CAN A CLINICIAN PREDICT THE TECHNICAL EQUIPMENT A PATIENT WILL NEED DURING INTENSIVE CARE UNIT TREATMENT? AN APPROACH TO STANDARDIZE AND REDESIGN THE INTENSIVE CARE UNIT WORKSTATION

Jonas Hähnel, MD, Wolfgang Friesdorf, MD, Bernhard Schwilk, MD, Thomas Marx, MD, and Silvia Blessing

Hähnel J, Friesdorf W, Schwilk B, Marx T, Blessing S. Can a clinician predict the technical equipment a patient will need during intensive care unit treatment? An approach to standardize and redesign the intensive care unit workstation.

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ABSTRACT. The technical equipment of today's intensive care unit (ICU) workstation has been characterized by a gradual, incremental accumulation of individual devices, whose presence is dictated by patient needs. These devices usually present differently designed controls, operate under different alarm philosophies, and cannot communicate with each other. By contrast, ICU workstations could be equipped permanently and in a standardized manner with electronically linked modules if the attending physicians could reliably predict, at the time of admission, the patient's equipment needs. Over a period of 3½ months, the doctors working in our 20-bed surgical ICU made 1,000 predictions concerning outcome, equipment need, duration of artificial ventilation, and duration of hospitalization for 300 recently admitted patients. The interviews were made within the first 24 hours after admission. The doctors being interviewed were usually (i.e., in over 90% of cases) unfamiliar with the patient. Information concerning the patient's general state of health, special pre-ICU events, and complications was offered to the interviewed clinician because this information represents standard admission data. It was found that the equipment need (represented by two different setups, "high tech" and "low tech") could be predicted most reliably (96.4% correct predictions) compared with a prediction on outcome of ICU treatment (94.5%), on duration of artificial ventilation (75.4%), and on duration of stay (43.4%). There was no significant ($p > 0.05$) difference in the reliability of predictions between residents and consultants. Factors influencing the postoperative equipment need varied with surgical specialty. The general state of health, as indicated by the ASA classification ($p < 0.001$), and the specific intervention (all multiple-valve replacements needed the high-level equipment standard) appeared to be most important in cardiac surgery, while a state of septicemia was important in general surgery ($p < 0.001$). Our findings suggest that ICU workstations may be standardized into at least two types.

KEY WORDS. Equipment. Intensive care units.

In the last two decades, the outcome of intensive care unit (ICU) patients has improved dramatically, and technical progress has doubtlessly contributed considerably to this success. Each year, manufacturers offer new devices with ever more technologically advanced functions. In our ICU, we were able to identify 80 different devices. Each workstation looked different, because it was set up according to the requirements of an individual patient. Devices were added and removed, with chaotic results: a conglomeration of quite different devices, cables, tubes, and lines surrounding the patient like a cobweb.

In 1988, with this chaotic workstation in mind, our group put forward the concept of the integrated workplace (Fig 1), attempting both the integration of the

From the Department of Anaesthesia, University of Ulm, Ulm, Germany.

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Address correspondence to Dr Hähnel, Universitätsklinik fur Anästhesiologie, Steinhövelstr. 9, D-7900 Ulm, Germany.

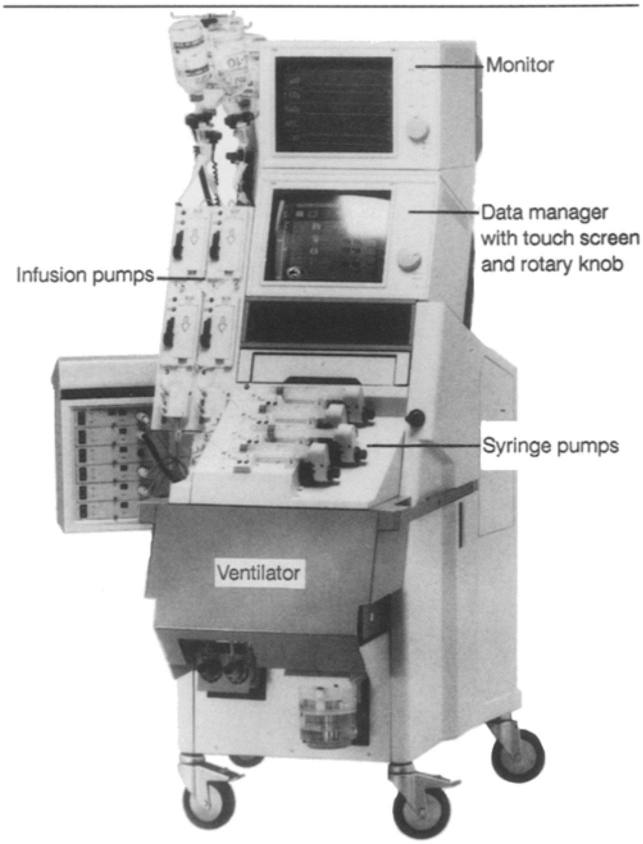

Fig 1. Prototype of the integrated workplace.

most frequently used devices using one housing (monitoring, ventilator, eight fluid pumps, all linked to a data manager) and standardization of the ICU work station [1].

With this integrated workplace, most of our patients could be treated appropriately. There are only a few exceptions for which modular expandability should be preserved, such as cardiac surgery patients who may need some additional fluid pumps. On the other hand, there are patients who will never need the entire integrated workplace. Thus, we favor as an optimum at least two standard combinations, a "low tech" and a "high tech" workstation, described below, with the option of adding special devices to the low tech station if they are really needed (e.g., a hemofiltration device, an intra-aortic balloon pump, etc.).

Using this background, we have tried to answer the following questions:

1. Is the admitting clinician able to predict individual patient's requirements for equipment? In other words, could he correctly assign a patient to one of two standard workstations?
2. How reliable is this prediction compared with other predictions, e.g., survival, length of ICU treatment, and duration of artificial ventilation?
3. Are there pre-ICU variables that determine the individual equipment requirements during ICU treatment?
4. Could these variables constitute a kind of scoring system?

METHODS

The study was conducted over a 3½-month period in our 20-bed anesthesiology ICU. Three or four clinicians working in the ward were asked to predict the ICU course of each of 300 patients. These predictions were made within 24 hours of admission. Generally, the responding clinicians were not familiar with the respective patient; they were not necessarily involved in the treatment.

Prior to prediction, the clinicians were given the following information concerning each patient: age and sex, pre-existing organ insufficiency and ASA classification; primary diagnosis, surgical intervention, and anesthetic management; special events and complications prior to ICU admission; and lost and replaced blood and fluids.

The clinicians predicted the prognosis for survival ("good," "doubtful," or "gloomy"—"doubtful" could not qualify as a correct prediction), duration of ICU treatment in days, duration of ventilation in days, and equipment that would suffice for the entire ICU stay. The equipment was either "low-tech" (4-channel monitor for electrocardiogram, intravascular arterial, central venous, and intracranial pressure, simple ventilator, up to 5 fluid pumps for infusions or drugs) or "high tech" (8-channel monitor for advanced cardiovascular monitoring, sophisticated ventilator, more than 5 fluid pumps, intra-aortic balloon pump, hemofiltration etc.).

The rationale for offering these alternative equipment standards was based on a preliminary study that investigated the frequency of use of the individual devices [2].

Statistical significance was tested by means of the χ^2 test or by calculating the point-biserial coefficient of correlation (r_{pbis}). Significance was presumed at $p < 0.05$.

RESULTS

A total of 1,000 predictions for 300 patients were analyzed. On an average of 15.9 hours after admission, 308 predictions were made by consultants and 692 were made by residents.

Patients came from four different surgical depart-

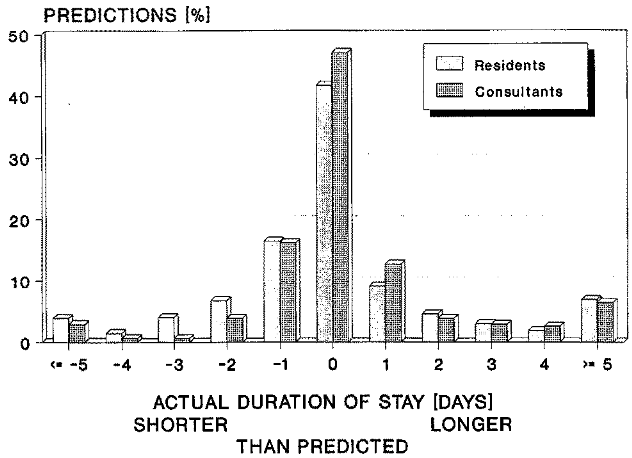

Fig 2. Relative frequency of correct and incorrect predictions, related to the total number of predictions, plotted against duration of stay. The values have been subdivided by consultants and residents. The columns above "0" represent the fraction of correct predictions. On the left, the actual stay was shorter (indicated in days) than predicted; on the right, it was longer.

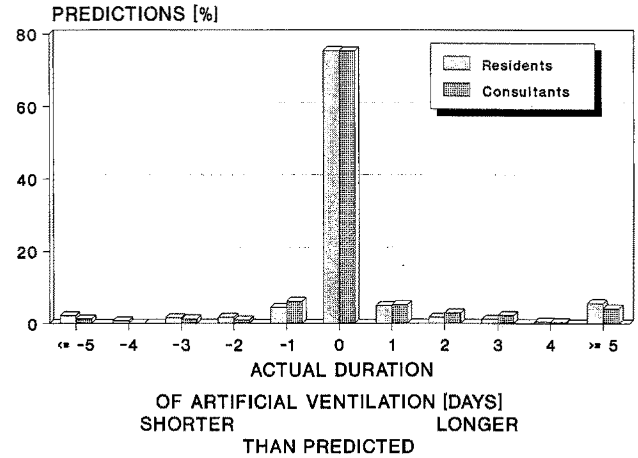

Fig 3. Relative frequency of correct and incorrect predictions, related to the total number of predictions, plotted against duration of artificial ventilation. The values have been subdivided into predictions made by consultants and residents.

ments: 44% cardiac surgery, 24% general surgery, 20% vascular surgery, and 12% trauma/orthopedic surgery.

Duration of ICU Stay

The shortest registered stay in the ICU was 1 day (i.e., any period shorter than 24 hours; 26% of patients), and the longest was 60 days. Eighty percent of the patients stayed less than 5 days in our ICU. Figure 2 shows the differences between the actual and the predicted ICU stay. In 43.4%, predictions were accurate to the day; in 70.0%, the true duration was predicted within ±1 day.

The predictions are displayed separately for residents and consultants. We did not find any significant difference ($p > 0.05$) in the accuracy of predictions between these two groups.

Duration of Artificial Ventilation

Seventy-seven percent of the patients were mechanically ventilated for no longer than 1 day; 25% of the patients were already extubated on the day of admission.

In 75.4%, the predicted duration of artificial ventilation was correct (Fig 3); in 85.4%, the true duration was predicted within 1 day.

Equipment Requirements

"Low tech" equipment was sufficient for 197 patients (65.7%). "High tech" equipment was required for 103 patients (34.3%). This requirement was predicted correctly in 96.4% of the 1,000 predictions. In other words, only 3.6% of these predictions were wrong. In 1.7%, the clinicians anticipated "low tech" equipment, but "high tech" equipment was needed. In 1.9%, "high tech" equipment was predicted, but the patient actually required only "low tech" equipment.

Although the required equipment was highly dependent on the type of surgical intervention, we found no substantial differences in the reliability of predictions between the different surgical disciplines; 96.5% correct predictions in cardiac surgery patients, 94.0% in general surgery, 98.5% in vascular surgery, and 97.4% in trauma surgery.

Outcome

Ten patients (3.3%) died during the course of ICU treatment. Three had undergone cardiac surgery, four gastrointestinal surgery, and three vascular surgery. We found no statistical significance ($p > 0.05$) between the surgical disciplines.

The total outcome was predicted correctly 94.5% of the time. In 0.9%, survival was predicted but the patient died, and in 0.9%, the patient was predicted to die but survived. The remaining predictions (3.7%) were due to a prediction of "doubtful."

Equipment requirements could be predicted best (96.4%), followed by prediction on outcome (94.5%), duration of artificial ventilation (75.4%), and duration of stay (43.4%).

Table 1. Influence of ASA Classification and Other Single Factors on "Low Tech" and "High Tech" Demand

No. of Patients Accepted to Surgical Specialties	"Low Tech"				"High Tech"		
	Cardiac—6	General—62	Vascular—53	Trauma—36	Cardiac—85	General—11	Vascular—7
ASA I-III/IV-V	32/14	52/10	41/12	26/10	31/54	3/8	3/4
Age (yr; mean ± SD)	50.0 ± 21.7	61.4 ± 17.7	58.1 ± 14.9	50.7 ± 20.1	60.4 ± 10.4	62.6 ± 7.1	62.0 ± 10.6
Male/female	30/16	33/29	40/13	21/15	62/23	8/3	7/0
Duration of surgery or primary care (min; mean ± SD)	183 ± 63	256 ± 120	205 ± 65	142 ± 124	238 ± 65	191 ± 92	251 ± 88
Blood replacement (ml; mean ± SD)	1,990 ± 1,250	2,510 ± 1,730	2,570 ± 1,770	3,280 ± 3,860	2,680 ± 940	4,040 ± 3,630	3,540 ± 2,880
"Nonsurgical" complications (arrhythmias, difficult intubation etc; %)	8.3	40.3	45.3	30.6	47.1	27.3	14.3

Pre-ICU Determinants of Equipment Requirements

Table 1 shows the available pre-ICU information in relation to the required equipment. During this study, there was no trauma patient needing "high tech" equipment, so we cannot compare "high tech" and "low tech" in this group.

Coronary bypass surgery and single valve replacements dominated in cardiac surgery patients (combinations of both were not analyzed): "low tech," 25 bypass operations and 4 single valve replacements; "high tech," 55 bypass operations and 17 single valve replacements.

Considerably more single (and all multiple) valve replacements were in the "high tech" group, whereas "other" cardiac surgery procedures (e.g., congenital abnormalities such as atrial septal defect) predominated in the "low tech" group. Differences in previous general state of health as expressed by the ASA classification were highly significant ($p < 0.001$).

Although statistical significance at the 5% level was just missed in patients after vascular surgery, general state of health as well as blood replacement and duration of surgery, taken together, worked well as predictors of a need for "high tech" equipment. Each patient with "high tech" equipment after vascular surgery had undergone a different operation from the others, thus not allowing an allocation of "high tech" need to specific disorders in this category of surgery.

This diversity contrasts with "high tech" patients suffering from gastrointestinal disorders, in whom 8 of 11 had a primary septic focus in the abdomen. In the remaining 62 "low tech" patients who underwent general surgery, only 3 had an inflammatory intra-abdominal process with a minimum of peritoneal spread. This means that a state of septicemia is very important in determining the need for "high tech" equipment in these patients ($p < 0.001$).

DISCUSSION

Terms such as "standard," "scoring," and "quality assurance" have gained considerable importance in any discussion of cost-benefit relations in modern medicine [3]. This discussion has been intensified by the achievements of today's high tech devices used in diagnosis and intensive care. This equipment often enables us to stabilize or substitute an organ system temporarily and to cure patients of extreme age groups suffering from most serious diseases. Simultaneously, however, the costs have risen dramatically. In the future, costs and ethical factors may become a determinant for our decisions, not just feasibility [4].

The development of scoring systems, whether their applicability may be restricted to certain conditions or not [5–11], represents an effort to escape this dilemma and to optimize limited resources. Scoring systems may help evaluate different treatment strategies and predict individual treatment courses with high reliability, although the remaining uncertainty makes it unacceptable to base a decision about ICU treatment only on scores [12, 13]. The overall judgment by experienced clinicians is still indispensable, although a score may consist of nothing else but abstracted clinical experience [14].

However, the struggle for reliable criteria may be of interest for less grave decisions. For example, a computer-supported treatment planning system could offer a set of diagnostic and therapeutic routines that are adapted to a group of patients and that only have to be modified according to a few individual requirements.

Another application is addressed by this study. If we could predict the ICU equipment needed at the time of the patient's admission, it would be possible to define some standards of bedside equipment. Thus, we could redesign the ICU workstations taking ergonomic factors into account. The bothersome accumulation of numerous stand-alone devices forming an individual and badly arranged workstation could be put to an end.

Our results make us confident that we can define standard workstations for our ICU and that our clinicians are able to reliably allocate patients to these workstations (96.4% on average). The few incorrect allocations could be compensated for without endangering the patient simply by adding the necessary equipment to the low tech station.

The underlying dichotomy between the "low tech" and "high tech" equipment in this study provides a simple and somewhat arbitrary, but useful, alternative for our ICU [2]. Other ICUs could define their standards according to the requirements of their patients.

Too many types of workstations could actually decrease the ICU's flexibility, because workstation supply and demand will not always be equal in most instances. Therefore, modular devices in the standardized workstations have to be preserved, allowing an up- or down-grading according to need. It should be emphasized, however, that standardization of ICU workstations is possible.

Over the last 3 years, the mortality rate in our ICU remained constant at approximately 9%. Thus, there was an unusually high number of survivors during our investigation, making the high prediction accuracy (>94%) less of an accomplishment. Nevertheless, prediction accuracy on equipment needs was even higher (>96%).

Residents did as well as the consultants in our study. This observation might be related to the fact that, as a rule, our residents do not start ICU training before they have had 3 years of experience in anesthesiology.

When analyzing the information transmitted during the admission of a patient to the ICU, the following factors determining equipment requirements may tentatively be addressed.

A "low tech" station may be predicted if the patient has a good or at least "acceptable" general state of health (ASA classification I-III): only 20% of these patients required "high tech" equipment. On the other hand, a poor general state of health (ASA IV, V) is not such a strong determinant. Some 40% were treated with "low tech" equipment, but 60% required "high tech" equipment.

The patients in the "high tech" group were slightly older (mean, 60.7 years) than those in the "low tech" group (mean, 55.9 years).

Cardiac surgery in particular shows the influence of surgical intervention on required ICU equipment: 65% needed "high tech" compared with only 11% in the noncardiac surgery group.

In general surgery, septicemia is an indicator for "high tech" requirements.

Although not statistically significant at the 5% level, "high tech" equipment demand in vascular surgery may be related to the general state of health of the patient and to difficult operative conditions, as indicated by different distributions in ASA classification, duration of surgery, and blood replacement.

CONCLUSION

Equipment requirements for treatment in surgical ICUs can be predicted with good reliability (96.4%) compared with other important course determinants, such as prognosis quo ad vitam (94.5%), duration of artificial ventilation (75.4%), and length of ICU treatment (43.4%). This renders ICU workstations accessible to standardization.

In cardiac surgery patients, the general state of health ($p < 0.001$) and type of surgical intervention influenced the need for "high tech" or "low tech" equipment. Following general surgery, septicemia was the primary indicator for a "high tech" workstation ($p < 0.001$).

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