Short Communications

Circabidian rhythm: its appearance and disappearance in association with a bright light pulse

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Summary. A shift from circadian to circabidian periods or vice versa was observed in the rhythm of sleep and wakefulness under temporal isolation. The shift occurred in two subjects, 3 times in association with a single bright light pulse applied, 4 times in all. The finding suggests that the bright light pulse has an additional effect to the phase shift on the human circadian system.
Key words. Circadian rhythm; circabidian rhythm; sleep; bright light; temporal isolation.

Circabidian (about 48-h day) rhythms in sleep and wakefulness have been reported in human subjects who were isolated in a cave [1-3] or in an isolation facility [4] without knowledge of time. The circabidian rhythm is characterized by a period of about 48 h, and by an extremely lengthened waking time with a relatively small increase in sleep time. The waking time is often interrupted by a sleep episode which lasts as long as the normal night sleep, but which is taken by the subject as a nap [5]. The most interesting phenomenon associated with the circabidian rhythm is a change in the time sense of subjects. The subject perceives this approximately 48-h period as a 24-h day, and usually takes three meals during the prolonged waking period. On the other hand, the circadian rhythms in other body functions such as the rectal temperature persist, so that there are two peaks, for instance, in the body temperature during one sleep-wake cycle. Circabidian rhythms reported so far in healthy subjects appeared under free-run conditions, and spontaneously, without any recognizable triggering stimulus.

It is well known that the circadian organization of human body functions becomes altered under free-run conditions, and in an extreme case internal desynchronization takes place between the circadian rhythm in rectal temperature and the sleep-wake cycle [4]. The circabidian rhythm is called an apparent internal desynchronization [5], since the state is not a real desynchronization but a synchronization in 1:2 ratio. The human circadian system is thought to be protected from such disorganization by entraining to time cues (zeitgeber) in the external environment, because the internal desynchronization, regardless of whether it is real or apparent, has rarely been observed under entrain conditions, at least in healthy men.

Recently, bright light of more than 5000 1 × was demonstrated to be a potential zeitgeber for the human circadian system [6-8]. An artificial light cycle with bright light entrained the circadian rhythm in rectal temperature and the sleep-wake cycle [8]. In addition, a bright light pulse was shown to shift the phase of the free-running circadian rhythms in these variables [9]. The amount and direction (delay or advance) of the phase shift depended on the phase at which the light pulse was given.

In the present paper, we reported the appearance and disappearance of circabidian rhythms in association with a bright light pulse.

Two young subjects (A: male, 26 years; B: female, 20 years) separately spent 3 weeks in an isolation unit without knowledge of time.The time of sleep and wakefulness, the rectal temperature and several behaviors such as meal intake were monitored as described previously [8, 9]. We instructed the subjects not to sleep elsewhere than on the bed. The sleep pattern in routine life was recorded for one week immediately before and after the isolation experiment. There were two kinds of illumination in the unit, one with ordinary fluorescent light and the other one with fluorescent bright light. The light intensity of the ordinary light was 300–500 1 × at the level of the head in the living room, the kitchen, and the toilet. The subject was allowed to use the ordinary lights at any time. The instrument for bright light was located on the ceiling of the living room and could be controlled only from outside the unit. Its intensity was 5000 1 × at the level of the desk and 500 1 × at the position of a pillow on the bed. One week after the beginning of the experiment, the living room was illuminated by the bright light for either 3 or 6 h (light pulse). One week later, the room was illuminated again.

Figure 1 illustrates the sleep patterns and the troughs in the circadian temperature rhythm determined by visual inspection. Subject A showed a circabidian rhythm from day 3 in the isolation unit for 3 cycles. The mean sleep time was 9 h and 28 min (SD = 56 min) and the mean waking time was 39 h and 22 min (SD = 1 h and 30 min). The subject perceived this long waking period as a usual waking time. A short sleep episode on day 8 was taken as a nap by the subject. On day 9, a bright light pulse of 3 h duration was given in the early subjective day (morning). On the following days, the sleep pattern of the subject was changed from circabidian to circadian, and this circadian rhythm persisted for 8 cycles. The trough of the temperature rhythm slightly phase-advanced in response to the light pulse. On day 6, a 3-h light pulse was applied again at the late subjective day (evening). On the following day, the subject did not sleep at all and the waking time was extended up to 40 h and 30 min. The circabidian rhythm persisted for only one cycle this time. The phase of trough of the temperature rhythm was not influenced by the light pulse. The subject took 3 meals during the waking time, regardless of whether he showed a circadian or circabidian rhythm. The rectal temperature rhythm had a period of 25.5 h from day 10 to day 22.

A circabidian rhythm in sleep and wakefulness appeared in subject B after a light pulse of 6 h duration applied in the middle of sleep (day 8). On the day following the light pulse, the subject slept for a long time, 14 h. An extremely prolonged sleep (17 h and 25 min) was also observed two days after. A short sleep episode in between (day 10) was taken as a nap by the subject. As a result, the waking time was calculated to be 34 h and 25 min. The circadian temperature rhythm persisted but phase-advanced after this bright light pulse. This subject was exposed to bright light only for the last 2 h of the 6-h lighting period. This shortened light pulse, however, seemed to be effective in both the phase shift and the switch from circadian to circabidian periods, because, with the second light pulse, the subject was exposed to the lower intensity of light (500 1 ×) during sleep, as was the case with the first light pulse, but did not wake up until the light was turned off, and neither phase-shifting nor switching of the rhythm was observed. The circadian temperature rhythm had a period of 25.2 h from day 12 to day 20.

Figure 2 demonstrated the circadian temperature rhythms in both subjects during the circabidian rhythm. It is evident

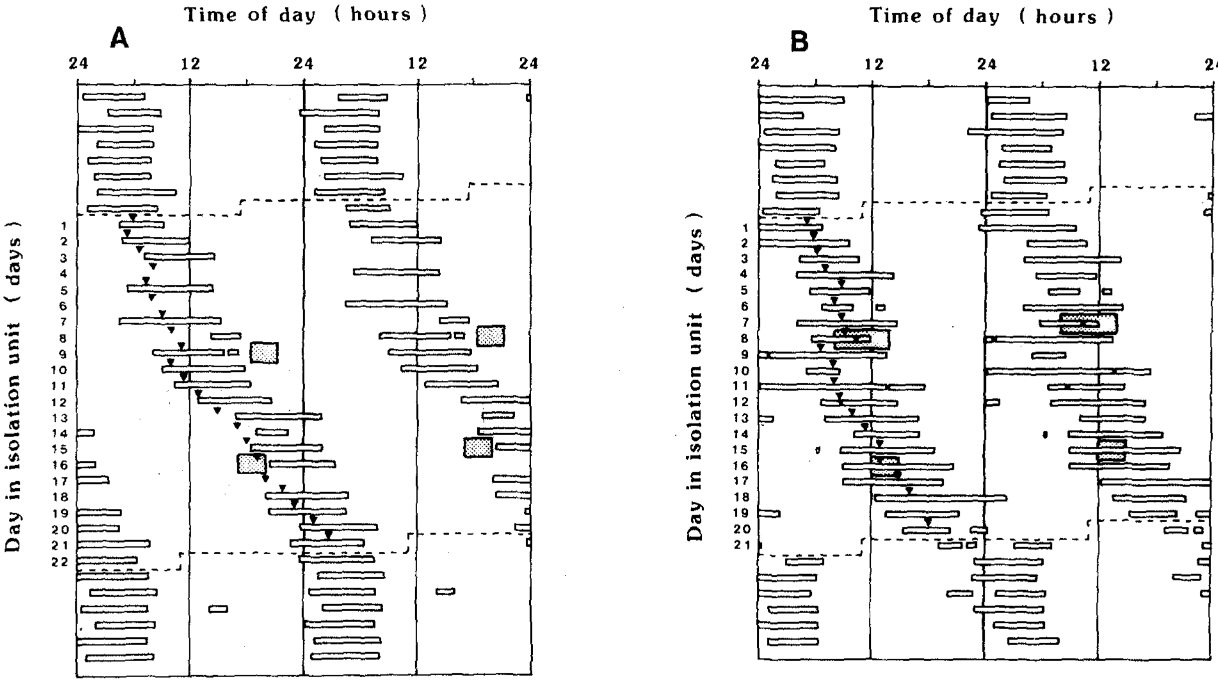

Figure 1. Double-plotted sleep rhythms and the daily troughs of the rectal temperature rhythm in two subjects (A and B). A horizontal open bar indicates a sleep episode and a closed triangle a time of the temperature trough. Shadowed squares represent bright light pulses; a long square is a pulse of 6 h duration and a short is a pulse of 3 h. Sleep episodes immediately before and after the isolation experiment are indicated above and below the dotted lines, respectively.

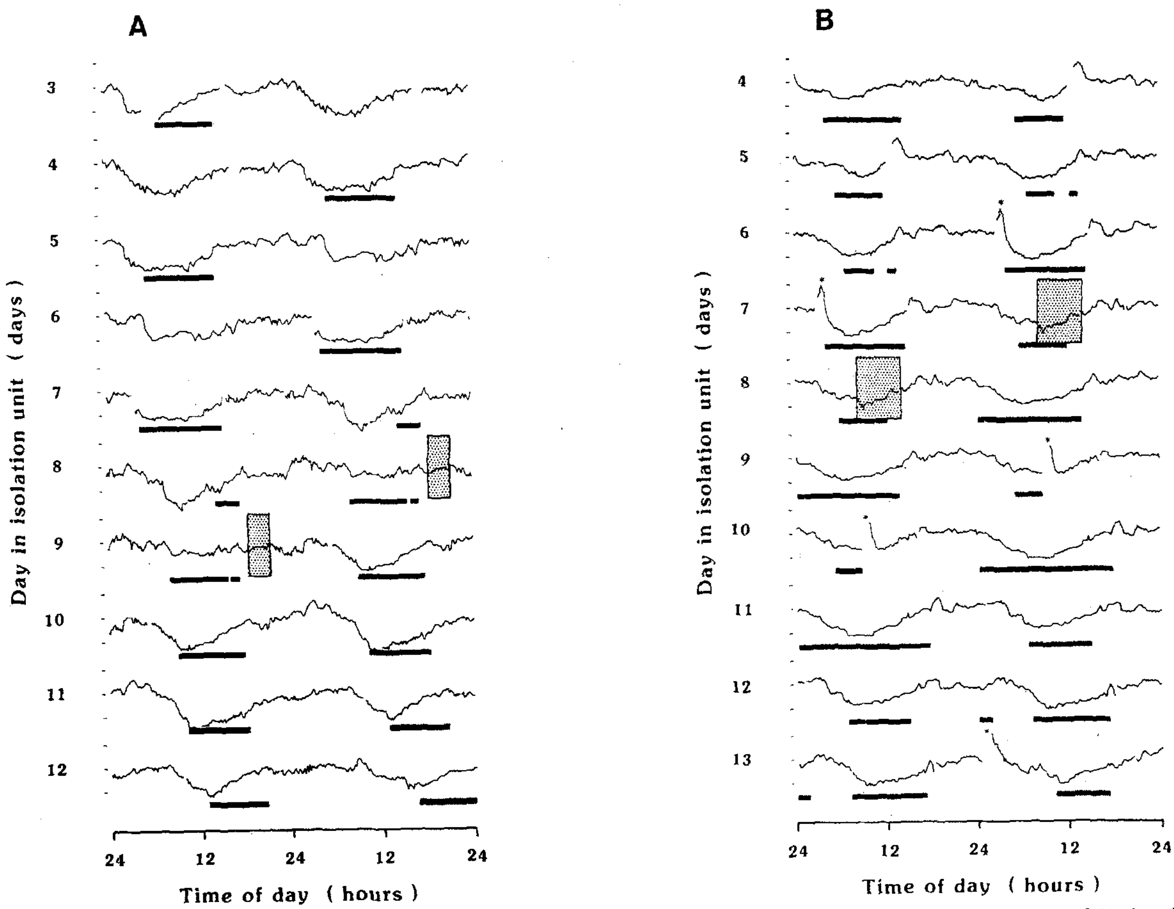

Figure 2. Double-plotted temperature rhythms in two subjects (A and B). A horizontal closed bar indicates a sleep episode. Shadowed squares represent bright light pulses; a long square is a pulse of 6 h duration and a short is a pulse of 3 h. Asterisk indicates the time of shower taking.

that the circadian temperature rhythm persisted without damping during the circabidian period.

Parts of the sleep-wake pattern observed in the present subjects are regarded as the circabidian rhythm. In subject A, the mean circabidian period of sleep-wake cycle was 48 h and 50 min from day 3 to day 8, and 49 h and 50 min from day 9 to day 11, while the body temperature rhythm kept a circadian period. In subject B, the circabidian rhythm persisted for only one cycle with two long sleep episodes with a short nap in between, and had a period of 49 h and 50 min. The circabidian rhythm in subject A appeared spontaneously the first time, and the second time on the day following the light pulse. The first circabidian rhythm disappeared after the light pulse, but the second one was replaced by the circadian rhythm without any recognizable trigger. The circabidian rhythm in subject B appeared on the day following the light pulse and disappeared spontaneously.

It is not known whether or not there is a causal relation between bright light and the circabidian rhythm. The vicissitude of the circabidian rhythm observed in association with the light pulse might be an accidental coincidence. However, it is possible to relate the appearance and disappearance of the circabidian rhythm to the bright light pulse. The bright light pulse phase-advanced the free-running human circadian rhythms when it was applied early in the subjective day, and slightly phase-delayed them when applied late in the subjective day[9]. In addition to the phase shift, Czeisler et al.[10] reported that bright light changes the amplitude of the circadian rhythm in rectal temperature. On the other hand, Daan et al.[11] predicted in their two-process model that the change in the amplitude of the circadian oscillation (represented by the circadian temperature rhythm) will produce a circabidian period in the sleep-wake cycle. Taking these together, it is tempting to speculate that the bright light pulse changes the amplitude of the circabidian rhythm. Alternatively, the bright light pulse may change the threshold for sleep, which is also a possible cause of the circabidian rhythm in the two-process model[11].

The circabidian rhythm in mood has been reported in psychiatric disorders, especially in manic-depressives[12-14]. Recently, bright light therapies have been introduced in the treatment of a certain type of depression[15]. The pathophysiology of why bright light is beneficial is a matter of debate, but it seems to be generally accepted that an abrupt change in the circadian system is related to the improvement of the illness[16]. This is also suggestive of a causal relationship between the bright light pulse and the circabidian rhythm.

Of course, it is premature to draw any conclusion from the present two cases on the causal relation between bright light and the circabidian rhythm. However, the findings obtained here may provide some insight into the mechanism of the circabidian rhythm.

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Nonlinear dynamics in sudden cardiac death syndrome: Heartrate oscillations and bifurcations

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Summary. Patients at high risk of sudden cardiac death show evidence of nonlinear heartrate dynamics, including abrupt spectral changes (bifurcations) and sustained low frequency (.01 – .04 Hz) oscillations in heartrate.
Key words. Autonomic nervous system; electrocardiography; fractals; heart failure; nonlinear dynamics; ventricular fibrillation; ventricular tachycardia.

In the United States, sudden cardiac death is the leading cause of death among men aged 20–60 years[1]. We proposed[2-5] that nonlinear dynamics, a new branch of the basic sciences devoted to the mathematical analysis of complex systems, could be used to interpret the fluctuations in heartrate associated with the electrical instability exhibited