The History of Polysomnography

Maryann Deak, MD[a,*], Lawrence J. Epstein, MD[a,b]

KEYWORDS

• Polysomnography • Sleep • Sleep stages
• Rapid eye movement • Sleep apnea • Narcolepsy

The state of sleep has fascinated people for a very long time. In his treatise on sleep and sleeplessness, Aristotle wrote that sleep is "a seizure of the primary sense-organ, rendering it unable to actualize its powers; arising of necessity… for the sake of its conservation." But, he wondered, "what are the processes in which the affection of waking and sleeping originates, and whence do they arise? We must also inquire what the dream is, and from what cause sleepers sometimes dream, and sometimes do not and whether it is possible or not to foresee the future (in dreams)."[1]

It should not be surprising to be curious about something that occupies a third of our lives. It was not until technology was developed that allowed one to peer inside the resting brain, however, that an understanding of sleep began. The development of sleep science and sleep medicine has been intertwined with the development of the polysomnogram, the method for recording the physiologic changes during sleep that has allowed the description of what happens during what one early writer called "the intermediate state between wakefulness and death."[2]

RECORDING SLEEP

Physiologic Recordings of Brain

Before the physiology of sleep could be explored, the scientific community needed a practical means of examining the natural oscillation of the brain from moment to moment. In 1875, Richard Caton (**Fig. 1**), a Scottish physiologist, was the first to record electrical rhythms originating from the brains of rabbits and monkeys.[3] In a brief paragraph summary of a live presentation, Caton recounted his observation that every brain he tested had electrical currents as indicated by a galvanometer. He rightly conjectured that the activity he observed was related to brain function.

Years later, in 1929, German psychiatrist Hans Berger (**Fig. 2**) succeeded in recording electrical activity of the human brain.[4] Not only did this discovery grant scientists a window into the brain's activity; the ability now existed to measure it quantitatively. Berger coined the term "electroencephalogram (EEG)." Moreover, Berger was able to demonstrate pattern changes between wakefulness and sleep.

Physiologic Recording of Sleep

In the 1930s, several American investigators used the EEG to describe intricately the brain's electrical activity. Two main research groups generated prolific writings on the subject: Harvey, Hobart, Loomis, Davis, and others at Harvard University,[5,6] and Blake, Gerard, and Kleitman at the University of Chicago.[7,8] Loomis and coworkers[9] were the first to describe the characteristic features that now comprise non–rapid eye movement sleep. Loomis recorded overnight and daytime sleep in 30 individuals. He characterized sleep into five stages: A (alpha), B (low voltage), C (spindle), D (spindle and random), and E (random). Alpha was described as the normal waking rhythm. "Low voltage" occurred when alpha disappeared, which corresponds to today's stage 1 sleep. Stage C or "spindles" were 14-Hz waves, which were also accompanied by "random" or delta waves.

[a] Division of Sleep Medicine, Brigham and Women's Hospital, Harvard Medical School, 75 Francis Street, Boston, MA 02115, USA
[b] Sleep Health*Centers*, 1505 commonwealth Avenue, Brighton, MA 02135, USA
* Corresponding author.
E-mail address: maryann_deak@sleephealth.com (M. Deak).

Sleep Med Clin 4 (2009) 313–321
doi:10.1016/j.jsmc.2009.04.001
1556-407X/09/$ – see front matter © 2009 Elsevier Inc. All rights reserved.

Fig. 1. Richard Caton. Pioneer who developed a method for recording electrical impulses from the surface of brains in animals.

Loomis described delta waves as becoming longer in stage D until they became predominant and spindles disappeared in stage E, similar to the current description of stage 3 sleep. Loomis and colleagues[9] listed the stages in order of appearance and "in order of resistance to change by disturbances." Blake and Gerald[7] further explored sleep depth by studying the sleep of healthy adults, attempting to disturb sleep at each stage and measuring the amount and duration of a stimulus that was required to elicit a response from the research subject. They concluded that "deep sleep" is associated with large amplitude, slow waves at a frequency of 0.5 to 3 per second.

The series of articles that followed from the Harvard and the University of Chicago groups further described the stages initially proposed by Loomis. Not only did these experiments serve to explore and define the normal physiology of sleep, but the experimenters began to modify and improve the methods through which sleep was studied. Nathaniel Kleitman (**Fig. 3**) designed a means of measuring movement during sleep and used this technique during experimental sleep recordings.[8] Through the work of these scientists and others, EEG recording methods evolved, including use of amplifiers and high- and low-pass filters. Additionally, the experimenters learned that certain waveforms that characterize stages of sleep versus wakefulness were best recorded from specific regions of the brain.[8] The "14 per second rhythm"

Fig. 2. Hans Berger. He made the first recording of electrical activity of the human brain.

Fig. 3. Nathaniel Kleitman. Established one of the foremost laboratories for the study of sleep at the University of Chicago, where full-night sleep studies allowed the discovery of rapid eye movement sleep.

that was termed a "spindle" was best seen at the vertex. The "10 per second" trains that were present in wakefulness with eyes closed were observed most frequently at the occiput. As a result, certain channels of the EEG gained importance in the recording of sleep. In addition to EEG and movement, sleep researchers experimented with channels that recorded new ancillary information, such as heart rate and respirations.[9]

In the 1950s, the discovery of rapid eye movement sleep (REM) by Kleitman's group advanced the field of sleep research. Kleitman had a particular interest in eye movement as a potential indicator of cortical activity in sleep. Aserinsky, a graduate student working with Kleitman at the University of Chicago, began directly observing eye movements in sleeping infants, noting distinct periods of eye motility and quiescence in sleep. He observed similar periods in sleeping adults. To avoid the necessity of direct observation, Kleitman and Aserinksy devised the electro-oculogram (EOG) as a means of conveniently and quantitatively measuring eye movements. This device distinguished between slow eye movements and REM. When used in conjunction with EEG and body movement channels, EOG extended the ability to evaluate the physiology of sleep.

During one experiment, Kleitman and Aserinksy observed the sleep of 20 healthy adults, awakening some of the subjects during periods of REM or quiescence for questioning on the content of their dreams.[10] They noted that patients were more likely to report vivid dreams, particularly involving visual imagery, during periods of REM than during periods when eye movements were not present. During periods without REM, the patients could not recall dreams or dreams were ill-defined. The EEG that accompanied REM periods consisted of a low voltage pattern that did not contain spindles or delta waves. Additionally, Aserinsky and Kleitman noted that respiration and heart rate increased during periods of REM. They concluded that the REMs and accompanying autonomic changes represented physiologic alterations associated with dreaming.

Although the discovery of Aserinsky and Kleitman brought the field closer to the notion that REMs represented a distinct stage of sleep, the periodicity and order of sleep stages was not understood. To conserve resources, experimenters had hitherto used short sleep recordings or intermittent sampling of sleep throughout the night to examine sleep. Kleitman and Dement wished to explore REM further to confirm the presence of characteristic concomitant EEG changes and determine the frequency of such periods. They realized that they needed to study full nights of uninterrupted sleep intensively to achieve their goal. Kleitman and Dement (**Fig. 4**) used EEG, EOG, and movement channels to study 126 nights of sleep in 33 adults.[11] They discovered a recurring sequence of sleep stages, beginning with light (stage 1) sleep and progressing to deeper stages of sleep until reaching stage 4. After stage 4, sleep would lighten again. REM periods occurred every 90 to 100 minutes, and the periods lengthened as the night progressed. The EEG during REM periods consisted of a characteristic pattern that closely resembled light sleep or stage 1. They noted that stage 1, however, which occurred only at sleep onset, was never associated with REM; and patients responded to auditory stimuli more readily during stage 1 than during REM. Importantly, they observed that body movement dropped sharply at the onset of REM and rebounded at the conclusion of REM. This sequence was predictable among individuals and within one individual from night to night. From studying full nights of sleep, Kleitman and Dement were able to describe the human sleep cycle and created a new precedent for EEG recording.

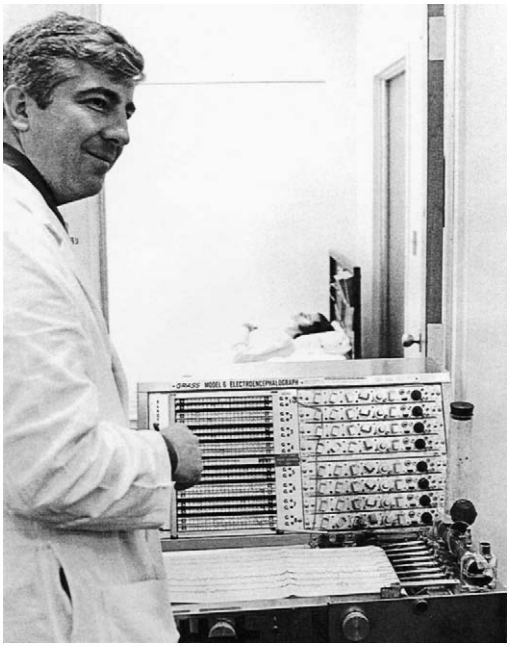

Fig. 4. William Dement. He participated in the discovery and description of the human sleep cycle and started the first sleep clinic at Stanford University. (*From* Dement WC, Kushida CA, Chang J. History of sleep deprivation. In: Kushida C, editor. Sleep deprivation: basic science, physiology, and behavior. New York: Taylor and Francis (previously Marcel Dekker); 2005. p. 38; with permission.)

FROM RECORDING TO SCORING SLEEP

The Rechtschaffen and Kales Manual

After Dement and Kleitman's article was published in 1957,[11] sleep researchers began to routinely use their description of clinical sleep stages. Over the subsequent 10 years, the sleep community expressed growing concern about the reproducibility and interrater reliability of sleep scoring. Moreover, researchers wanted to ensure that results of research studies could be reasonably compared, which would not be possible if laboratories used different methods of scoring sleep. Monroe[12] published an article in 1969 that showed that interrater reliability between laboratories was low, particularly for scoring of non-REM sleep.

A group of sleep researchers decided to meet to begin discussing the development of a standard scoring system for stages of sleep. The first meeting of the Association for the Psychophysiological Study of Sleep was held in 1960, but it was not until 1967 that a committee of investigators with considerable experience scoring sleep records, led by Allan Rechtschaffen and Anthony Kales, was tasked with developing a terminology and scoring system that might be universally used by sleep researchers.[13] The group devised a manual of sleep scoring entitled *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*, which was published in 1968.[13] The work of Dement and Kleitman formed the cornerstone of the newly published manual. The Rechtschaffen and Kales manual included a detailed description of sleep stage scoring based on the characteristics of the EEG, EOG, and electromyogram when viewed in 30-second epochs. Additionally, the manual included technical considerations for the recording of sleep. The intention of Rechtschaffen and Kales was for the publication to be "viewed as a working instrument rather than a statute," with the idea that the handbook required revision over time.

Limitations of Rechtschaffen and Kales

The sleep community widely accepted the Rechtschaffen and Kales manual, which became the gold standard for sleep stage scoring and remained so for nearly 40 years. As the field advanced, limitations of the sleep manual became apparent. Moreover, the manual was not revised to account for changes in the field, as intended by the original editors. Of concern was the use of the Rechtschaffen and Kales manual to study pathologic sleep when it had only been designed to study normal sleep.[14] The manual did not take into account important phenomenon including arousals; autonomic nervous system activity, such as cardiac rate and rhythm; respiratory abnormalities; body movement; or behavior in sleep. The manual was designed for paper recordings; many technical considerations in the original manual were no longer applicable with the widespread use of digital recordings. Additionally, some researchers disagreed with specific channel choices in the original manual, such as the use of only one EEG channel of central derivation.

Development of a New Scoring Manual

Although there were earlier attempts to revise the rules for sleep scoring, including a system for scoring arousals[15] and a manual for scoring the sleep of newborns,[16] a full-scale revision of the scoring manual was not accomplished until the American Academy of Sleep Medicine (AASM) commissioned the development of a new scoring manual. The effort was spearheaded by a steering committee of sleep experts. Between 2004 and 2006, several task forces were assigned to review the published evidence on specific topics and write a review article. The topics covered by the task forces included visual scoring, digital scoring, arousal, movement, respiratory issues, and cardiac issues.[17] Two additional task forces reviewed sleep scoring for pediatric and geriatric patient populations. The work of the task forces, in concert with the steering committee, culminated in a series of review articles published in the *Journal of Clinical Sleep Medicine*,[18–24] followed by publication of the *AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology, and Technical Specifications* in 2007.[17]

ROLE OF POLYSOMNOGRAPHY IN THE DEVELOPMENT OF SLEEP MEDICINE

From the 1930s through the 1950s, scientists worked to reveal the properties of normal sleep. Concomitantly, the technology of recording sleep evolved. By the end of the 1950s, experimenters were performing full-night recordings of sleep. Beginning in the early 1960s and going forward, sleep researchers began to apply the new technology to study sleep pathology. The field of clinical sleep medicine began to develop beside a growing discipline of sleep research.

Narcolepsy

Although the clinical manifestations of narcolepsy had been described previously, narcolepsy as a clinical entity was poorly understood in the late

1950s and early 1960s. Narcolepsy was not substantiated as an epileptic phenomenon by EEG studies in narcolepsy patients.[25] Many scientists theorized that narcolepsy was a psychiatric disorder, and the clinical features of narcolepsy represented "repression of feelings" that are "unacceptable to consciousness."[26] By recording sleep in narcolepsy patients, however, physicians gained new insight into the disorder.

In 1959, Charles Fisher recorded a sleep-onset REM period in a patient with narcolepsy at Mount Sinai Hospital. The next year, Gerald Vogel published a case report of a patient with narcolepsy, which documented sleep-onset REM on EEG during a sleep attack. As the patient described dreams at sleep onset, Vogel[27] surmised that narcolepsy patients had an inherent need to dream "for the projection of fantasy." Finally, in 1963, Rechtschaffen and coworkers[28] observed full-night sleep recordings in nine narcolepsy patients. The patients were each studied for 18 nights, between one and three nights in succession, and the data were compared with control subject data. The most striking finding was the presence of sleep-onset REM periods in narcolepsy patients. The authors conjectured that cataplexy, sleep paralysis, and hypnagogic hallucinations represented features of REM occurring in wakefulness. They further speculated about the underlying cause of narcolepsy. Based on the contemporary understanding that REM sleep originated in the pontine reticular formation, the authors surmised that "precocious triggering" of this region of the brain led to narcolepsy. The concept that a specific neuroanatomic localization could be tied to narcolepsy was novel. Once again, full-night sleep recordings completely revolutionized the existing theories about sleep and sleep disorders.

The Stanford Narcolepsy Clinic

When Dement moved to Stanford University in the early 1960s, he hoped to continue to research the sleep of narcolepsy patients.[29] When recruitment of patients proved difficult, Dement placed an advertisement in the *San Francisco Chronicle*, which yielded a large number of responders. Half of the patients who responded to the advertisement were diagnosed with narcolepsy with cataplexy. Dement and Stephen Mitchel began to follow narcolepsy patients clinically at regular intervals. Working within the constraints of testing permitted by insurance companies, they performed daytime sleep recordings on all patients and full-night sleep recordings whenever possible. The Stanford clinic represented the first specialized sleep clinic of its kind, growing out of the clinical research interests of its founders. As research interests grew, so did the number and diversity of patients in the clinic, including insomnia patients. By the 1970s, several sleep centers developed, which also grew from clinical research interests. There are now over 1500 sleep centers and laboratories accredited by the AASM, which likely represents about half of the existing centers and laboratories.

Sleep Apnea

In 1956, Bickelmann and colleagues[30] described a patient with obesity, hypoventilation, muscular twitching, and hypersomnolence. They named this constellation of symptoms the "pickwickian syndrome," based on the similarity to a character in Charles Dicken's *The Posthumous Papers of the Pickwick Club*. In the 1956 paper, which was based on observations of the patient during the day, the authors ascribed the patient's sleepiness to hypercapnia. This idea was perpetuated and accepted by the medical community until further clinical studies using overnight sleep recordings demonstrated the existence of sleep apnea.

EEG, EOG, and body movement channels were used in the first full-night recordings of sleep. As the sleep field advanced, researchers began to study other aspects of sleep, including respirations. In the early 1960s, two groups of researchers in Europe examined full-night sleep recordings in patients with the pickwickian syndrome. In Germany, Jung and Kuhlo recorded EEG, chest movements with an inflatable belt, carbon dioxide content of expired air, and heart rate in three patients. They observed that pickwickian patients experienced discontinuous sleep, interrupted by apneic periods. The apneic episodes were followed by a deep breath and acceleration of heart rate, which the authors interpreted as "an emergency reaction to severe hypercapnia and hypoxia." The patients rarely attained deep stages of sleep or significant periods of REM sleep. With regard to the underlying etiology of the phenomena they observed, the authors surmised that pickwickian patients had decreased sensitivity to carbon dioxide, causing not only the apneas observed in sleep but chronic hypoventilation in wakefulness. In all three patients, loss of 10 to 20 kg of weight resulted in remarkable improvement in daytime symptoms, although apneas persisted in two out of the three patients.

In France, Gastaut and coworkers[31] studied a similar patient population with all-night sleep recordings. An important change in technique

permitted a markedly different interpretation of their findings, however, compared with Jung and Kuhlo. Rather than testing the carbon dioxide content of expired air, the French group analyzed airflow in the nostrils and mouth. Both the German and French experimenters measured movement of the thorax. Gastaut and colleagues[31] observed that despite a cessation of airflow at the mouth and nose during an apnea, movement of the thorax and respiratory muscle activity persisted. The authors concluded that a blockage in the airway triggered the episodes of apnea, rather than central nervous system dysfunction related to sensitivity to carbon dioxide, as previously suggested. The idea of airway obstruction was further supported by studies that observed polygraph recordings before and after tracheostomy.[32,33] Improvement in patient symptoms that accompanied resolution of obstruction revealed that daytime somnolence was more likely to be related to sleep disruption than to hypercapnia. Using similar techniques to perform additional overnight recordings, Gastaut and others were able further to characterize apnea as obstructive, central, or mixed. Once again, innovative techniques for recording sleep were necessary to advance sleep research.

Growth of Clinical Application of Polysomnography

Advancement in sleep research in concert with full-night sleep recordings permitted valuable insights into disease processes, sometimes in unexpected ways. Another example was restless leg syndrome. When patients with restless leg syndrome underwent sleep recordings, they demonstrated periodic involuntary leg movements.[34] EEG proved that these periodic limb movements were not a form of epilepsy; rather, restless leg syndrome could be counted among the sleep disorders.

As full-night sleep recordings gained importance, so did the specific techniques use by laboratories. Because many of the research studies that described sleep apnea occurred in Europe, researchers outside of the United States began routinely using cardiac and respiratory channels in their full-night sleep recordings before their American counterparts. When French neurologist and psychiatrist, Christian Guilleminault, joined the Stanford group in 1972, he introduced the routine monitoring of respiratory and cardiac parameters in sleep recordings at the Stanford clinic.[29] Although the Stanford clinic began by treating narcolepsy and, later, added insomnia patients, the clinic was now equipped to diagnose and treat patients with sleep apnea. Jerome Holland first coined the term "polysomnogram" in 1974 to describe the measurement of multiple physiologic parameters during sleep.[35]

Barriers to Use of Polysomnography

Barriers to the use of polysomnography (PSG) surfaced as the number of sleep clinics and use of sleep testing grew.[29,36] The studies required clinicians to work through the night, which was unpopular especially for an outpatient test. Also, it was nearly impossible for clinicians to work in clinic during the day and conduct sleep studies in the laboratory through the night. The studies were very involved for the patients, and the idea of spending a night in the sleep laboratory took some adjustment. From a practical standpoint, the studies were expensive, and PSG was not established as a reimbursable test until 1975. The polygraphs were large, used ink pens, and required careful calibration before each study (**Fig. 5**). Also, the studies generated a tremendous amount of paper, which was difficult for laboratories to manage. The sleep field worked to alleviate some of these concerns by lobbying for reimbursement and developing computer polysomnograms that made recording sleep easier. Additionally, the medical community did not easily accept sleep medicine as a field. Only after years of research and clinical work did the importance of sleep disorders begin to gain recognition.

PARALLEL GROWTH OF THE FIELD OF SLEEP TECHNOLOGY

Against the backdrop of increasing demand for PSG and the growing clinical applicability of PSG, it became more impractical for sleep clinicians to perform PSG on a nightly basis. The growing sleep field required a new group of skilled professionals to ensure accurate and meticulous execution of this important diagnostic test. The first technologists originated from diverse backgrounds, including electroneurodiagnostics and respiratory therapy.[37] In 1978, a group of technologists met at an academic meeting and created the Association of Polysomnographic Technologists. The group's mission was to unite a cohesive group of professionals for the promotion of education and advancement of the new field.[38] The group appointed a committee, the American Board of Registered Polysomnographic Technologists, to create a certification examination. In 1979, the first examination was administered by the renamed Board of Registered Polysomnographic Technologists. The profession of sleep technology has grown in parallel to the field of

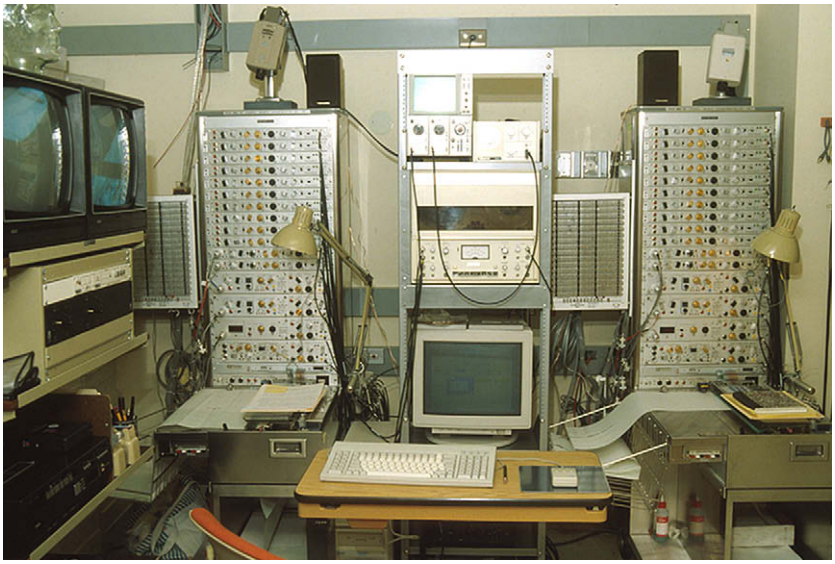

Fig. 5. Analog sleep system. Two-bed sleep laboratory at the University of Wisconsin, 1988. (*Courtesy of* S. Weber, Madison, WI.)

sleep medicine, experiencing an exponential increase in certified sleep technologists to over 13,000 technologists since the inception of the board examination.

Sleep medicine originated from other specialties. Once a sufficient body of knowledge requiring a unique skill set developed, an independent medical specialty evolved. A similar course has been followed by sleep technology. Training in electroneurodiagnostics, respiratory therapy, or cardiopulmonary technology is no longer sufficient to acquire all the skills required for sleep technology without additional training. Training in sleep technology was initially available only as on-the-job training. This localized training resulted in site-specific protocols and inconsistency in the practice of sleep technology. To address this issue the AASM launched a sleep technology initiative in 2005 in conjunction with the American Association of Sleep Technology (the successor to Association of Polysomnographic Technologists) and the Board of Registered Polysomnographic Technologists.[37] The goals of the initiative were to standardize training in sleep technology, raise the educational level of sleep technology training programs, and ensure proper credentialing of all technologists.

The AASM created the accredited sleep technologist education program (called ASTEP) to standardize on-the-job training training. Step 1 is a standardized didactic entry course. Step 2 is on-the-job training in a laboratory along with completion of computerized self-education modules. The last step is credentialing by the Board of Registered Polysomnographic Technologists following 18 months of on-the-job training. At the same time, college-based sleep technology allied health programs are being developed. The programs are accredited by the Commission on Accreditation of Allied Health Education Programs, the accrediting body for allied health training programs. These programs can be in addition to respiratory therapy or electroneurodiagnostic training, or stand-alone sleep technology programs. Once there are sufficient college-based programs to supply the field adequately, the on-the-job training programs will be phased out. At that point, the field of sleep technology will have the same training pathways as other allied health fields. In addition, state legislatures have begun to establish licensing requirements for sleep technologists. The field of sleep technology has come of age.

SUMMARY

Similar to the first anatomists or the first radiographers, sleep scientists and physicians used EEG and later PSG as means of "peering in" to the workings of the human body with the hope of gaining understanding. The rapid advancement of sleep research, made possible by the development of the PSG, permitted not only a deeper understanding of normal sleep, but a more complete picture of the pathologic processes that affect sleep. The twentieth century not only fine-tuned the PSG as a research tool and vital diagnostic test, but also made possible the creation of a new medical specialty and a new allied health field.

REFERENCES

1. Aristotle. On sleep and sleeplessness. Beare JI, trans. Adelaide, Australia: eBooks@Adelaide, University of Adelaide; 2007
2. Macnish R. The philosophy of sleep. Glasgow: W.R. McPhun; 1836.
3. Caton R. The electric currents of the brain. Br Med J 1875;2:278.
4. Berger H. Uber das elektroenenkeephalogramm des menschen [On the human electroencephalogram]. Archiv f. Psychiatr Nervenkr 1929;87:527–70 [in German].
5. Davis H, Davis PA, Loomis AL, et al. Changes in human brain potentials during the onset of sleep. Science 1937;86(2237):448–50.
6. Davis H, Davis PA, Loomis AL, et al. Human brain potentials during the onset of sleep. J Neurophysiol 1938;1:24–38.
7. Blake H, Gerard RW. Brain potentials during sleep. Am J Physiol 1937;119:692–703.
8. Blake H, Gerard RW, Kleitman N. Factors influencing brain potentials during sleep. J Neurophysiol 1939; 2:48–60.
9. Loomis AL, Harvey EN, Hobart GA. Cerebral states during sleep as studied by human brain potentials. J Exp Psychol 1937;21:127–44.
10. Aserinsky E, Kleitman N. Regularly occurring periods of eye motility, and concomitant phenomena, during sleep. Science 1953;118(3062):273–4.
11. Dement W, Kleitman N. Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. Electroencephalogr Clin Neurophysiol 1957;9(4):673–90.
12. Monroe LJ. Inter-rater reliability and the role of experience in scoring EEG sleep records: Phase 1. Psychophysiology 1969;5(4):376–84.
13. Rechtschaffen A, Kales A. A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Los Angeles: Brain Information Service/Brain Research Institute University of California; 1968.
14. Himanen SL, Hasan J. Limitations of Rechtschaffen and Kales. Sleep Med Rev 2000;4(2):149–67.
15. EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. Sleep 1992;15(2):173–84.
16. Anders T, Emde R, Parmelee AH. A manual of standardized terminology, techniques and criteria for scoring of states of sleep and wakefulness in newborn infants. Los Angeles (CA): UCLA Brain Information Services, NINDS Neurological Information Network; 1971.
17. Iber C, Ancoli-Israel S, Chesson A, et al. The AASM Manual for the scoring of sleep and associated events: rules, terminology and technical specifications. 1st edition. Westchester (IL): American Academy of Sleep Medicine; 2007.
18. Penzel T, Hirshkowitz M, Harsh J, et al. Digital analysis and technical specifications. J Clin Sleep Med 2007;3(2):109–20.
19. Silber MH, Ancoli-Israel S, Bonnet MH, et al. The visual scoring of sleep in adults. J Clin Sleep Med 2007;3(2):121–31.
20. Bonnet MH, Doghramji K, Roehrs T, et al. The scoring of arousal in sleep: reliability, validity, and alternatives. J Clin Sleep Med 2007;3(2): 133–45.
21. Caples SM, Rosen CL, Shen WK, et al. The scoring of cardiac events during sleep. J Clin Sleep Med 2007;3(2):147–54.
22. Walters AS, Lavigne G, Hening W, et al. The scoring of movements in sleep. J Clin Sleep Med 2007;3(2): 155–67.
23. Redline S, Budhiraja R, Kapur V, et al. The scoring of respiratory events in sleep: reliability and validity. J Clin Sleep Med 2007;3(2):169–200.
24. Grigg-Damberger M, Gozal D, Marcus CL, et al. The visual scoring of sleep and arousal in infants and children. J Clin Sleep Med 2007;3(2):201–40.
25. Daly DD, Yoss RE. Electroencephalogram in narcolepsy. Electroencephalogr Clin Neurophysiol 1957; 9(1):109–20.
26. Switzer RE, Berman AD. Comments and observations on the nature of narcolepsy. Ann Intern Med 1956;44(5):938–57.
27. Vogel G. Studies in psychophysiology of dreams. III. The dream of narcolepsy. Arch Gen Psychiatry 1960;3:421–8.
28. Rechtschaffen A, Wolpert EA, Dement WC, et al. Nocturnal sleep of narcoleptics. Electroencephalogr Clin Neurophysiol 1963;15:599–609.
29. Dement WC. History of sleep physiology and medicine. In: Kryger MH, Roth T, Dement W, editors. Principles and practice of sleep medicine. 4th edition. Philadelphia: Elsevier; 2005. p. 1–12.
30. Bickelmann AG, Burwell CS, Robin ED, et al. Extreme obesity associated with alveolar hypoventilation; a pickwickian syndrome. Am J Med 1956; 21(5):811–8.
31. Gastaut H, Tassinari CA, Duron B. [Polygraphic study of diurnal and nocturnal (hypnic and respiratory) episodal manifestations of Pickwick syndrome]. Rev Neurol (Paris) 1965;112(6):568–79 [in French].
32. Kuhlo W, Doll E, Franck MC. [Successful management of pickwickian syndrome using long-term tracheostomy]. Dtsch Med Wochenschr 1969; 94(24):1286–90 [in German].
33. Lugaresi E, Coccagna G, Mantovani M, et al. [Effects of tracheotomy in hypersomnia with periodic respiration]. Rev Neurol (Paris) 1970;123(4):267–8 [in French].

34. Lugaresi E, Coccagna G, Tassinari CA, et al. [Polygraphic data on motor phenomena in the restless legs syndrome]. Riv Neurol 1965;35(6):550–61 [in Italian].
35. Atkinson JW. The evolution of polysomnographic technology. In: Butkov N, Lee-Chiong T, editors. Fundamentals of sleep technology. Philadelphia: Lippincott, Williams & Wilkins; 2007. p. 1–5.
36. Kuhl W. History of clinical research on the sleep apnea syndrome: the early days of polysomnography. Respiration 1997;64(Suppl 1):5–10.
37. Epstein LJ. Polysomnographic technologists: troubled waters ahead? J Clin Sleep Med 2005;1(1):14–5.
38. Shepard JW Jr, Buysse DJ, Chesson AL Jr, et al. History of the development of sleep medicine in the United States. J Clin Sleep Med 2005;1(1):61–82.