International Journal of Clinical Monitoring and Computing **9**: 111–116, 1992.

A computerized system for acquisition and evaluation of polysomnographic recordings

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Accepted 31 January 1992

Key words: data acquisition, data collection, polysomnography, sleep apnea syndrome, chronic obstuctive pulmonary disease

Abstract

A computer system has been designed for acquisition and evaluation of polysomnographic recordings. The aim is to create a system running on a microcomputer emulating all functions of a conventional chart recorder and offering the advantage of making computer assisted evaluations. We have done 87 investigations in the first year of operation and were fully satisfied by the performance of the system. The standard signals we recorded were SaO2, heart rate, respiratory effort, nasal and oral airflow and ECG, as well as EOG, EMG and EEG. Due to this new method, evaluation of the recording can be done in less time than with strip chart recordings and the use of hundreds of pages of paper per night can be avoided.

Introduction

Some years ago polysomnographic recordings were exclusively done with chart recorders producing several hundred pages of paper per night. The evaluation took a long time, including sleep staging up to 4 hours. With the development of faster microcomputers and a wide range of add-ons for personal computers it was possible to devise systems capable of recording several parameters for several hours. As the diagnostic interest in the sleep apnea syndrome increased we had to determine what system we could use. At that time we were not satisfied by the computer systems available for medical use because the costs were pretty high and the performance not as good as we expected. So we decided to develop our own system [1, 2]. It had to fulfil the following criteria:

(1) Use of a standard microcomputer with easily available hard- and software.
(2) Online data display and storage at sample rates high enough to get EEG and ECG signals.
(3) Easily programmable to satisfy individual requirements.
(4) Compatibility with the existing and projected hospital computer system.

Description of the system

Hardware

The computer is an IBM-AT compatible personal computer with an 80286/12 CPU. Our prototype has one 5 1/4' floppy disk drive (1.2 MB) and one harddisk with 80 MB (20 ms). For display we use a color monitor/grafics adapter combination with EGA-resolution (350 × 640 pixel). Although today VGA resolution is standard, we have to use EGA-hardware because the acquisition hardware

can only handle video signals produced by original enhanced grafics adapters. This will be discussed later.

For safety reasons all devices are powered by a 600 W security transformer to be isolated from the mains according to local laws [3]. Anyhow a safety transformer is recommended for computer applications to protect the system from voltage peaks in the supply line.

Data backup is perfomed on tape streamer cartridges (120 to 240 MB, Irwin). Our streamer is located at a remote site connected via Ethernet and Novell Netware 2.2. It replaces data storage to 2400 ft magnetic tapes on a PDP11/73 used formerly [4].

For data acquisition we use an AD-converter card with 12 bit resolution and 16 single ended inputs (Burr Brown PCI 20089W-1). The core of the data acquisition is a special adapter card called 'waveform scroller' (WFS 200, Fa. DATAQ Instruments, Akron, OH). This card features three different functions if used with the provided software:

(1) The card reads data from the AD-converter board.
(2) The card provides a mode of sending data continuously to harddisk at speeds up to 8000 bytes per second on a 80286/12 CPU.
(3) While streaming data to disk the card displays acquired data to the screen in real time. This is achieved through a vector grafic subunit on the card displaying up to 8 data vectors (selectable out of the 16 input channels) simultanously. The curves are scrolled from the right to left side of the screen in the way ECG-monitors do. This provides a good display of data during acquisition and replay.

    It is possible to extend this system to online data analysis if the full sample rate is not used. Software drivers and examples are provided at no extra costs. Our software currently does not use this feature.

The AD-converter is connected to several analogue devices such as pulsoxymeter (providing SaO2 and heart rate), induction plethysmograph for respiratory effort, thermistors for nasal and oral airflow and preamplifiers for ECG, EMG, EEG and EOG.

Software

Currently the system runs under MS-DOS 5.00. To allow easy access of not specially trained personal we installed the DOSSHELL. From this level the desired functions can be selected. The software consists of one main program and several subprograms. The main program originally written in dBase III (trademark of Ashton Tate) was compiled and adapted for higher execution speed with CLIPPER S87 and covers all patient data management.

It mainly handles a database containing data like patient name, date of birth, sex, projected date and time of investigation, kind and reference number of investigation, name of admitting doctor and several additional parameters like diagnosis and current therapy. These data are stored on a Novell fileserver and can be updated at any time from any connected workstation. This feature is only necessary when large numbers of patients must be scheduled.

At the beginning of the overnight polysomnografy the investigator selects the requested patient by name and date or, if the patient is not available, enters a new entry. After the reference number has been entered, the program generates names for the datafiles and writes them to short batch files. These can be called in any order via DOSSHELL.

When data acquisition is requested, a program (CODAS.EXE) provided with the WFS 200 board is executed. Through the batch file it is informed about name and size of the datafile. The datafile is created at the beginning and filled with zeros. This provides security in case there is a power failure during acquisition. In this case, data written up to this moment to the file are still available.

For manual evaluation the program POSTACQ.EXE can be used, which is also provided with WFS 200. It allows display of all recorded channels with all features like display compression, measurement of amplitudes and measurement of dura-

tions or calibration of individual channels. Regions of interest can be exported to file all major formats like binary, ASCII, Asystant or Lotus are supported. The output may also be directed to the printer. Hardcopy shows all selected (up to 16) curves on the printer in unlimited length when using pin-feed paper.

Although in newer versions external programs can be called from within POSTACQ, we found it more convenient to install SIDEKICK.COM each time before starting POSTACQ. This provides a very fast access to an editor and remarks to the current evaluation can be recorded quickly during the review of data. We code each event with an alphanumeric 3-digit prefix followed by its value. For example an obstructive apnea with duration of 25 seconds is coded 'OA 25', a central apnea 'ZA 25' or a mixed Apnea 'XA 25'. We found it important to install DOSSHELL with activated program swaping, because SIDEKICK is removed after completing the evaluation. This is necessary, as it interferes with the program CODAS.EXE when resident in memory.

When viewing of data is completed, a special evaluation program (SACALC.COM written in Turbo pascal) is started, that calculates statistics of all recorded remarks. The results are output to a text file together with patient name and patient data. At the end of the file a proposal for interpretation is made by the program. The type of sleep apnea (obstructive or central), the severity of the disease and the amount of oxygen desaturation are verbalized. These interpretations and the whole file can be modified and completed with additional remarks (See appendix 1 which shows the sample of a patient with severe obstructive sleep apnea syndrome. Note that this is the raw output without manual added comments. In Appendix 2 a sample of a hardcopy of the raw data of the same patient is given showing several apneas with SaO2 desaturation).

Optionally we use a program (also written in Turbo Pascal) that scans data for apnoeic or hypopnoeic events and calculates statistics for heart rate and O2-saturation. But as the accuracy of this program for respiratory data is affected by artefacts, we use it only in cases with severe sleep apnea where several hundred apneas must be counted. All other cases with less than 50 apneas per recording are evaluated faster when scoring by hand.

Experience

During the first year of operation we performed 87 polysomnographic investigations in 71 patients with suspected sleep apnea syndrome. The evaluation was performed by hand and the report was produced by the computer as described above. Major problems occured neither from hardware nor from software. The integration into a local area network added more convenience in handling patient data and managing data backup.

Although the indication for polysomnography [5] was obtained only from clinical symptoms and signs like obesity, arterial hypertension or daytime sleepiness etc. we found in 44% (n = 31) individuals an increased amount of apnoea and hypopnoea during sleep (apnoea + hypopnoea index [AHI] >= 5/h). In 31% (n = 22) of patients the diagnosis of sleep apnea syndrome could be established (AHI >= 10/h). 21% (n = 15) had AHI >= 20. People with sleep apnoea syndrome and chronic obstructive pulmonary disease (COPD) also known as 'overlap syndrome' showed low SaO2 values while awake and additional cyclic desaturations during sleep. 11 persons with normal SaO2 while awake showed also severe SaO2-desaturation with SaO2 lower than 85% up to 2 hours 45 minutes per night. In these patients treatment with nasal continuous positive airway pressure (nCPAP) was performed [6]. In 6 of them longterm nCPAP therapy was accepted with good therapeutic effect. The other patients were treated with weight reduction. Long time oxygen was given when there was hypoxaemia due to COPD during daytime.

Discussion

One problem in handling polysomnographic re-

cordings is data storage. As raw data can take more than 40 MB of disk space per night, there is the requirement for sufficent mass storage devices. For short time storage harddisks are used. A variety of disk subsystems in the range of 200–600 MB are available nowadays. For midrange data storage tape streamers seem sufficient. Streamer cartridges with 120–250 MB are quite inexpensive and are normally used in small LAN's (local area networks) for routine data backup. For bigger LAN's tapes in the range of 1 to 10 GB are available. For long time storage tapes are not recommended. There the use of optical disks seems to be the best choice. Although eraseable optical disks are available, most centers use WORM-drives (write once read multiple) to store their raw data. There are two reasons to do so. One is that the data reliability is guaranteed for up to 30 years on WORM-disks. The other is, that many centers have accepted WORM-disks quasi as standard. So the exchange of raw data between different centers is simplified.

Another problem is the development of automatic evaluating software. We have been working on this since 1988. The program of current use was written in Turbo Pascal 3.0. The main problem it shows is lack of speed. One pass over a one night recording takes about 20 minutes when calculating SaO2, heart rate and respiratory parameters. When automatic sleep staging is requested, larger input files have to be used and this would result in a longer processing time. For these purposes the online evaluation would be quite usefull. For EEG or EOG registration sample rates of 50 to 100/sec turned out to be sufficient for the purpose of sleep staging (not for diagnostic purposes of course) [7, 8]. If 12 channels are used with a sample rate of 100 Hz the computer makes 1200 measurements per second. This is about 15% of the performance a 80286/12 CPU is capable of. So more than 85% of CPU time could be used for online preprocessing and evaluation.

One severe problem for creating evaluation programs is, that fast algorithms are not very accurate and there can be great differences between manual scoring and automatic evaluation. We tested some commercial programs and found none that shows reliable automatic scoring. The same opinion is represented by all national sleep research associations (American Sleep Disorders Association, Canadian Sleep Society, American thoracic society [5]). An optimistic outlook to the future might be the use of program systems capable of learning. First experiences with neural networks in evaluation of polysomnografic recordings seems encouraging for this particular purpose. It should be mentioned that for efficient use of such programs computers with 80486SX CPU or faster are recommended.

Until now (1991) we have performed over 350 recordings and have more than 30 patients on nCPAP. Due to adaptations of the software the system is now working fairly stable with very little problems. We have installed a second unit with exactly the same hardware configuration on our ICU for scientific research. The computer is used to record data for measurement of respiratory parameters in mechanically ventilated patients like P 0.1 or intrinsic positive endexpiratiory pressure [9].

Conclusions

The described system turned out to be a quite useful tool in diagnosis and quantification of sleep apnea syndrome. It fully emulates a chart recorder without the need of using large amounts of paper during one session. Because all data are temporarily stored to hard disk, the management and evaluation is quite easy. Hardcopy on paper is also available of all registered channels (up to 16). Measurement of time (eg. apnea duration) and the determination of values of SaO2 or heart rate can be done directly on the screen. As there is the option of including a calibration signal, the reliability of the connected devices can be checked. Evaluation by hand is faster and more accurate than when performed with paper recordings.

We recommend the described basic hard- and software configuration to all who wish to record large amounts of data without the need of programming basic functions like data acquisition or data replay.

Appendix 1. Example of a report form.

SEITE 1/2

PULMOLOGISCHES ZENTRUM DER STADT WIEN DVR:0000191
II.INTERNE ABTEILUNG - ATEMPHYSIOLOGISCHES LABOR
TEL:0222/949060/2716
S C H L A F A P N O E - B E F U N D /2717

ID : SA910142
NAME : XXXXX XXXXX geb.27-08-55
ZUWEIS. : XXX
DATUM : 12-12-91

Z E I T E N

TOTAL RECORDING TIME :	7: 6:30
TOTAL EVALUABLE TIME :	6:55: 0
TOTAL SLEEP TIME :	6:33:20

A P N O E - P H A S E N

SUMME DER APNOE-PHASEN :	488
APNOE-INDEX :	74.45 Ph/h
MITTLERE APNOE-DAUER :	22.2 sec
LAENGSTE APNOE-DAUER :	42 sec
MITTLERE APNOEZEIT/STUNDE :	27:28 [mm:ss]

VERTEILUNG :	OBSTRUKTIV	GEMISCHT	ZENTRAL
n	466	20	2
%	95.5	4.1	0.4

H Y P O P N O E - P H A S E N

SUMME DER HYPOPNOE-PHASEN :	5
HYPOPNOE-INDEX :	0.75 Ph/h
MITTLERE HYPOPNOE-DAUER :	24.5 sec
LAENGSTE HYPOPNOE-DAUER :	38 sec
MITTLERE HYPOPNOEZEIT/STUNDE :	0:18 [mm:ss]

VERTEILUNG :	OBSTRUKTIV	GEMISCHT	ZENTRAL
n	5	0	0
%	100.0	0.0	0.0

APNOE + HYPOPNOE-PHASEN :	493
KOMB. APNOE-HYPOPNOE-INDEX :	75.20 Ph/h
MITTL. APNOE+HYPOPNOEZEIT/STUNDE :	27:46 [mm:ss]

H F & S a O 2

MITTLERE SaO2 (Normalatmung):	94.7 %
MITTL. MINIMUM SaO2 (A+HYPO):	75.0 %
ABSOL. MINIMUM SaO2 (A+HYPO):	70.0 %
ZEIT DER SaO2 < 85% :	0:59: 5 [hh:mm:ss]
MITTLERE HERZFREQUENZ :	82.5 /min
MINIMALE HERZFREQUENZ :	61.0 /min
MAXIMALE HERZFREQUENZ :	104.0 /min
MAXIMALER nCPAP-DRUCK :	0.0 cm H2O

SEITE 2/2 IDNR: SA910142 NAME: XXXXX XXXXXX geb.27-08-55

S C H L A F - P H A S E N

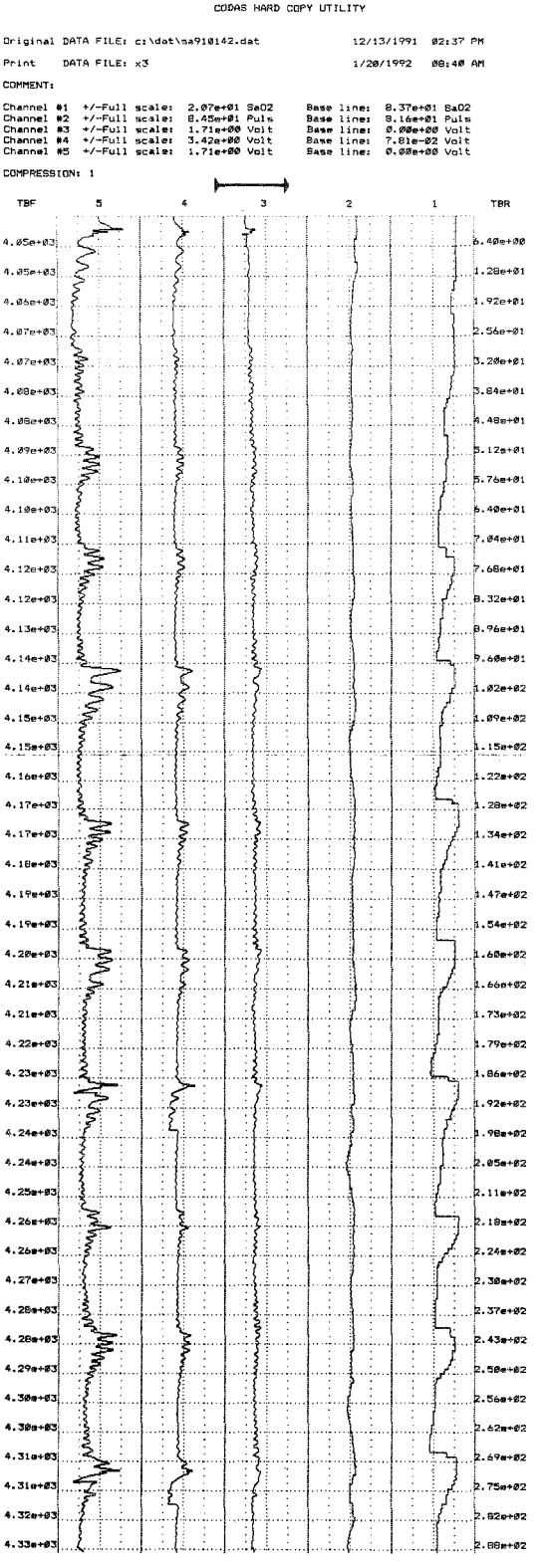
AUS DEN VORLIEGENDEN MESSDATEN KEINE DIFFERENZIERUNG MOEGLICH.

KOMMENTAR : Schlafapnoesyndrom extrem schweren Grades
vorwiegend obstruktiver Typ
mit beträchtlicher Gasaustauschstörung (SaO2 < 85%)

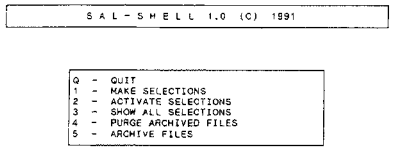
mit kollegialen Gruessen,

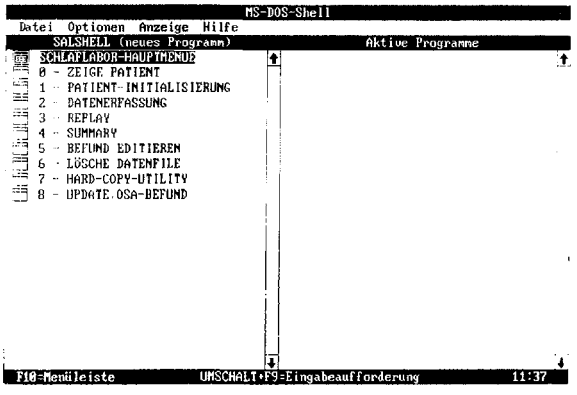
PRIM.DR.N.VETTER DA.DR.G.KAPFHAMMER

Appendix 2. Hardcopy printout of respiratory parameters.



Appendix 3. Sample of main-menue and patient-selection.





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