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Alternative shift models and the quality of patient care

An empirical study in surgical intensive care units

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Abstract On 1 January 1996, the German *Arbeitszeitgesetz* (working-time regulation) came into effect for hospital physicians. It states that working hours must not exceed 8 h per day, even for physician in hospitals. As a consequence, the prevalent two-shift model is legally inadmissible. The intention of this law is to protect the physician and to create better conditions for the patients. However, a systematic evaluation of the postulated benefits is still lacking. *Aim:* The aim of our study was to analyze the influence of the length of daily working hours on the quality of patient care by measuring the outcome of patients in intensive care units (ICUs), comparing the two-shift model (2-SM) – two 12-h shifts – with the three-shift model (3-SM) – three 8-h shifts. *Materials and methods:* In a prospective multicenter study, we compared the outcome of patients in six ICUs (organized by surgeons) with different models of working hours. The health status of each patient and the course on ICU [described by hospital mortality, number of complications, readmission to the ICU, reinterventions, duration of the stay in an ICU and hospital, the course of the *Acute Physiology and Chronic Health Evaluation* (APACHE) II score] were uni- and multivariately analyzed. In addition, the technical and personnel resources of the ICUs and the hospitals were documented. *Results:* Three hundred and forty seven patients (103 2-SM, 244 3-SM) were included. The epidemiological and the health status on admission to the ICU were comparable. Patients in the 3-SM stayed 1.6 days longer on ICU and 2.3 days longer in the hospital than the 2-SM patients. The frequency of complications, reinterventions, and readmissions to ICU was higher in the 3-SM. The median of the APACHE-II score decreased more for 2-SM than for 3-SM patients. This means a significantly quicker recovery of the patients in 2-SM ($P<0.05$). The multivariate analysis with individual outcome measures as dependent variables revealed a significant positive effect of the 2-SM on the physicians' assessment of postoperative course, on the relative frequency of therapeutic procedures, and to a lesser extent on the duration of stay in the ICU.

Keywords Quality assurance · Intensive care · Surgery

Introduction

"Limiting hours does not guarantee better care, and further efforts should investigate the specific effects of the intervention in a variety of settings." This is the remarkable result of a study on the impact of a restriction of physicians' working hours enforced by the State of New York ("Code 405") [1]. The authors' asked for further investigation of the effects of limited hours on the quality of patient care. It would be necessary to analyze the impact of alternative shift models on the quality of patient care in the setting of surgical intensive care units (ICUs) of university hospitals. Our study was motivated by an alteration of the German *Arbeitszeitgesetz* (working-time regulation), which came into force for hospital physicians on 1 January 1996 [2]. According to this new law, working hours must not exceed an average level of 8 h per day. In consequence, the prevalent two-shift model (2-SM), in which the 24-h operating time is divided into two 12-h shifts, is legally inadmissible. That is why many ICUs have switched to a three-shift model (3-SM) in which each shift lasts for approximately 8 h per day.

The aim of our study was to analyze the influence of the length of daily working time on the quality of patient care measured by the outcome of patients in ICUs.

Theoretical background from organizational economics

Two contrary effects on the quality of the patient care have to be distinguished when assessing the impact of alternative shift models. On the one hand, extraordinary long coherent working hours lead to fatigue of the physicians on duty. This may entail failures in the process of medical care and may consequently deteriorate the quality of patient care [3, 4, 5, 6]. Hence, with regard to physicians' work load, the 3-SM with a working day of 8 h may be accompanied by better treatment results than the 2-SM with a working day of 12 h. On the other hand, relatively short coherent working hours raise coordination and organization problems in the process of patient care. One of the key factors of well-functioning hospital care is a seamless transfer of the physicians' information about patients' characteristics and needs. The feasibility of information transfer depends, among other things, on the length of daily working hours. The risk of a loss of information increases with the number of changes of shifts. Therefore, the coordination of physicians' work and the continuity of patient care is harder to achieve in a 3-SM than in a 2-SM. The importance of continuity of patient care and the negative impact of short coherent working hours for continuity of care have already been demonstrated previously [7, 8].

Hence, the overall effect of alternative shift models on quality of patient care depends on the relative weight of two contrary effects. On the one hand, the longer the daily working hours the higher the risk of fatigue-induced treatment failures. On the other hand, the longer the daily working hours the more difficult it is to achieve a well-functioning transfer of information, continuity of care, and control of physicians [9, 10]. On these theoretical grounds, the optimum length of daily working hours can be evaluated only empirically. If the fatigue effect is relatively more important than the organizational effect, we would rather expect a higher quality of patient care from the 2-SM and vice versa. The remainder of this paper tries to empirically investigate the weight of the contrary impacts of shift models.

Materials and methods

Design of the study

In a prospective multicenter study, we compared the outcome of patients in ICUs with different models of working hours – the 2-SM (two 12-h shifts) and the 3-SM (three 8-h shifts). Six hospitals with an ICU organized by surgeons were included in the study (four hospitals with 3-SM, 2 hospitals with 2-SM).

During 1 month (time span between 1 November 1997 and 1 March 1998), consecutive patients admitted to the surgical ICU were included in the study. For each patient, demographic data, diagnosis on admission, concomitant diagnosis according to the *International Statistical Classification of Diseases and Related Health Problems* (ICD-9) [11], surgical procedure according to the *International Classification of Procedures and Methods* (ICPM) [12], and the preoperative estimation of intraoperative risk according to the *American Society of Anesthesiology* (ASA classification) were collected [13, 14].

We have classified the severity of illness of the patients including the diagnosis, the co-morbidity and the surgical procedure (1 = uncomplicated to 6 = high risk). This estimation was performed by a senior physician blinded for the center the patients came from.

To evaluate the health status of the patients on the day of admission and during the stay on the ICU, the *Acute Physiology and Chronic Health Evaluation* (APACHE)-II score was calculated. This score quantifies the actual health status of a patient using the diversity of physiological parameters. These parameters are temperature, mean arterial pressure, heart rate, oxygenation, arterial pH, serum creatinine, etc. The APACHE-II score is well established for daily evaluation of health status and prognosis of patients on ICU [15, 16, 17].

The APACHE-II score was calculated at the first hour on the ICU and then each day at the same time; the scores were checked by a second physician. The outcome of each patient in this study was described by mortality on ICU, number of medical complications on ICU, readmission to the ICU, reinterventions, duration of the stay in an ICU and hospital, and the course of the APACHE-II score. A subjective measurement of the course on the ICU, named "outcome" (1= very good, 2 = normal, 3 = severe, 4 = death) was generated by the physician at the end of the stay [18].

A medical complication on the ICU was defined as any untoward medical event that was not present at the time of admission. Specific criteria were prospectively defined for each event including hospital-acquired infection, adverse drug reactions, thrombotic events, respiratory failure, renal insufficiency, and electrolyte abnormalities. Reintervention was defined as an intervention that was not planned at the time of admission to the ICU. In addition, the technical and personnel resources of the ICUs and the hospitals were documented.

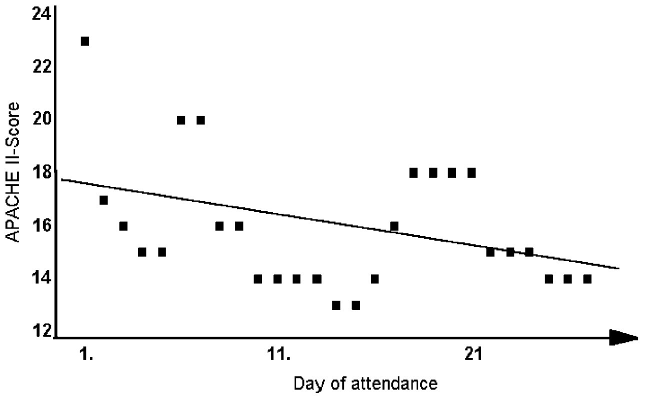

Fig. 1 Example of linear regression function of the *Acute Physiology and Chronic Health Evaluation* (APACHE)-II score

Statistical analysis

Univariate analysis

We described and compared the patients' characteristics at the day of admission to the ICU between the 2-SM and 3-SM. To describe the course of each patient on an ICU, we used the slope b of the linear regression function f(t) of all APACHE-II scores during the stay [f(t)=a+b* (t)] (Fig. 1). This calculation was done only for patients with at least two measurements, that means a stay longer than 8 h. The courses on an ICU were uni- and multivariately analyzed. To compare measuring variables with a normal distribution, we used the students *t*-test; the other variables were compared using the Mann-Whitney-U-test. For nominal data, we used the Chi-square test. The differences were called significant if $P<0.05$.

Multivariate analysis

In addition to univariate analysis, the impact of shift models on quality of patient care was analyzed multivariately. It is impossible to measure the dependent variable "quality of patient care" directly. We used various outcome indicators as an approximation:

1. Our first indicator of quality of patient care is the slope coefficient of a regression of the APACHE scores on the day of attendance for each patient on ICU. The smaller ("the more negative") this slope is, the more substantial is the extent of the patient's recovery on ICU and the higher is the quality of patient care.
2. Our second outcome indicator is mortality. The smaller this indicator is, the higher is the quality of patient care.
3. The third outcome indicator is the length of stay on ICU. The smaller this indicator is, the higher is the quality of patient care.

All multivariate analyses will be conducted alternatively with these three outcome indicators to check for the robustness of results. Confounding factors are the hospitals' personnel endowment (measured by the number of physicians on ICU), the hospitals' technical endowment (measured by a senior physician's evaluation on a metric scale), patients' severity of illness (measured by an expert double-blinded evaluation on a metric scale), and patients' ages. The independent variable shift model is constructed as a dummy variable with value zero for 3-SM hospitals and value one for 2-SM hospitals. The multivariate analysis was performed by an "ordinary least squares" (OLS) estimation of the following equation:

$$\ln \text{OUTCOME} = \text{CONSTANT} + \beta_1 * \ln \text{PERS} + \beta_2 * \ln \text{TECH} + \beta_3 * \ln \text{SEVERITY} + \beta_4 * \ln \text{AGE} + \beta_5 * \text{SHIFT}, \quad (1)$$

with:

- OUTCOME: outcome indicator
- PERS: hospital's personnel endowment
- TECH: hospital's technical endowment
- SEVERITY: patient's severity of illness
- AGE: patient's age
- SHIFT: shift model: 0=3-SM, 1=2-SM

Equation 1 is built in analogy to a so-called *Cobb-Douglas-production function*, which is a widely used specification in economics. A production function describes the technical relationship between an output variable (here, the outcome indicators) and those input factors influencing it. It is necessary to take the log of variables (save of the dummy variable shift) because of the exponential form of a Cobb-Douglas function. This form implies that the various inputs can be peripherally substituted against each other [19, 20].

The coefficient β_5 enables us to assess the impact of the alternative shift models on quality of patient care. For all alternative outcome indicators, a negative β_5 indicates that 2-SM hospitals reach a higher quality of patient care than 3-SM hospitals, and vice versa.

All calculations and statistics were done using SPSS-Statistical Package Version 7.5 for Windows (SPSS-Illinois, Chicago).

Results

Univariate results

We included 347 patients in the study, 103 in the 2-SM and 244 in the 3-SM. Most of the patients came postoperatively after surgical procedures (74.2% 2-SM and 82.2% 3-SM, n.s.) to the ICU. The diagnoses of the patients were comparable: 69% 2-SM and 67% 3-SM from general and thoracic surgery; 21% 2-SM and 14% 3-SM from vascular-surgery; 10% 2-SM and 19% 3-SM with trauma-injuries; n.s.

The epidemiological and health status on admission to the ICU were in both systems comparable (Table 1). The course of the patients in the ICU is demonstrated in Table 2. One of the significant differences ($P<0.01$) between the two groups is the "outcome" of the patients. The average stay on the ICU for a 3-SM patient was 1.6 days longer than on the 2-SM, and the mean total stay was 2.3 days longer. The frequency of complications in the 3-SM was higher than in the 2-SM, reinterventions were necessary more frequently, and more patients were readmitted. These results were not significant; the power was 0.5–0.6.

From the starting point of APACHE-II scores (16 vs 12 for 2-SM and 3-SM, respectively), the median values of the APACHE-II score decreased more quickly for patients from the 2-SM than from the 3-SM. The mean of the slope calculated by the APACHE-II score had a greater negative value for patients from the 2-SM than from the 3-SM. This means a significantly quicker recovery of the patients in the 2-SM ($P<0.05$).

Table 1 Epidemiological data and health status of patients on day of admission to intensive care unit (ICU). *LQ* lower quartile; *UQ* upper quartile; *min* minimum; *max* maximum; *n.s.* nonsignificant; *C.I.* confidence interval

	2-SM *n*=103	3-SM *n*=244	Significance
Age [mean, min–max (years)]	62 (18–91)	63 (9–94)	n.s.
Gender (male:female)	66:37	133:111	n.s.
ASA (median, LQ-UQ)	3 (2–3)	3 (3–3)	n.s.
APACHE II score, 1 day on ICU (median, LQ-UQ)	16 (11–19)	12 (7–17)	n.s.
Expected mortality rate[a], (95% CI)	18 (16–20)%	19 (17–21)%	
No. of patients			
<8 h on ICU (%)	*n*=5 (5%)	*n*=21 (9%)	n.s.
<24 h on ICU (%)	*n*=61 (59%)	*n*=103 (42%)	*P*<0.05
Severity of disease (1–6) 1 = Uncomplicated, 2 = Normal, 3 = Moderate, 4 = Severe, 5 = High risk, 6 = Extremely high risk	1=1 (1%) 2=15 (15%) 3=31 (30%) 4=24 (23%) 5=23 (22%) 6=9 (9%)	1=8 (3%) 2=54 (22%) 3=62 (25%) 4=64 (26%) 5=34 (14%) 6=22 (10%)	n.s.
Duration of surgical intervention (median, LQ-UQ) hours	3.0 (2–4.0)	3.0 (2–4.5)	n.s.

[a] Calculation of the expected mortality rate according Knaus et al. for surgical patients [16]

Table 2 Course of patients on the intensive care unit (ICU) comparing the two-shift model with the three-shift model (C.I. = 95% confidence interval)

	Two-shift model *n*=103	Three-shift model *n*=244	Significance
No. of days on ICU (mean, 95% C.I.)	5.6 (3.6–7.1)	7.2 (5.3–7.8)	*P*<0.01
No. of days in hospital (mean, 95% C.I.)	20.5 (17.4–23-5)	22.8 (20.3–25.3)	n.s.
Total no. of complications	62	216	
No. of patients who had at least one complication (%)	17 (17%)	53 (22%)	n.s.
Frequency of reinterventions	10.2%	15.9%	n.s.
Frequency of readmissions to ICU	*n*=4 4.0%	*n*=16 6.6%	n.s
Postoperative course "outcome" (1 = very good, 2 = normal, 3 = severe, 4 = death on ICU)	1–8.6% 2–71.2% 3–6.1% 4–5.1%	1–12.9% 2–58.3% 3–21.7% 4–8.7%	*P*<0.01
Slope b of course of APACHE-II score on ICU (f(t) = a + b*t) Mean, 95% C.I.	–4.6 (–5.8 to –3.4)	–2.1 (–2.5 to –1.7)	*P*<0.01

Multivariante analysis

Table 3 shows the standardized regression coefficients (*t* values in parentheses) of an ordinary least square (OLS)-regression for the three alternative outcome indicators. The standardized regression coefficients of shift are significantly different from zero except for the third estimation version (for which *P* is slightly above 5%) and have a negative sign in all versions. This implies that the various outcome indicators improve to a greater extent for patients in 2-SM hospitals than for those in 3-SM hospitals. In other words, 2-SM-hospitals reach a higher quality of patient care than 3-SM hospitals (other things equal). The estimation results for the other independent variables are in general plausible and robust with one exception – the coefficient of ln TECH has an implausible sign in the second version. This exception could result from a multicolinearity problem (see below).

Discussion

The study originated from the pressure executed from legal prescription. The intention of this law was to protect the physician and to create better conditions for the patients. However, a systematic evaluation of the postulated benefits has been lacking. The aim of our study was to evaluate the impact of different long working hours on the quality of patient care.

The findings of the study show that the quality of patient management is rather ineffective in the 3-SM model. There is a tendency to lengthen the stay. Furthermore, the

Table 3 Results of multivariate analysis: shift model and quality of patient care. *ln* logarithmus naturalis; *PERS* hospital's quantitative and qualitative personnel endowment; *TECH* hospital's technical endowment; *SHIFT* hospital's shift model

Independent variables	Dependent variables					
	ln Slope coefficient of APACHE scores		ln Mortality		ln Length of stay on ICU	
(CONSTANT)	–	(85.357**)	–	(0.370+)	–	(1.782+)
ln PERS	–0.249	(–4.281**)	–0.088	(–1.452+)	–0.107	(–1.917+)
ln TECH	–0.186	(–2.559*)	0.189	(2.503*)	–0.060	(–0.851+)
ln SEVERITY	0.112	(2.096*)	0.168	(3.024**)	0.371	(7.211**)
ln AGE	0.047	(0.878+)	0.122	(2.193*)	0.054	(1.059+)
SHIFT	–0.197	(–2.828**)	–0.179	(–2.477*)	–0.129	(–1.927+)
R-square	20.4%		5.5%		16.2%	

+Not significant, *P<0.05; **P<0.01

curing takes more time. The longer stay in the ICU correlates with a higher number of complications and a higher rate of reintervention. These findings do not always prove to be of significance because of the lower number of cases in the 2-SM. This problem only occurred in the course of the study. Due to the pressure of legal restrictions, several clinics that planned to take part in the study changed to the 3-SM within the period under investigation. Two other institutions with the 2-SM in their ICUs refused to participate in the study, as legal action had been taken against them because of violation of this law.

Since the study could not be blinded, a potential bias in the study could be induced by the fact that physicians traditionally favor the 2-SM. In our study, this effect might be only a small one, because the centers with the 3-SMs were, as well as the others, convinced of the better functions in their own unit than with the other model. Some of these units try to practice alternative models of working together, but it would be necessary to validate these results in bigger databases.

In addition to the multivariate analysis presented, an alternative model of the impact of shift models on patient outcomes was estimated. It used a variety of single indicators for the measurement of patient outcomes: the slope coefficient of APACHE scores, physicians' assessment of postoperative course, relative frequency of complications, relative frequency of reinterventions, relative frequency of respiration, mortality on ICU, duration in ICU, duration in hospital, and the relative frequency of diagnostic and therapeutic procedures. All these indicators correlate closely and with plausible signs. That is, patients with a high reduction of APACHE scores tend also to have a positive rating by the physician, a short duration of stay, relatively few complications, and so on. Therefore, the single indicators were summarized by means of a factor analysis. The resulting factor component correlated strongly, especially with the indicators "physicians' assessment" and "relative frequency of complications". Using this factor component as the dependent variable in a model with the same specification as the one described above produced a negative coefficient of the shift variable. That is, the result of the superiority of the 2-SM remains stable after an inclusion of additional outcome measures.

Our results are generally in line with those of Laine et al. [1] and Cydulka et al. [21]. Laine concludes that after New York State's Code 405 came into force, the relative frequency of complications and delays of diagnostic tests increased significantly. Hence, at least with respect to these outcome measures, quality of patient care deteriorated due to this restriction of working hours. Commenting on their results, Laine points out that they did not control differences in medical staff. This variable as well as the qualitative personnel and technical endowment were confounding factors in our multivariate analysis with the key result of the profitability of long coherent working hours being robust. Cydulka did not find any significant differences in the stress level of emergency physicians working for 12-h and 8-h shifts. This confirms our conclusion that fatigue-induced failures do not play a major role in comparing the impact of the 2-SM and 3-SM.

Supporters of short working shifts cite the numerous investigations performed in industry and investigating mainly assembly line production. Depending on the length of working shifts, severe losses in quality may occur. For physicians, this detail has not been investigated thoroughly. Wesnes et al. [22] reported a shortage of concentration ability in surgeons in training, which has been observed in normal shifts directly after extremely long weekend shifts. On the impact of shift working on the health of the employee, there are numerous publications [23]. However, if these results are valid for experienced surgeons, it has not yet been examined.

Restrictions of our results mainly stem from methodical problems. Our study is a cross-sectional analysis: the impact of alternative shift models on quality of care was assessed by a comparison of several hospitals. To be sure, hospitals' main differences in endowment and patient characteristics were controlled. Nevertheless, the remaining uncontrolled differences which impair the comparison of treatment results cannot be completely avoided. A second restriction is the limited number of hospitals (especially of those with a 2-SM), which raised problems of multicollinearity in our OLS estimation. Third, our empirical study focused on a certain medical specialty, i.e., on surgical ICUs at university hospitals.

Whether our results can be transferred to other medical specialties is an open question.

Our results suggest the relative superiority of a 2-SM over a 3-SM. Whether a working day of even more than 12 h is superior to a 2-SM in terms of quality of patient care cannot be judged from our empirical results. Two recent studies suggest that quality could be harmed by shift durations of about 18 h or 24 h per day [22, 24]. Obviously, the work load that can be put on hospital staff without serious damage for patient care has its limits. Therefore, the results of our study must not be misunderstood as an entitlement for any excessive daily or weekly working hours.

There is no answer to one important question – what is the reason for a 3-SM leading to a worse outcome. It might be caused by the loss of information from one shift to the next, but no study exists to confirm this assumption. Therefore, the study results are a strong argument for a structured and extended system for reporting the patient' condition and previous events.

The restrictions of our study point directly at the remaining needs of investigation. For validating our results, further empirical studies of the impact of alternative working time schedules on the quality of patient care should be carried out. For ICUs, our results should be reproduced for different patient cohorts or different hospitals. However, empirical studies in other medical specialties also merit further investigation because production processes of medical care differ as does the impact of alternative shift models [25].

Despite these questions remaining unanswered, our study might be valuable in trying to close the existing research deficit of the effects of alternative working time schedules on quality of patient care. Our results confirm that restriction of physicians' working hours does not only affect the work load being put on medical staff but also affects the organization of production processes. Until now, this aspect has not appropriately been taken account of by hospital administrators or governmental legislators.

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