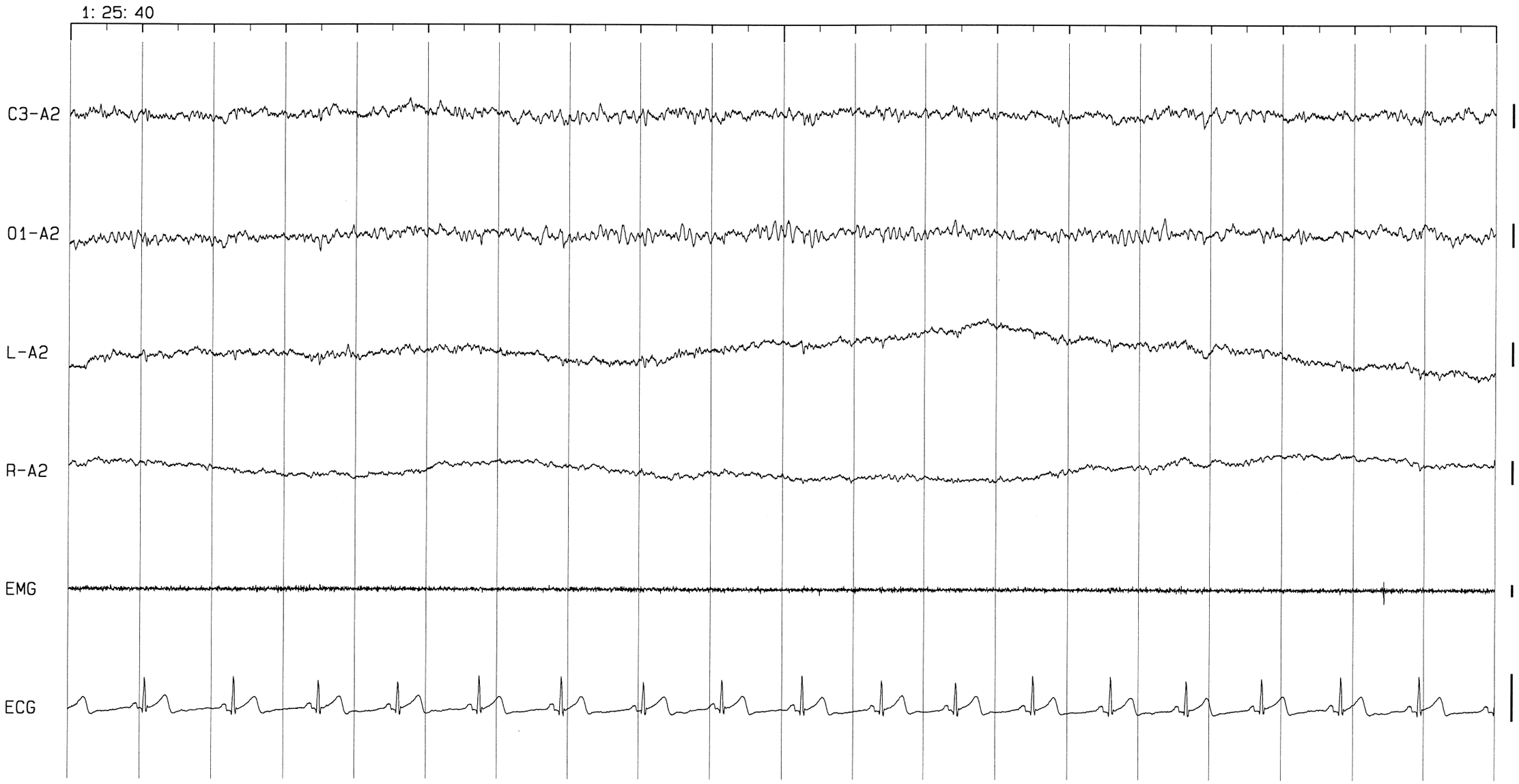
stage REM: REMs are observed and EMG level is low. A twitch is found in the last half.



stage REM: REMs are observed and EMG level is low.

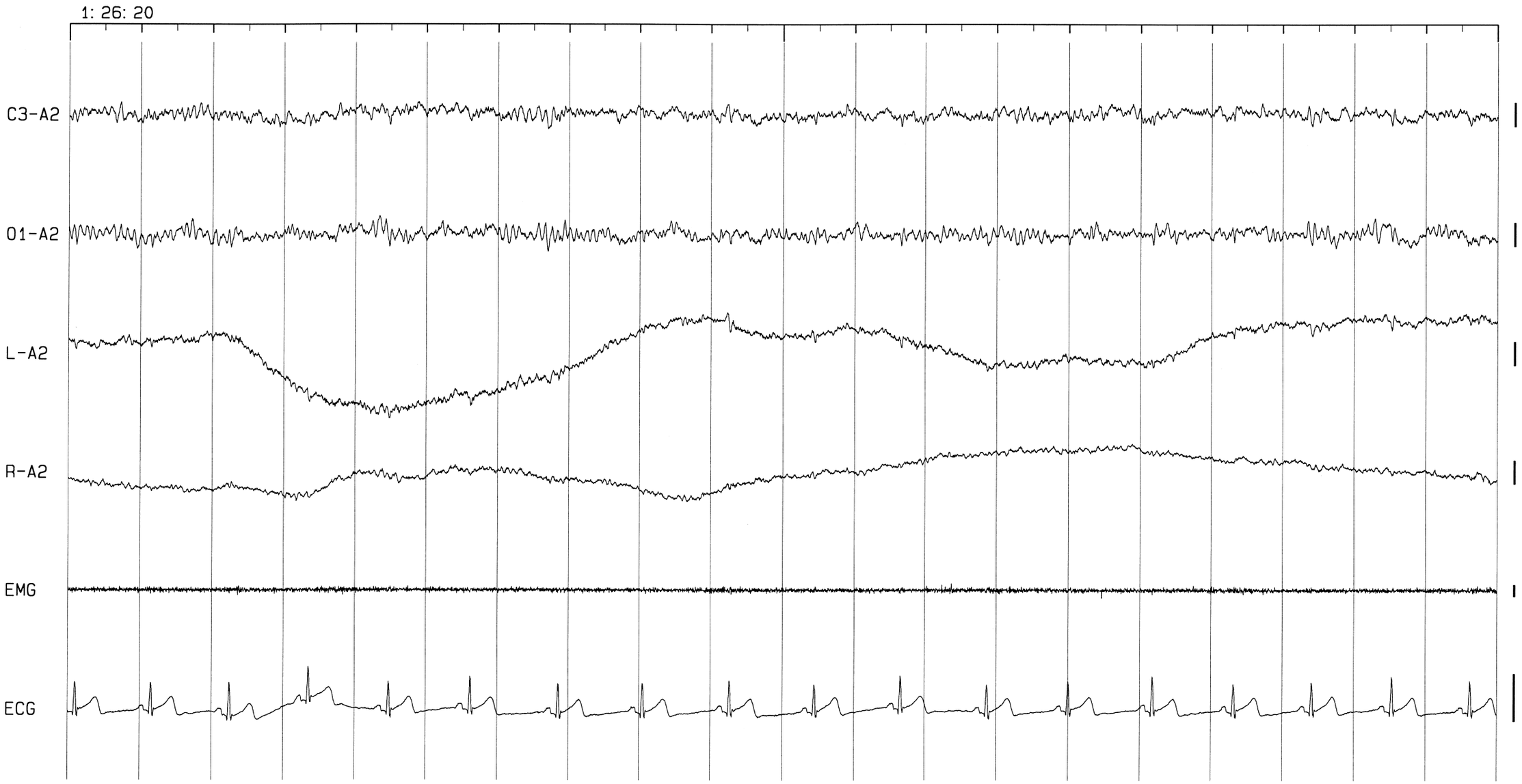


stage REM: While a movement arousal is observed in the middle of this page, REMs are found on page of “1:28:00”. Until that page, no movement arousal nor sleep stage changes are observed and the lowest level EMG continues.

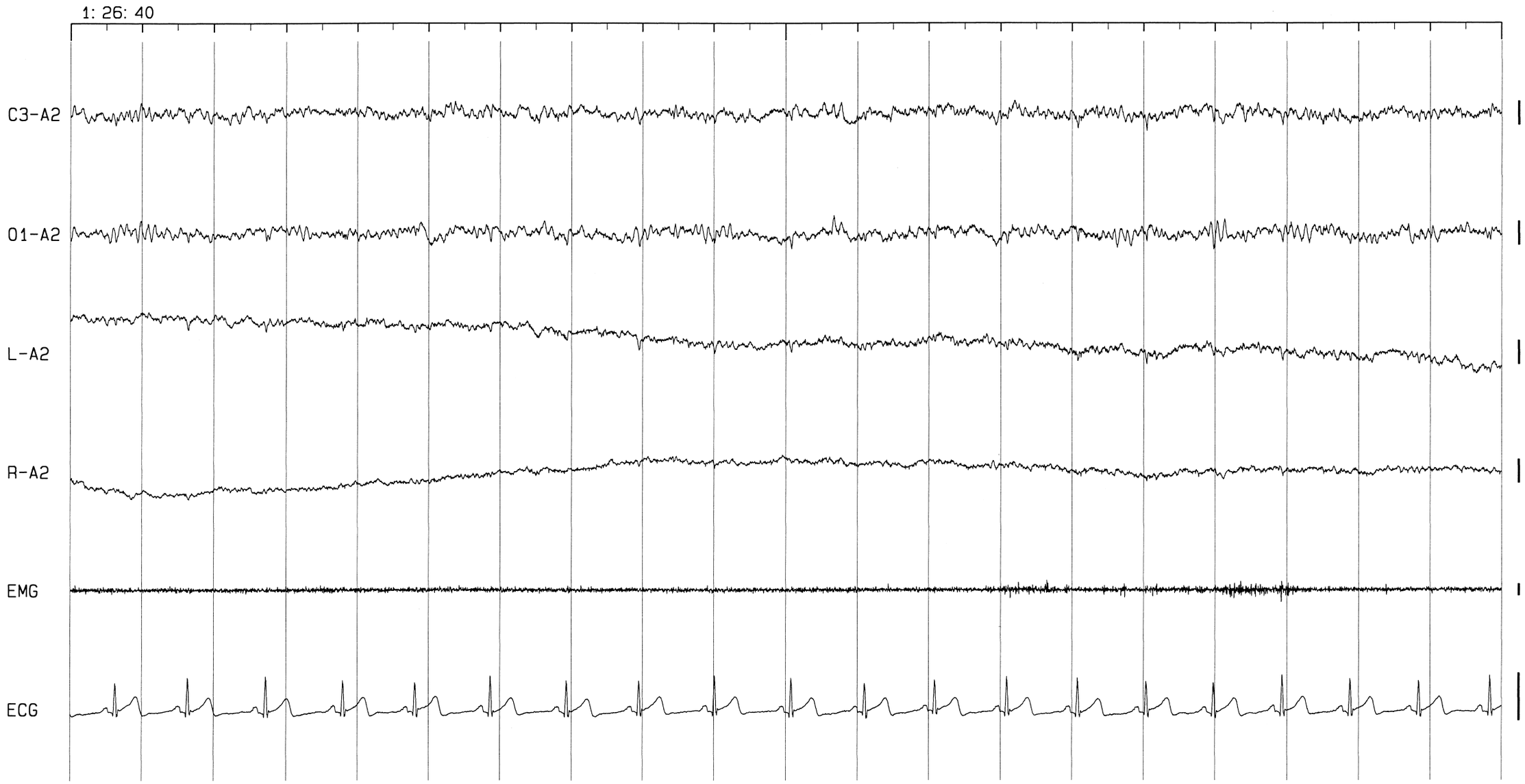


stage REM: REMs are found in the page of “1:28:00”. Until that page, no movement arousal nor sleep stage changes are observed and the lowest level EMG continues.

stage REM: Twitches are observed in the first half of this page. Alpha activities are recognized on O1 EEG recording. K-complex like activity is found, however, its amplitude is not large enough (less than 200 μV). This page is scored as stage REM according to the preceeding page of stage REM.

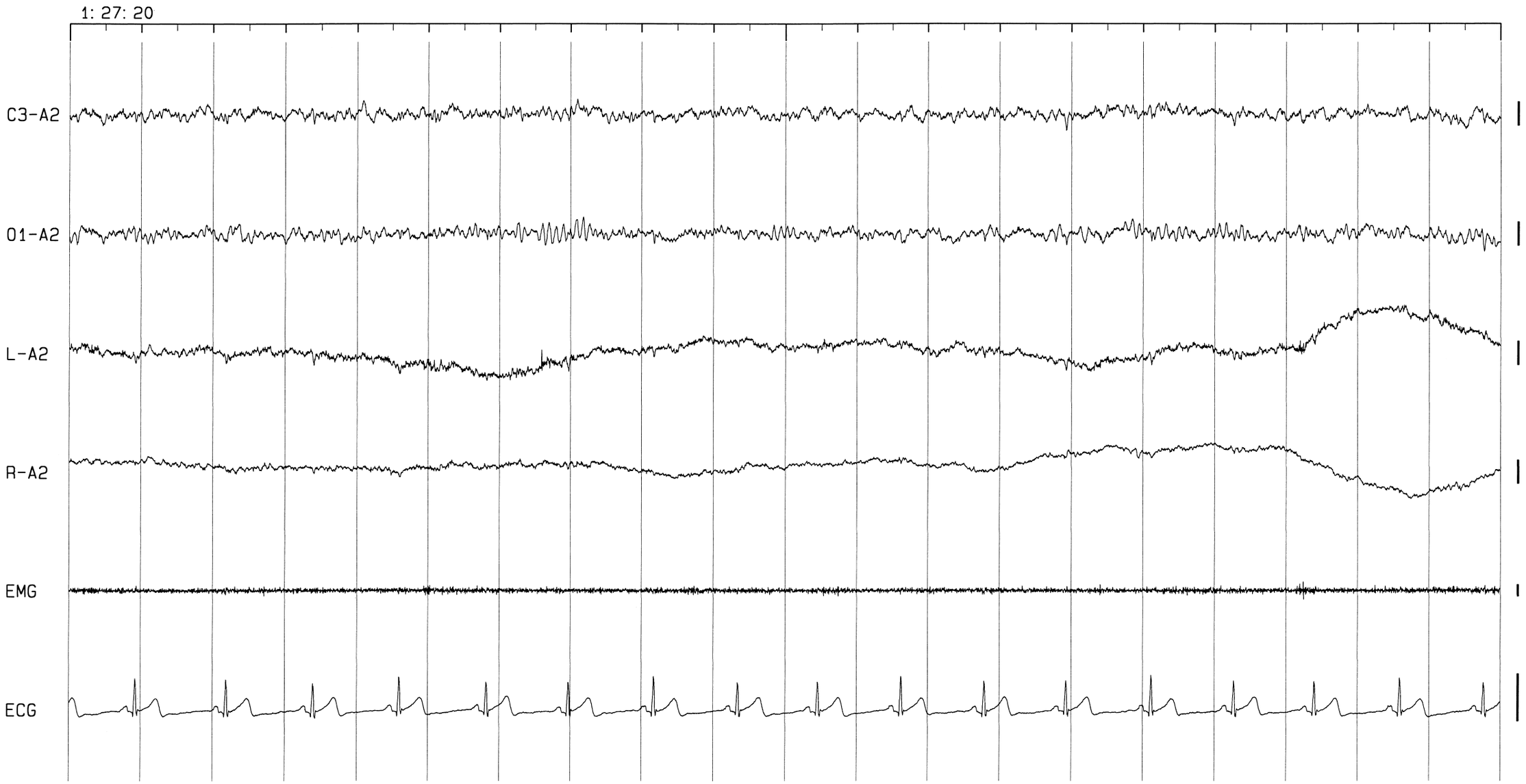


stage REM: Alpha activity occupies less than 50% of this page. While slow eye movements are observed, there is no preceding movement arousal. This page is scored as stage REM according to the preceding page of stage REM.



stage REM: REMs are found in the page of “1:28:00”. Until that page, no movement arousal nor sleep stage change are observed and the lowest level EMG continues.

stage REM: Clear EMG artifact is observed on left EOG recording. This page is scored as stage REM according to the preceding page of stage REM.



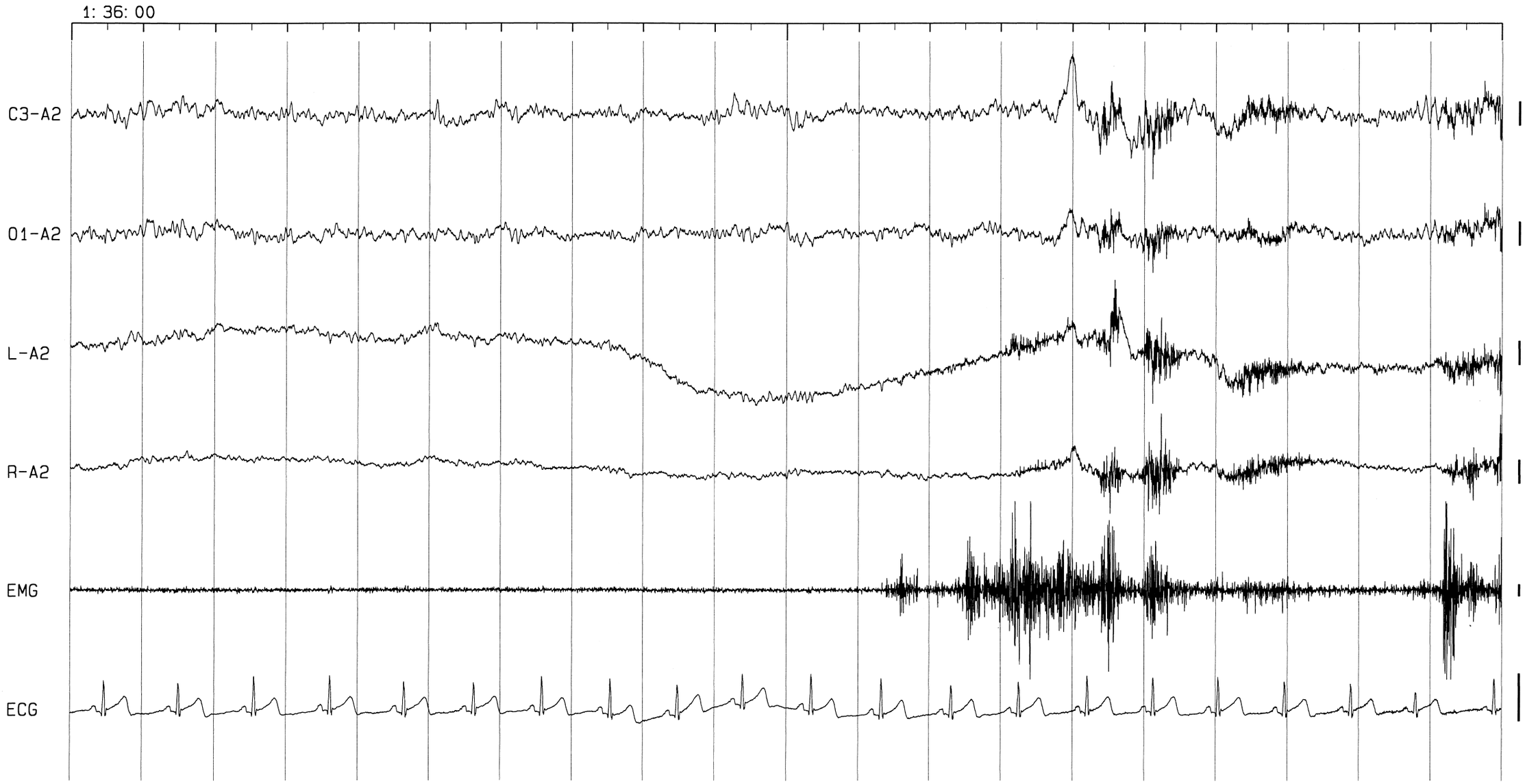
stage REM: REMs are found in the page of “1:28:00”. Until that page, no movement arousal nor sleep stage change are observed and the lowest level EMG continues.

stage REM: Alpha activity occupies less than 50% of this page. While slow eye movements are observed, there is no preceding movement arousal. This page is scored as stage REM according to the preceding page of stage REM.

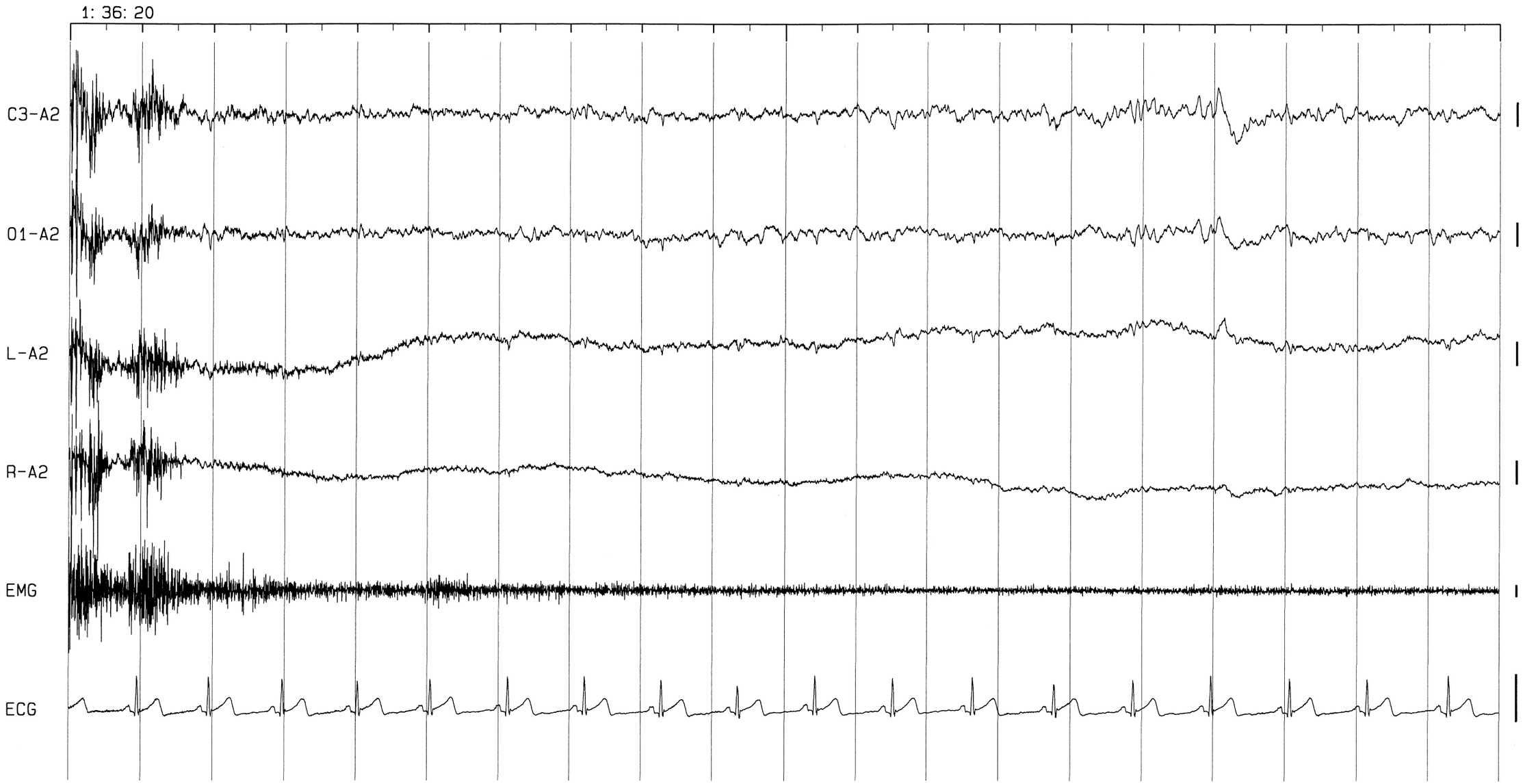
stage REM: REMs are found in the last half of this page, and EMG level is low.

stage REM: REMs are found in the last half of this page, and EMG level is low.

stage REM: While REMs are not observed, low level EMG continues and preceding movement arousal is not observed.



stage REM: A movement arousal is observed in the last half of this page. Until the movement arousal, low level EMG continues, which occupies more than 50% of this page. This page is scored as stage REM.



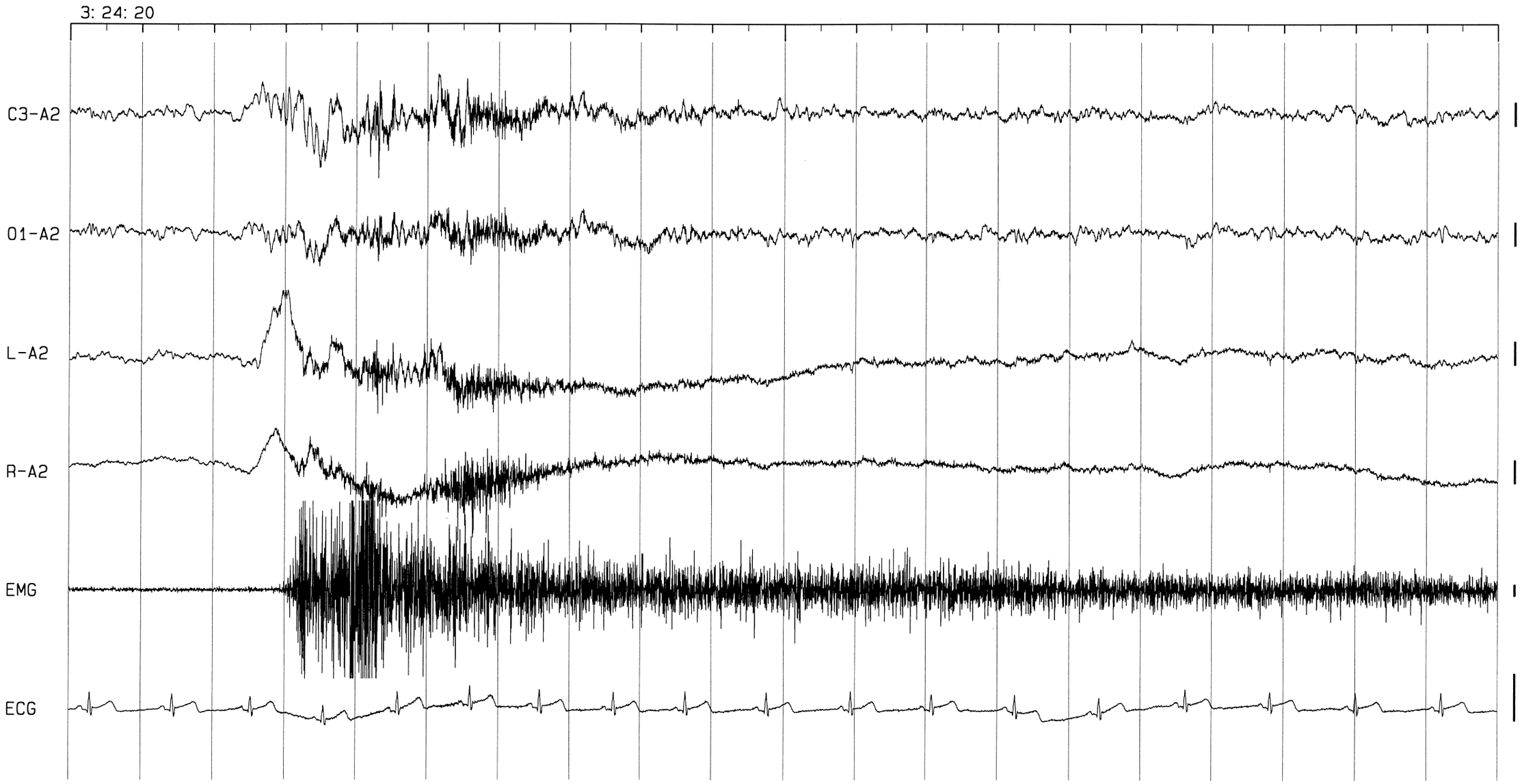
stage 1: After the movement arousal in the previous page, continuous increase of EMG is observed. Typical stage 1 EEG is recognized.

stage 1: A sleep spindle is recognized in the last half of this page, however, portion of typical EEG pattern of stage 1 occupies more than 50% of this page.

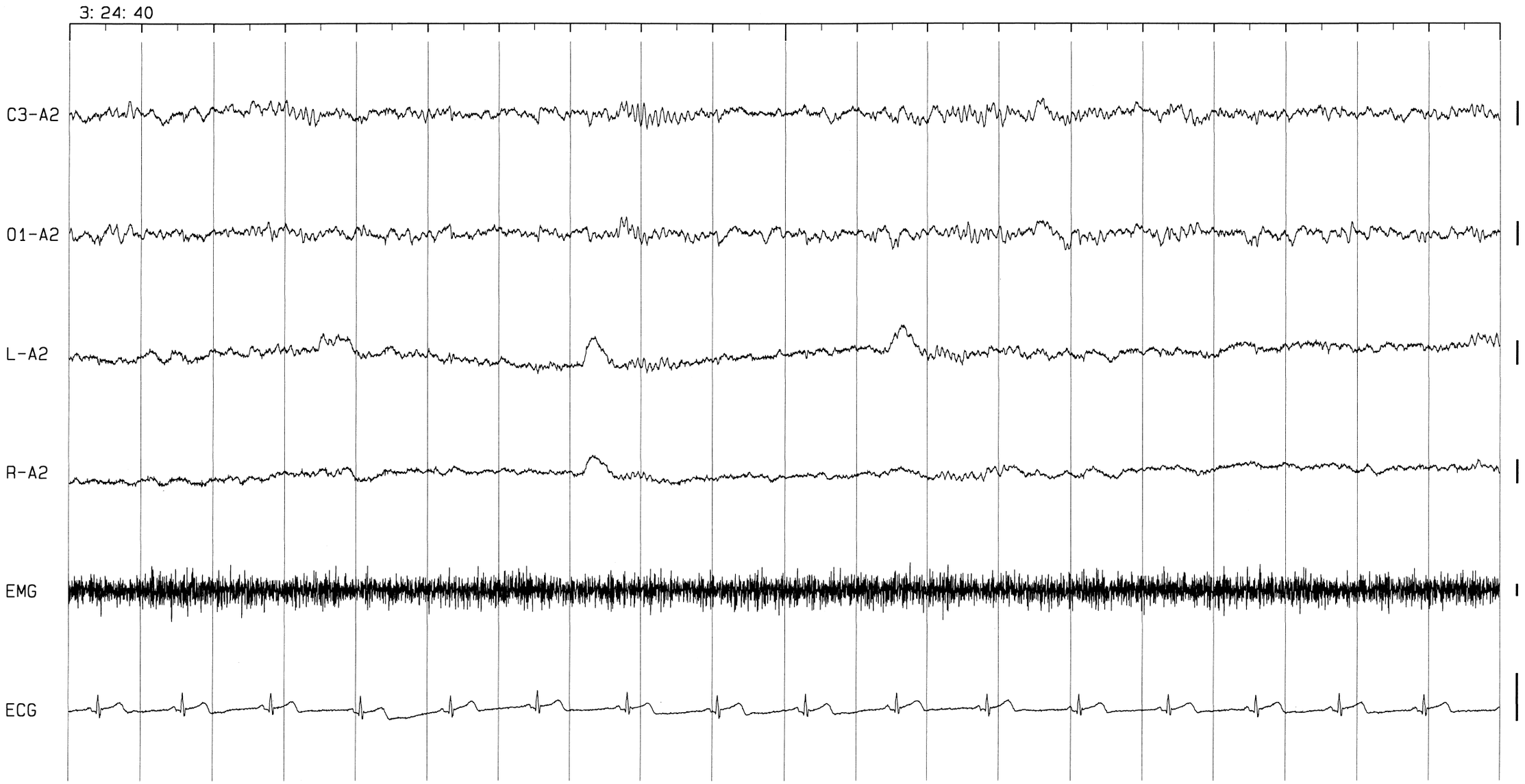
stage 2: Sleep spindles are observed in the first half of this page.

9. Constant appearance of sleep spindles, typically observed during the last half of nighttime sleep

stage 2: Sleep spindles are observed in the first and the last half of this page.

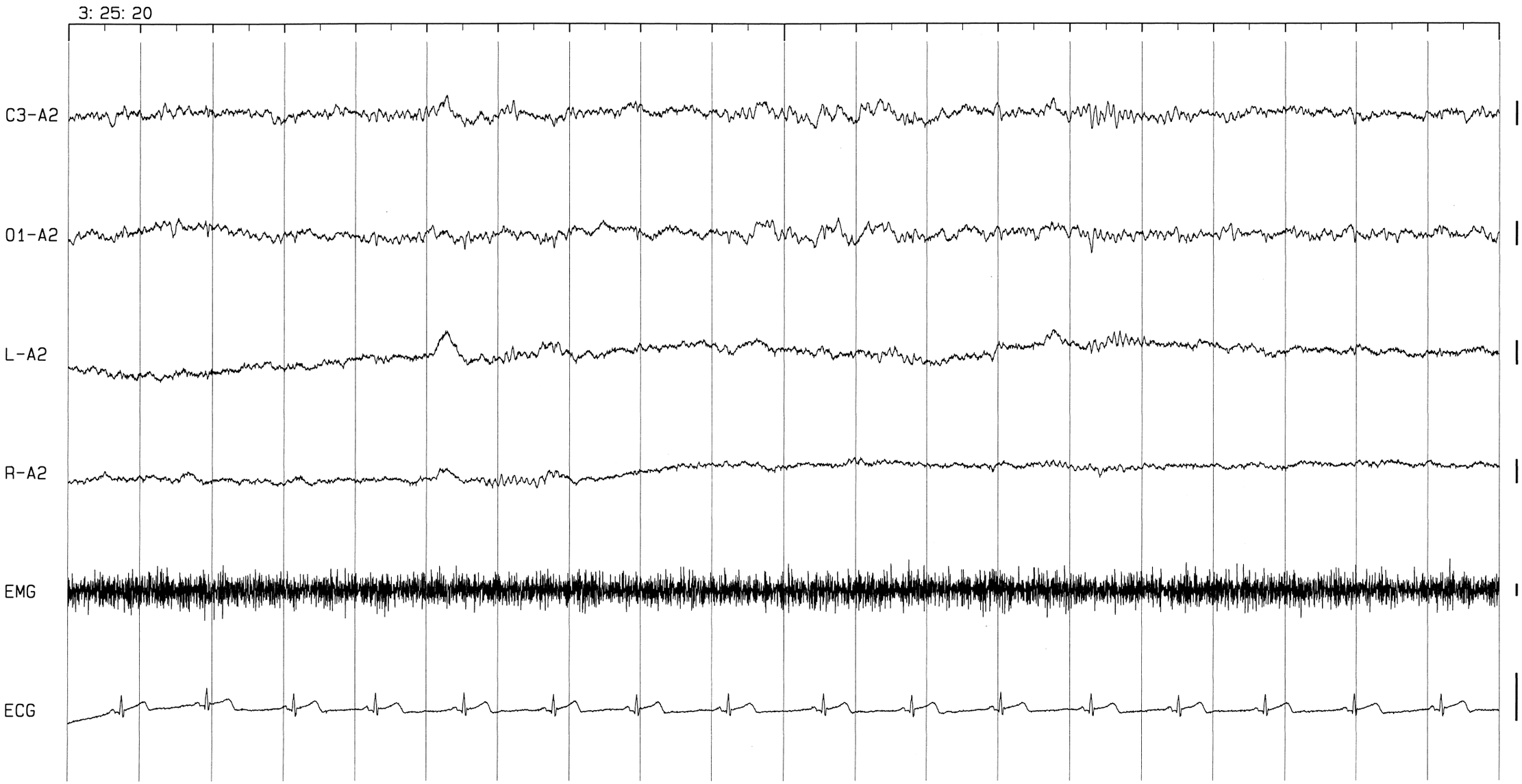


stage 1: A movement arousal is found in the first half of this page. After the movement arousal, continuous increase of EMG is observed, and the typical EEG pattern of stage 1 is recognized.



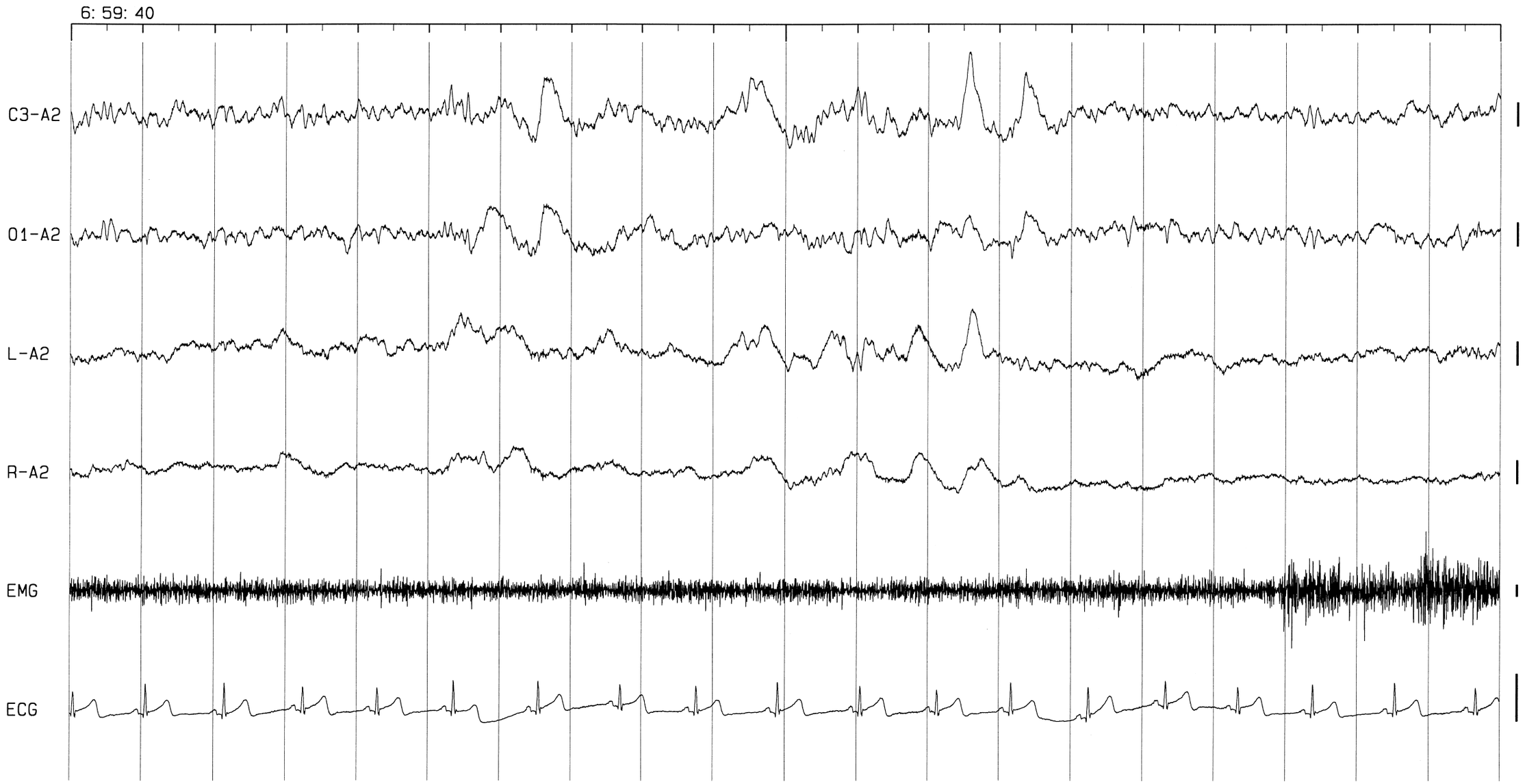
stage 2: Sleep spindles are observed in the first and the last half of this page.

stage 2: Sleep spindles are observed in the first and the last half of this page.

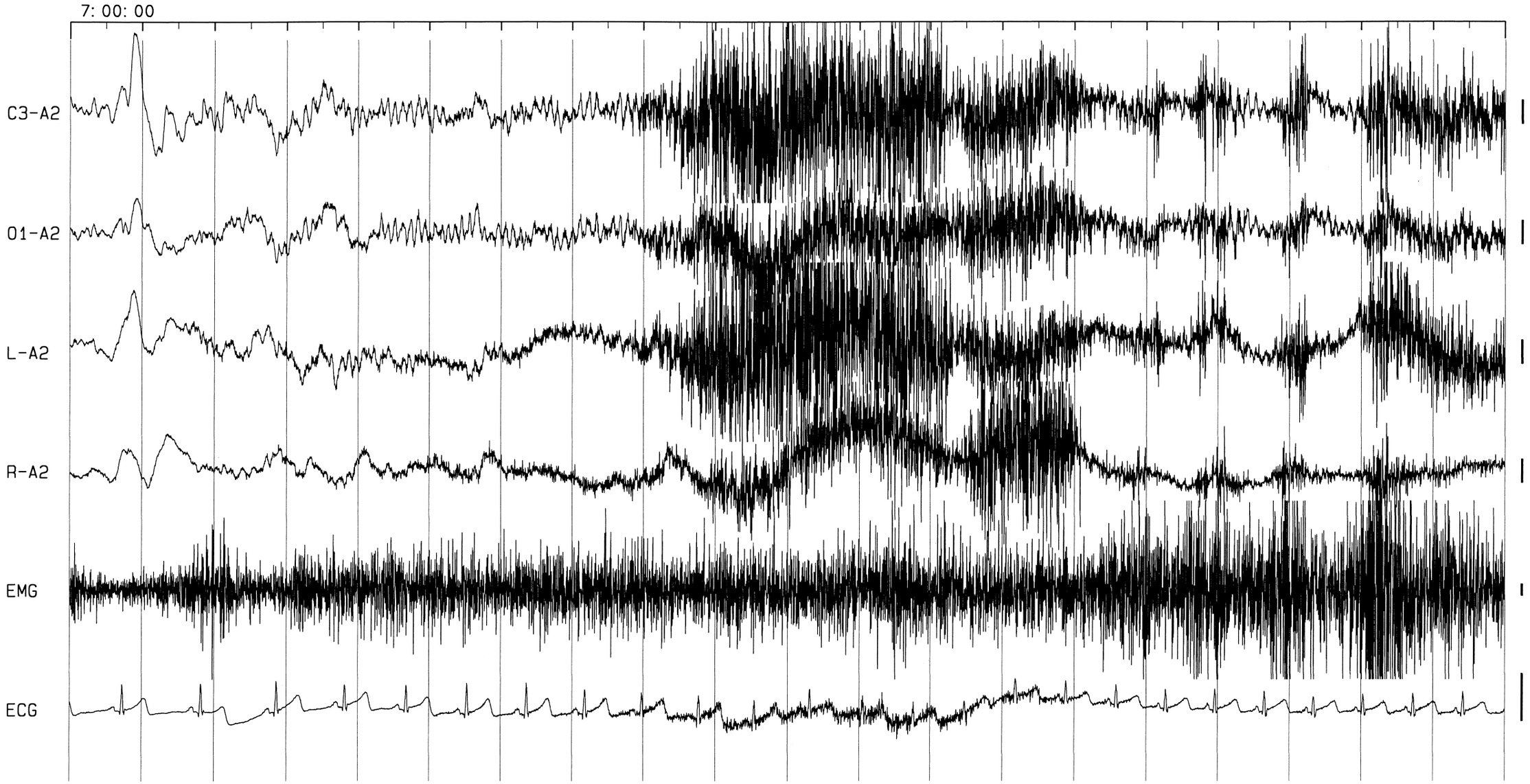


stage 2: A sleep spindle is observed in the last half, and there is no movement arousal.

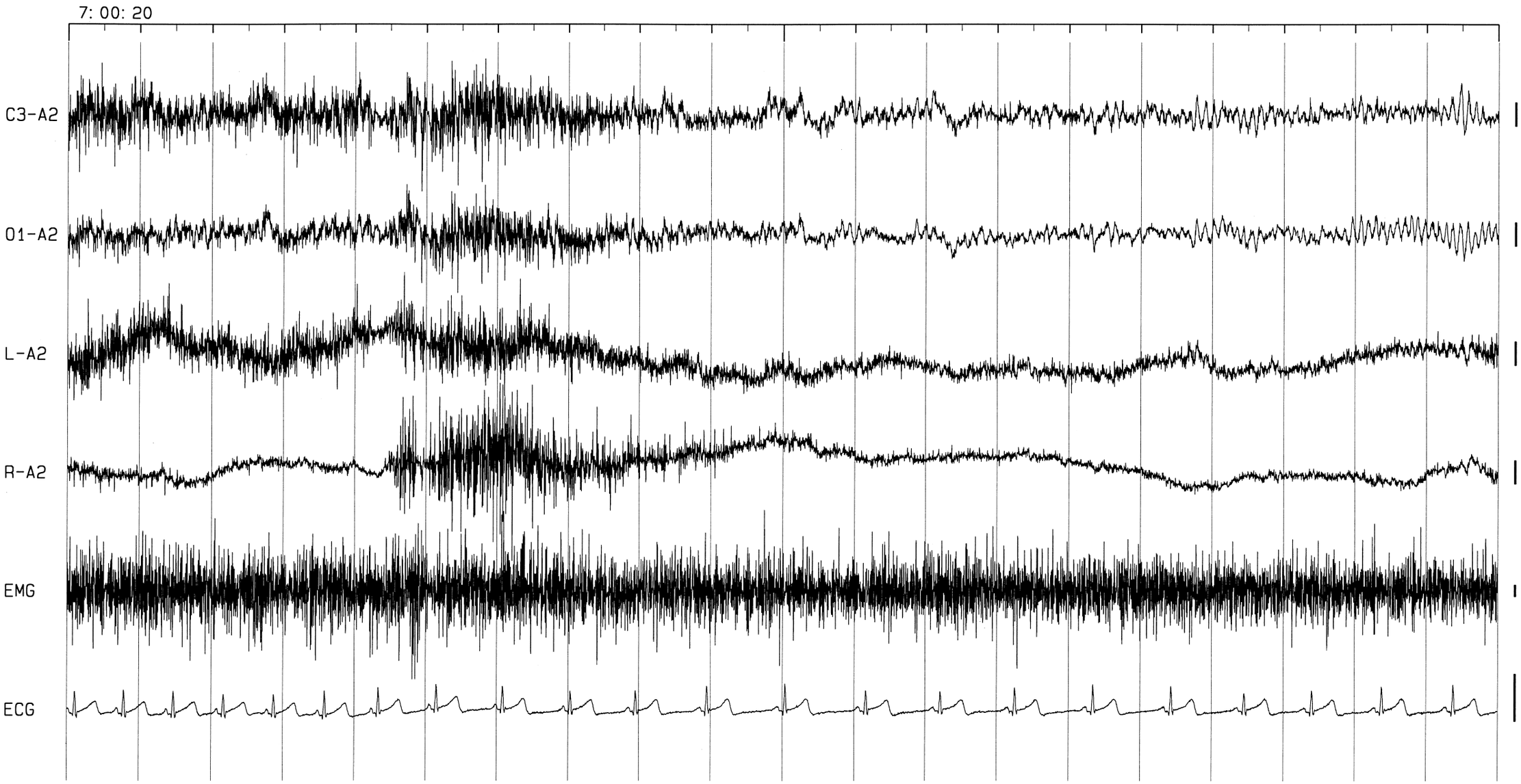
10. Sleep termination (offset) process



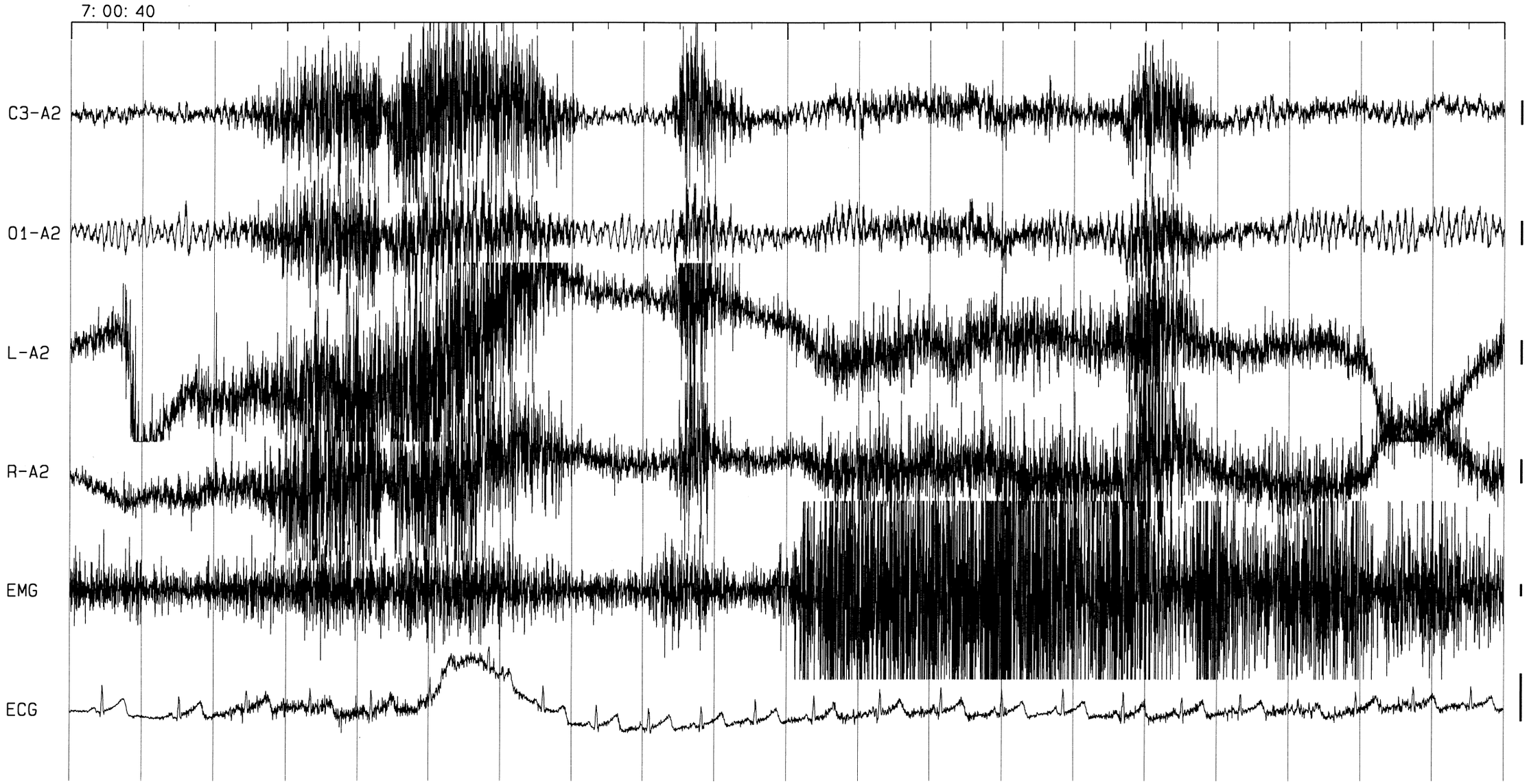
stage 2: While sleep spindles are not so clear, EMG increase is observed only at the end of this page.



stage W: A K-complex is recognized in the beginning of this page. Immediately after the K-complex, EMG increase and alpha activity are recognized. Prominent EMG artifacts on EEG and EOG recodings are observed after the middle of this page.



stage W: EMG artifacts are observed on EEG and EOG recordings in the first half of this page. Continuous alpha activity is observed in the last half.



stage W: Prominent EMG artifacts and alpha activity are recognized.