Abstract. Electronic patient data management systems (PDMS) were clinically used for the first time in the 1970s. Their purpose was to automatically document vital parameters sampled by monitors and to replace handwritten medical files. Because of the continuous development of computer technology, however, demands on PDMS have increased immensely. PDMS are currently expected to assist clinicians at every level of intensive care, i.e., at the strategic level of physicians’ orders and prescriptions, at the operational level, and at the administrative level. In 1994, a PDMS (CareVue; Agilent Technologies) was installed and further developed in the anesthesiologic intensive care unit of the university hospital in Tübingen. The goals of this article were to describe the current demands on PDMS, to communicate our experiences in implementing a PDMS, to list the costs of purchasing and maintaining the system, and to report on the acceptance among physicians and nursing personnel. This article may assist new users in planning for, purchasing, and implementing a PDMS.

Four Levels of Action in Intensive Care

For intensive care medicine, normative, strategic, operational, and administrative levels of action may be differentiated. At the normative level, treatment rules are generated. Ethical considerations and the current state of knowledge, based on findings from clinical practice and controlled trials, establish currently valid treatment rules. The rules are only partially recorded in writing; however, they are effective as common sense. At the strategic level of intensive care, the rules of treatment are applied to actual cases and lead to specific therapies. For these applications, physicians require patient data, which must describe the problems of the patients as comprehensively as possible. At the operational level, the orders of physicians are translated into action, and therapeutic effects on the patients are measured and recorded. These are primarily the tasks of the nursing personnel. Finally, at the level of administration, patient data and data on treatments and their costs are compiled and recorded. Those data must be processed to be available for other departments of the hospital, such as the administration, the quality control department, and the accounting department. These data form an essential basis for quality assurance analyses, economic efficiency, and the responsible use of available resources.

Patient Data Management System (PDMS) Assistance at the Four Levels of Action in Intensive Care

PDMS could be of great help at the normative level if several ICU were connected to each other in an “intensive care network.” Such a network could foster the exchange of experiences, could enable online discussions of specific treatment problems, and could support clinicians in formulating standardized rules of treatment. However, this concept would require records that could be easily exported out of a PDMS and placed at the disposal of other users, e.g., via the Internet. According to our latest information, an intensive care network of this kind has not been established. Also, no PDMS that might support this function currently exists.

At the strategic level, a PDMS can be successfully used if patient data are presented in a clearly structured manner and thus can be retrieved without problems. For users, it must be possible to configure data sheets according to individual needs, to enable problem-orientated data presentation. For example, clinicians should be able to observe all relevant data concerning infection control, such as body temperature, leukocyte count, duration of intravascular catheterization, all microbiologic findings previously marked as relevant, findings of Gram stain analysis of tracheal secretions, and results of the last thoracic x-ray screening, on one screen. A PDMS should make possible individual configurations for data presentation and online transfer of laboratory results, as well as microbiologic and radiologic findings.

Automated alerts, which indicate patient allergies, medication overdoses, or drug incompatibilities, should be integrated into a computer-controlled physician order entry system. Prob-
lem-oriented presentation of stored data could significantly improve communication and interaction at the bedside.

At the operational level, nurses may benefit not only from a readable format for physician orders but also from simplified documentation of drug administration, as a result of automated transmission into patient records of physician orders, flow rates for syringe pumps and drip controllers, and vital parameters from monitors; they would only need to validate such data. Standardized entries regarding general care and automated preparation of patient transfer reports using previously stored patient data can be considered valuable, time-saving functions of a PDMS.

A PDMS may be considered a data warehouse storing all cases of treatment, which permits queries of various types at the administrative level. Answers to specific epidemiologic questions may be provided; also, researchers may extract treatment results for particular patient groups. For study design or for investigation of how many patients treated each year meet the criteria for study inclusion, data queries could be of great help.

For these queries, the PDMS must support an automated survey of scores (Acute Physiology and Chronic Health Care II [APACHE II], Simplified Acute Physiology Score [SAPS], and Therapeutic Intervention Scoring System [TISS]). In addition, the system should generate alerts when data needed for the calculation of such scores are lacking. Access to stored data, as well as analysis using a specific approach, must be performed easily, i.e., without consultation with computer specialists and without requiring much time.

**Practical Experiences with PDMS**

In Europe, an Austrian team and a Dutch team, which recruited their members from several ICU, evaluated PDMS. The Dutch team provided a catalogue listing all required PDMS functions. On the basis of this list, they investigated the Clinisoft (Datex-Engström, Helsinki, Finland), Emtel System 2000 (Siemens/Motorola, Erlangen, Germany), CareVue (Hewlett Packard, Böblingen, Germany), IRS (IRS, Amsterdam, Netherlands), and ICIS (Inad, Amsterdam, Netherlands) systems. In their article published in 1998 (3), they could not present a single PDMS that completely met the established standards. Missing links to the hospital information system and to other diagnostic departments (the laboratory and the departments of microbiology and radiology), which could be used to ask for examinations or to request findings, were widespread deficiencies of the tested PDMS. The generation of nursing care plans and therapy plans was reported to be difficult or not feasible at all in four cases. Five systems were not equipped with automated links between the formats for therapy plans and patient data files, which might have enabled the transfer of records for performed and validated therapeutic demands into patient data files. Only the Clinisoft system provided an alerting system that indicated therapies still to be administered, incompatible drug combinations, or allergies. No PDMS was furnished with a warning signal to remind clinicians of missing values needed for the calculation of scores. The authors came to the conclusion that there might be great potential benefits to using a PDMS but no existing PDMS fulfills all clinical requirements (3).

The Austrian team performed a study of the practical utility of PDMS and examined the time of the interaction between the user and the system required for specific functions. The systems differed significantly in their response times. The time necessary to display the liquid balance for the previous 5 d varied between a minimum of 3 to 4 s using one PDMS and a maximum of 30 or 40 s using two others. Depending on the utilization of the computer capacity, the response times for the same question may vary even for the same PDMS. The Clinisoft information system, for example, required between 3 and 32 s to process hemodynamic data collected 5 h earlier for a single patient (4).

Both studies show that PDMS are expected to fulfill not only functional but also practical requirements, to guarantee user satisfaction. Before a PDMS is purchased, therefore, the first essential step is to define functional and practical needs as specifically and measurably as possible. Commercially available systems can then be evaluated on the basis of this list of requirements. Functional requirements can easily be checked on the basis of the description provided by the manufacturer, whereas practical requirements (response times and user/PDMS interactions) must be tested in direct use.

**Experiences in Implementing a PDMS**

The initial costs for a PDMS are approximately 30,000 to 40,000 German mark ($15,000 to $20,000 American) per workstation. Approximately 5% of the initial cost/yr must be taken into account for subsequent system maintenance. System maintenance includes the replacement of defective components as well as software updating. The maintenance of installed systems requires approximately 4 h/wk and costs $25,000 American/yr. This is equivalent to one-half the salary of a computer scientist who graduated from a college of higher education.

Our 24 bedside ICU workstations are run by two servers. Each server supports 12 workstations. However, data entered at each bedside workstation are stored on both servers and exist in two copies. Each day, data stored during the last 24 h are transferred to a compact disc.

In the past 6 yr, we have experienced two software breakdowns, which could be eliminated within a few hours. During those incidents, we needed to return to our paper charting practice. On one occasion, the data storage mode of one server failed but, because the other server remained in proper working order, there was no loss of data. We have never required the data stored on the compact disc. The implementation of a PDMS (CareVue) 6 yr ago was extremely time-consuming, requiring 11 mo. Technical installation required approximately 2 mo, and configuration of the system and training of our staff required approximately 9 mo. This time can be considerably reduced with the use of preconfigured systems. Our own experience in implementing a PDMS supports the observations of Marasovic et al. (5), i.e., nurses who were less experienced in intensive care demonstrated greater motivation in using a PDMS than did experienced nurses.
nurses and practical knowledge in using a computer had no influence on the motivation for working with a PDMS.

The following functions can currently be performed with our PDMS (CareVue): automatic registration of vital parameters, with the ability to validate and correct data; complete documentation of therapy and patient care; fluid intake/output balancing; automated adoption of the flow rates for syringe pumps and drip controllers; automated adoption of laboratory reports, blood gas analysis results, and microbiologic test results; configuration of problem-oriented data records; semiautomatic calculation of scores (APACHE II, SAPS, and TISS); constant updating of diagnoses and treatment lists; and preparation of patient transfer reports. Physician order entry and the documentation of radiologic results and consultant findings are still not provided these functions.

Effects of PDMS on Medical and Nursing Activities and Acceptance of PDMS

In 1983, De Calonne et al. (6) demonstrated that the number of incorrect medications could be decreased by using a PDMS. Using a PDMS seems to improve communication. Nurses are better informed, because relevant data are easily retrieved using a PDMS (7). Errors in communication with other departments in the hospital, as well as at shift changes, are reduced (8), and the problem-oriented presentation of patient data favors higher-quality interactions at the bedside, during ward rounds, and between nurses and physicians.

There are different opinions regarding time savings with the use of PDMS. Whereas Crew et al. (9,10) reported saving time by using computer systems, other researchers did not observe an immediate effect of saving time; instead, they reported more comprehensive data capture (8). Our own experiences have indicated that the time necessary for the documentation of data can be reduced. In addition, more data can be captured in the same time period.

Using a written anonymous interview form, we set out to survey the acceptance of the PDMS in our ICU (82 nurses and 22 physicians). Fifty-four nurses and 12 physicians returned the questionnaire. The questions referred to interactions with the PDMS, computer-aided documentation (compared with manual charting), and the benefits of the PDMS. The results of the survey are presented in Table 1.

With respect to the use of the PDMS, the majority of our staff consider data entry not to be very complicated. One-half of our staff, however, consider data retrieval to be too difficult; therefore, access to stored data and data files must be facilitated.

Many interviewees consider it advantageous that previously stored data can be analyzed at a later time. More extensive data sets can be documented using the PDMS, and the time required is thought to be less, compared with handwritten documentation. Sixty percent of our staff think that computer-based data presentation is more accurate than paper charting. Approximately two-thirds of those asked take the view that the PDMS helps save time, as well as helping to meet therapeutic standards.

<table>
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<tr>
<th>Table 1. Results of a staff survey (54 nurses and 12 physicians)*</th>
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<tr>
<td>Interaction with PDMS</td>
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<td>At data entry</td>
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<td>At data query</td>
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<td>Compared with handwritten documentation</td>
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<td>PDMS enables more extensive documentation</td>
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<td>Less time is needed to document the same amount of data</td>
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<td>Documented data are presented more clearly</td>
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<td>PDMS facilitates data analysis</td>
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<tr>
<th>Benefits of PDMS</th>
<th>Response (%)</th>
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<tr>
<td>PDMS helps save time</td>
<td>68</td>
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<tr>
<td>PDMS facilitates compliance with standards of therapy</td>
<td>66</td>
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<tr>
<td>PDMS supports therapy-planning</td>
<td>42</td>
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<td>PDMS facilitates therapeutic decision-making</td>
<td>34</td>
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*PDMS, patient data management system.

Whether the PDMS supports therapeutic decision-making and treatment-planning could not be answered by many of those asked. This finding is based on the fact that in the survey we received more answers from nurses than from physicians and nurses cannot form a judgement in this context, because they are not involved in therapeutic decision-making and treatment-planning. On the basis of the answers provided by physicians, 66% of our physicians think that the PDMS facilitates therapeutic decision-making and supports treatment-planning.

The results of our survey correspond to the findings of a survey performed by Urschitz et al. (11). Those authors concluded that two-thirds of their staff members preferred PDMS-based documentation, compared with handwritten charts, and that only 1 of 41 colleagues would prefer to return to the paper charting method. In our survey, 94% of those asked considered our PDMS to be helpful. Of those asked, 96% would no longer want to work without a PDMS.

Despite the functional and practical aspects of currently available PDMS, they still exhibit shortcomings. The functionality of PDMS could be optimized by facilitated physician order entry, by the ability to document findings of medical...
examinations in a standardized manner, by automated transfer of medication administration data onto the documentation sheet, and by easily activated interfaces with other diagnostic departments. Practical functions could be improved with shorter reaction times for data retrieval and simplified analyses of the data warehouse, which contains data for all cases of treatment. However, even now physicians and nurses appreciate PDMS as valuable tools in ICU medicine. PDMS will be indispensable in the foreseeable future, because only with their help can we manage the vast amount of ICU data and use stored data in a meaningful way.

References