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Generalizable items and modular structure for computerised physician staffing calculation on intensive care units

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Abstract

Intensive care medicine remains one of the most cost-driving areas within hospitals with high personnel costs. Under the scope of limited budgets and reimbursement, realistic needs are essential to justify personnel staffing. Unfortunately, all existing staffing models are top-down calculations with a high variability in results. We present a workload-oriented model, integrating quality of care, efficiency of processes, legal, educational, controlling, local, organisational and economic aspects. In our model, the physician's workload solely related to the intensive care unit depends on three tasks: Patient-oriented tasks, divided in basic tasks (performed in every patient) and additional tasks (necessary in patients with specific diagnostic and therapeutic requirements depending on their specific illness, only), and non patient-oriented tasks. All three tasks have to be taken into account for calculating the required number of physicians. The calculation tool further allows to determine minimal personnel staffing, distribution of calculated personnel demand regarding type of employee due to working hours per year, shift work or standby duty. This model was introduced and described first by the German Board of Anesthesiologists and the German Society of

Anesthesiology and Intensive Care Medicine in 2008 and since has been implemented and updated 2012 in Germany. The modular, flexible nature of the Excel-based calculation tool should allow adaption to the respective legal and organizational demands of different countries. After 8 years of experience with this calculation, we report the generalizable key aspects which may help physicians all around the world to justify realistic workload-oriented personnel staffing needs.

Key words: Budgets; Critical care; Economics; Humans; Intensive care units; Personnel hospital; Personnel staffing and scheduling; Physicians; Workload; Quality of health care

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Core tip: After 8 years of experience with the first calculation tool for physician staffing on intensive care units, generalizable key aspects are presented to help physicians all around the world to justify realistic personnel needs. A workload-oriented modular, flexible Excel-based calculation tool is presented, integrating quality of care, efficiency of processes, legal, educational, controlling, local, organisational and economic aspects. Staffing calculations reflect basic tasks (every patient), additional tasks (specific diagnostic and therapeutic requirements), non patient-oriented tasks, and, auxiliary calculations, such as minimal personnel staffing, distribution of personnel demand regarding type of employee due to working hours per year, shift work or standby duty.

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INTRODUCTION

Intensive care medicine is one of the most cost-driving areas within hospitals with high personnel costs^[1,2]. Thus, realistic requirements for personnel staffing are highly needed. Several professional societies in Germany (DGAI, BDA, DIVI, DGCH, BDCH)^[3], Europe (ESICM)^[4,5] or the United States (SCCM)^[6,7] made recommendations for the staffing and organisation of interdisciplinary intensive care units (ICUs). The presence of physicians on ICUs 24-h, 7 d a week, 365 d a year are justified by the physicians perspective^[3,4,6,7], and, in Germany, economically relevant for reimbursement. Unfortunately, all existing staffing models are top-down calculations with a high variability in the calculated results. In turn, this variability often reflects the range between sufficient personnel resources and being underpowered, thereby leading to controversial discussions. Taking into account quality of

care, it is necessary to calculate the need by a bottom-up method based on the performed procedures and actions. Furthermore, in the G-DRG-reimbursement system, costs for continuous medical education are insufficiently taken into consideration^[8]. Bearing these aspects in mind, the working group "personnel management of BDA und DGAI" published a workload-oriented modular calculation model for personnel staffing of physicians in the ICU in 2008^[9] and an update in 2012^[10]. Thereby, the actual-state of personnel staffing on the ICU can be compared with the necessary target-state and allows physician staffing on a workload basis. The BDA and DGAI tool enables an individualised systematic analysis for every type of hospital^[10]. The purpose of this paper is to present generalizable items and a modular structure for a computerised calculation tool for widespread use which may help physicians to justify realistic workload-oriented personnel staffing requirements on ICUs all around the world.

MODULAR CALCULATION OF STAFFING OF PHYSICIANS ON ICUS

Generalizable items of personnel staffing in the ICU are presented. The workload-oriented calculation^[9,10] has been developed for every type of ICU, taking into account various magnitudes, premises and organisational structures of hospitals, and degrees of care. The basic consideration in this model is analysing the workload of physicians on ICUs, which has been divided in basic tasks, additional tasks, and non patient-oriented tasks (including management issues and teaching). The personnel demand for these tasks can be calculated using Excel-based "calculation tools" (Tables 1-4). In addition, "assistance tools" can be provided to calculate minimal personnel staffing, distribution of calculated personnel need regarding type of employee due to working hours per year, shift work or stand by duty (Tables 5-8).

First of all, reflections are inevitable regarding the local situation, performance of the hospital, subset of patients, premises and organisational structures. Standard times regarding workload tasks have to be defined, at best should have been measured in the distinct hospital, and consented by different stakeholders.

However, before calculating workload-related personnel staffing, some aspects have to be clarified: (1) in-house times for admission, daily routine, omission and handing over by physicians; (2) in-house number and times for tasks, procedures and examinations, and non-recurring tasks performed per year per patients; (3) number of ICU beds; (4) number of cases and patient days per year; (5) average drop-out times (holidays, illness); (6) holidays given to shift workers, gross annual working time in hours per work-fellow; (7) number of physicians in specialist training with, e.g., less than 3 mo ICU experience; (8) time for non patient-oriented

Table 1 Basic patient-oriented tasks of physicians on the intensive care unit

		In-house	Standard	In-house time		Standard time		Physicians/ handing over
		Time (min)	Time (min)	Physician/ patient	Time/ patient	Physician/ patient	Time/ patient	
Admission (time per patient, including daily routine on day of admission)								
	Patient takeover	5	5					
	Clinical evaluation	5	5					
	Writing of admission documents	20	20					
	Writing of physician's instructions	10	10					
	Reimbursement documentation (DRGs)	10	10					
	Basic examination and controls	5	5					
	Handing over round	5	5					
	Senior physician round	5	5					
	Sum	65	65					
Daily routine (time per patient)								
	Transit time	5	5					
	Physical examination and status	5	5					
	Writing of physician's instructions	5	5					
	Documentation	2	2					
	Radiology round	2	2					
	Microbiology round	2	2					
	Physiotherapy round	10	10					
	Talking with relatives	5	5					
	Rounds with consultants	5	5					
	Sum	41	41					
Omission/demission (time per patient)								
	Final examination	3	3					
	Final documentation	15	15					
	Physician's letter	5	5					
	Handing over	2	2					
	Sum	25	25					
Handing over medical rounds (time per patient)								
Shift 1	Handing over 1 Mo - Fr			25	5	25	5	5
Shift 2	Handing over 2 Mo - Fr			25	5	25	5	5
Shift 3	Handing over 3 Mo - Fr			15	5	15	5	3
	Senior physician round Mo - Fr			10	10	5	5	1
	Sum Mo - Fr			75		70		
Shift 1	Handing over 1 Sa, Su, public holiday			15	5	15	5	3
Shift 2	Handing over 2 Sa, Su, public holiday			0	5	0	5	0
Shift 3	Handing over 3 Sa, Su, public holiday			15	5	15	5	3
	Senior physician round Sa, Su, public holiday			5	5	5	5	1
	Sum Sa, Su, public holidays			35		35		

tasks of the ICU physicians (*e.g.*, working groups, administration, teaching); (9) number of full-time and partial-time physicians and working hours per week and year; and (10) shift work and standby duty.

In respect to all these items, *e.g.*, with average drop-out time of 19.5% in a three-shift system and legal working regulations regarding handing over to other work-shifts, the workload results in 26.25 h for three physicians per day. In other words, 6.8 full-time physicians are necessary to run an ICU 24-h, 7 d a week, 365 d a year. This minimal staffing is independent of the number of beds and patients.

Thus, *e.g.*, with 12.75 h per day at maximum in shift work with at maximum 48 h per week and a standby duty of maximum 54 h per week, minimal staffing

demand can be calculated (Table 6). Weekly working hours multiplied with 52.2 result in the potential gross working time of a physician. The real net working time of a physician is yielded by subtracting the drop-out times (holidays, average times of illness) from the gross working time.

In the following, a modular calculation model for personnel staffing of physicians is presented. For better understanding, we filled the tables with a sample of a virtual ICU (Tables 1-8). After gathering the relevant data for the calculation sheets, the respective data can be filled in the input fields (Tables 1-8). When all the relevant white fields in the Tables of a distinct ICU are filled with the respective data, staff requirements/year in hours are summed up, and automatically transferred

Table 2 Additional patient-oriented tasks of physicians on the intensive care unit

	Inhouse time (min)	Standard time (min)	Numbers per yr	Total time
Examinations				
Angiography (diagnostic/interventional)	120	120	45	5400
CT scan	60	45	379	22740
Examination	20	20		
Preparation time for transit	20	20		
Transit time	20	20		
Magnetic resonance tomography MRT	65	65	80	5200
Examination	20	20		
Preparation time for transit	30	30		
Transit time	15	15		
Diagnostic bronchoscopy	40	40	298	11920
Twelve-lead ECG	10	10	0	0
Haemodynamics (PAC/PiCCO)	15	15	114	1710
Limon	30	30	0	0
CVVHF (Heparin)/setup, change	30	30	2	60
CVVHF (Citrate)/setup, change	40	40	398	15920
MARS	120	120	0	0
Thrombelastography (TEG)	20	20	0	0
Setting up	5	5		
Control	5	5		
Finalization	10	10		
Tasks/procedures				
Ascites puncture	20	20	0	0
Installation of arterial line	10	10	254	2540
ARDS - 135° position	20	20	280	5600
Transfusion blood/coagulation products (per unit)	5	5	2732	13660
Cardioversion	15	15	4	60
Insertion of central lines (CVC, Sheldon, PiCCO)	40	40	374	14960
Intracranial pressure measurement	15	15	16	240
Intubation	15	15	100	1500
Support of consultants	10	10	49	490
Transportation to operating theatre (in/out)	20	20	2600	52000
Installation of PAC/PiCCO	10	10	1	10
Isolation of patients (f.e. MRSA)/d	15	15	45	675
Installation of peridural catheters	30	30	6	180
Percutaneous puncture of bladder	30	30	0	0
Puncture of pleura (one-time)	20	20	0	0
Transesophageal echocardiography	45	45	31	1395
Chest tube	30	30	113	3390
Tracheotomy (dilation/plastically)	60	60	93	5580
Transvenous pacemaker	10	10	0	0
Ultrasonography of bladder	10	10	238	2380
Ultrasonography of pleura	10	10	200	2000
Transfer of patient to external institutions	30	30	0	0
Major wound care	15	15	50	750
Additional efforts (onetime/patient/stay)				
Physician's letter (extensive, multi-page)	30	30	708	21240
Final documentation in decease	30	30	113	3390
Inquires by health insurance	15	15	35	525
Preparation for rehabilitation	45	45	107	4815
Sum additional tasks				
In min				200330
In h				3339

CT: Computed tomography; MRI: Magnetic resonance imaging.

to the following tables.

WORKLOAD-ORIENTED STAFFING CALCULATIONS

Basic effort includes all duties of physicians, which have to be done in each patient on admission, on a daily basis, handing over to other work-shifts, and

on omission from the ICU, irrespective of severity of disease (Table 1). For calculation, different personnel staffing variations on working days, weekends and holidays have been taken into account.

The additional tasks, depending on severity of disease and organ dysfunctions, reflect all other tasks, procedures and examinations, as well as non-recurring tasks performed per year per patients (Table 2).

Table 3 Non patient-oriented tasks of physicians on the intensive care unit

		Time in h per year	FE net	
Working groups				Name working groups ... Projects
	Airway management	84	0.04	
	Haemostaseology	84	0.04	
	Regional anaesthesia	84	0.04	
	Working group A	84	0.04	Ultrasound
	Working group B	84	0.04	Quality management, SOPs
	Working group C	42	0.02	Hygiene standards
Administrative tasks				
	Waste management/recycling	42	0.02	
	Department homepage	42	0.02	
	Controlling	84	0.04	
	Duty rota/duty pay off	218	0.10	
	Inhouse continued education	42	0.02	
	Executive board meetings	104	0.05	
	Annual report	84	0.04	
	Documentation of effort	84	0.04	
	Computers and interconnection	84	0.04	
	Rotation	21	0.01	
	Emergency room management	21	0.01	
	Rota plan	42	0.02	
	Holiday plan	42	0.02	
	Certificates	42	0.02	
	Administrative task A	84	0.04	Strategy planning
	Administrative task B		0.00	
	Administrative task C		0.00	
Work in committees				
	Antibiotics	42	0.02	
	Drugs	42	0.02	
	Urban planning	84	0.04	
	Equipment	84	0.04	
	Materials management and control	42	0.02	
	Transfusions	42	0.02	
	Committee A	84	0.04	Patients's feedback
	Committee B		0.00	
	Committee C		0.00	
Students in practical year (PY)				
	Number of PY students per year			8
	Time demand of physicians for PY students (h)	2192	1.30	1 gross physician/8 PY-students
Work in projects				
	Project A	218	0.10	Antibiotic stewardship
	Project B		0.00	
	Project C		0.00	
	Project D		0.00	
	Project E		0.00	
Teaching				
	Nurses	500	0.23	
	Other matters		0.00	
Regulatory decrees/representatives				
	Worker protection	52	0.02	
	Data security	52	0.02	
	Diagnosis related groups	52	0.02	
	Hygiene	52	0.02	
	Devices	52	0.02	
	Hazardous material	52	0.02	
	Ordinance on medical devices	52	0.02	
	Quality management	52	0.02	
	Protection against X-rays	52	0.02	
	Transplantation	52	0.02	
Sum hours net per year (h)		5348.4	3.16	

Non patient-oriented-tasks reflect working groups, administrative tasks, collaboration in commissions, teaching of students or nurses, tasks in projects and regulatory decrees (e.g., X-rays, hygiene, quality management, laws regarding medical products)^[11], knowledge

development and continuation requirements (Table 3).

Total calculation results from patient days and cases per year, time efforts for basic and additional tasks, and for non patient-oriented tasks, which are summed up (Table 4). To result in the net annual working time,

Table 4 Total calculation of physician staffing on the intensive care unit

		Time demand per patient (min)	
Patient days per year	5868		
Caes per year	705		
Public holidays/yr	11		
Total amount			
Numbers of "admissions"	705	Admission	65
Numbers of "daily routine"	5163	Daily routine	41
Numbers of "discharges/transferrals"	705	Discharge/transferral	25
Numbers of "handing over rounds monday - friday"	4019	Handing over round monday - friday	75
Numbers of "handing over rounds Sat, Sun, public hol."	1849	Handing over rounds Sat, Sun, public holidays	35
Total times			
Time "takeover"	45825 min		
Time "daily routine"	211683 min		
Time "discharges/transferrals"	17625 min		
Time "handing over rounds monday - friday"	301438 min		
Numbers "handing over rounds Sat, Sun, public hol."	64709 min		
Total time BT	641280 min		
	10688 h		
Total time AT	3339 h		
Time demand (BT + AT)	14027 h		
Time for non patient-oriented tasks	5348 h		
Holidays for shift workers	205 h		
Total time expenditure	19580 h		
Rest allowance in %	19.5%		
Total time expenditure plus rest allowance	23398 h		
Working hours without break per day (h)	8.4		
Standard weekly hours of FE in h	42		
Annual net time per FE (h)	1691		
Number of FE	11.6	(net 1)	Gross time per FE 2192 h
Number of beds	16		
LS role	0.4	(0.15 FE/6 beds/net)	
Leadership role h/yr	676	(hours for 0.15 FE/6 beds/net)	
Number of physicians < 3 mo of ICU experience/yr	7		
PT	2.1	(0.3 FE/physician < 3 mo ICU experience/year/net)	
Postgraduate training hours per year	3550	(hours for 0.3 FE/physician < 3 mo ICU experience/yr/net)	
Total time + leader ship, PT	23806	h	
Number FE without continuing medical education	14.1	(net 2)	
CME/SA (h)	704		50 (h/yr/FE)
Continuing medical education/staff appraisal in FE	0.4		
Total time + LS, PT, CME, SA (net total)	24511	h	
Number FE (net total)	14.5		

BT: Basic tasks; AT: Additional tasks; FE: Full-time employee; LS: Leader ship role; PT: Postgraduate training; CME: Continuing medical education; SA: Staff appraisal.

festive seasons and holiday seasons have to be taken into account. Additional times, *e.g.*, for holidays given to shift workers, should be added. Following, times for rest allowance for full-time work-fellows should be stated. Rest allowance reflects holidays and average illness, and have to be defined as percentage of gross annual working time (Table 4). Real annual personnel demand in hours can be converted to annual full-time equivalents in that the sum of annual hours is divided through the net annual working time hours of an employee. If management functions are associated with the number of beds (*e.g.*, 0.15 physicians per 6 beds), proportional personnel staff for management can be calculated (*e.g.*, 0.3 physicians per fellows with less than 3 mo of ICU experience). Moreover, given the number of work-fellows in training per year, additional staff for teaching can be stated. On top, additional time

for work-fellow dialogue and knowledge continuation for each full-time work-fellow should be added. Taken together, all these items lead to the number of full-time physicians needed per year to fulfill the items named above.

AUXILIARY STAFFING CALCULATIONS

If the total workload and need of personnel staffing in full-time physicians per year is known, assistance tools can clarify how to distribute employees with differing average working time per week (Table 5). As shown in the example in Table 5, the mix with partial-time and full-time physicians results in sum in 17 work-fellows to fulfill the tasks which were calculated to be provided by 14.5 full-time employees.

Calculation of minimal physician staffing per year

Table 5 Calculation with work-fellows with different annual working times

Carryover of table total calculation, total time + rest allowance, leadership, postgraduate training CME, staff appraisal: AWT desired net value (h)							24511
	Standard weekly hours (h)	Public holidays	Gross AWT (h)	Rest allowance plus LS, PT, CME, SA (%)	Net AWT (h)	Number of physicians	Net AWT real (h)
Employee type 1	42.00	11	2192	19.5	1691	4.0	6762
Employee type 2	21.00	11	1096	19.5	808	2.0	1616
Employee type 3	48.00	11	2506	19.5	1943	1.0	1943
Employee type 4	54.00	11	2819	19.5	2195	3.0	6584
Employee type 5	10.50	11	548	19.5	367	1.0	367
Employee type 6	40.00	11	2088	19.5	1606	3.0	4819
Employee type 7	20.00	11	1044	19.5	766	3.0	2298
Employee type 8		11	0	19.5	-74		0
Employee type 9		11	0	19.5	-74		0
Employee type 10		11	0	19.5	-74		0
Sum employees						17.0	
Sum annual working time net (h)							24389
Hours net demand (if negative values) (h)							-121

Gross AWT = [Standard weekly hours : 5 (d)] × (261 workdays - public holidays), underlying (365 running days - 102 Saturdays; Sundays = 261 workdays).
 Net AWT = gross AWT - [gross AWT × (Rest allowance plus LS, PT, CME, SA)]. AWT: Annual working time; CME: Continuing medical education; LS: Leadership; PT: Postgraduate training; SA: Staff appraisal.

Table 6 Calculation of minimal physician staffing per year to run an intensive care unit

Time handing over round (min)	45					
Shift model hours		Number of handing overs day	Sum handing over (min) per day	Sum handing over (h) per day		
8 h		3	135	2.25		
12 h		2	90	1.50		
x h			0	0.00		
Standard weekly hours FE in h		42		Gross per year	Net per year	
Working hours per day in h		8.4		2192	1691	
Rest allowance in %		19.5				
Minimal demand of physicians						
Minimal occupancy: 1 physician, 24 h/d, 7 d/wk, 365 d/yr						
Number of physicians per shift	Shift		Net hours per day plus handing over	Net hours per year plus handing over	Gross hours per year plus handing over	FE net 42 h/wk
1	8 h		26.25	9581	11450	6.8
1	12 h		25.50	9308	11122	6.6
1	x h		24.00	8760	10468	6.2

Not considered: times for CME, LS, PT, SA. Take care for legal working regulations: e.g., at maximum 48 h/wk in shift work, as well as 54 h/wk with opt-out in standby duty! Take care for legal regulations: e.g., at maximum 12 h shift + 45 min handing over! AWT: Annual working time; CME: Continuing medical education; FE: Full-time employee; LS: Leadership; PT: Postgraduate training; SA: Staff appraisal.

to run an ICU is presented in Table 6. How many work-fellows do I need at minimum to guarantee a 24-h, 7-d a week, 365-d a year coverage with physician personnel, and in some countries, depending on that to get reimbursed or fulfill quality standards? Calculating the hours needed per year to cover full-time physician coverage, reflecting average drop-out times (holidays, average time for illness, e.g., 19.5% per year) and legal working regulations (e.g., 12.75 h per day at maximum in shift work with at maximum 48 h per week with standby duty of 54 h at maximum per week), minimal staffing

demand can be calculated (Table 6). In this calculation, times for non-patient-oriented tasks, continuing medical education, leadership tasks, postgraduate training and staff appraisal are not considered.

If the total workload and need of personnel staffing in full-time physicians is known, an assistance tool may help to calculate the personnel needed to run the ICU based on shift work (Table 7).

Also, with known total workload, with an assistance tool, calculation of the personnel needed to run the ICU based on standby duty is possible (Table 8).

Table 7 Calculation of physician staffing in shift work

Characteristics of shift work							Demand of physicians					
Duty hours (shift)			06:00-14:54				Carryover of table total calculation, total time plus RA, LS, PT, CME, SA =					
Public holidays/year			11									
Rest allowance in %			19.5									
Working hours without break per day (h)			8.4				Sum net annual working time desired (h)			24511		
Standard weekly hours of full-time employee (FE) in h			42				Sum number full-time physicians (net total) desired			14.5		
Gross annual time per full-time employee FE (h)			2192									
Net annual time per full-time employee FE (h) (without public holidays, holidays, illness)			1691									
Shift	Days	Shift model	Start	End	Break h	Working hours without break h	Physician/shift	Demand/week		Physicians	Demand /year	
								Workdays/ week (n)	Workhours/ week	Workdays/ year (n)	Workhours/ year net (h)	Full-time employees/ year net
a. m. shift	Weekday	8 h	6:00	14:54	0.5	8.4	5	5	210	250	10500	6.2
p. m. shift	Weekday	8 h	14:00	22:54	0.5	8.4	2	5	84	250	4200	2.5
night shift	Weekday	8 h	22:00	6:54	0.5	8.4	2	5	84	250	4200	2.5
a. m. shift	Weekday	8 h	6:00	14:54	0.5	8.4	2	2	33.6	104	1747.2	1
p. m. shift	Weekday	8 h	14:00	22:54	0.5	8.4	2	2	33.6	104	1747.2	1
night shift	Weekday	8 h	22:00	6:54	0.5	8.4	2	2	33.6	104	1747.2	1
a. m. shift	Public holiday	8 h	6:00	14:54	0.5	8.4	2			11	184.8	0.1
p. m. shift	Public holiday	8 h	14:00	22:54	0.5	8.4	2			11	184.8	0.1
night shift	Public holiday	8 h	22:00	6:54	0.5	8.4	2			11	184.8	0.1
Senior physician	Weekend/ public holiday		8:00	10:00	0	2	1	2	4	115	230	0.1
Inhouse special duty			0:00	0:00					0		0	0
								Sum	482.8		24926	14.7
								Net demand			-415.4	-0.2

Take care for legal regulations: *e.g.*, at maximum 12 h shift + 45 min handing over! Take care for legal working regulations: *e.g.*, at maximum 48 h/wk in shift work! CME: Continuing medical education; FE: Full-time employee; LS: Leadership, PT: Postgraduate training; SA: Staff appraisal.

DISCUSSION

One calculation tool cannot cover all aspects worldwide. However, modular tools, such as the BDA/DGAI tool^[10], have the key advantage to systematically look at the own performance spectrum, structural and legal conditions, and to calculate the corresponding personnel need. It should be kept in mind that besides all the workload-based calculations, due to arrange for manpower, a minimal personnel staffing is necessary to run an ICU with full-time coverage by a physician 24-h, 7-d a week, 365-d a year. This minimal staffing demand is independent of the workload, number of beds and patients.

Regarding medicolegal aspects, professional societies in Germany (DIVI, DGAI) and in Europe (ESICM) agree on the demand of continuous presence of physicians on the ICU. Previous top-down staffing models resulted in a high variability between sufficient and underpowered personnel resources. For example, the top-down calculation of the European Society of Intensive Care Medicine suggested the need of 5 physicians per ICU comprising 6 to 8 beds per year^[4,5]. Thus, calculation of

a 24 bed unit leads to a demand of 15 to 20 physicians, and, thereby, to a difference in demand of 5 physicians or 25%. In Germany, 24-h coverage by a physician is an inalienable prerequisite for reimbursement within the G-DRG system in terms of quality management. The presented calculation instrument directly couples workload to the personnel demand. Irrespective of quantitative calculations of staff, in Germany, reflecting legal demands, it has to be assured that performance is delivered all the time economically and according to commonly accepted standards of care and knowledge^[12] on the level of an experienced physician^[13], with benefit for the patient. Thus, besides quantitative, qualitative cornerstones for personnel requirement of physicians on ICUs have to be taken into account. The modular basis of the BDA/DGAI tool allows subsets of patients treated, social and industrial law, medical quality standards, economic and reimbursement items of the respective countries to be taken into consideration and to adapt the tool for personnel staffing in various countries and types of hospitals. In former days, the ICU personnel staffing tool was allocated *via* disc in Germany. Currently, it is provided online for free to all BDA/DGAI members, and,

Table 8 Calculation of physician staffing in standby duty

Charcteristics of standby duty								Demand of physicians					
Duty hours (shift)		07:15-16:09						Carryover of table total calculation, total time plus RA, LS, PT, CME, SA = Sum net annual working time desired (h) 24511 Sum number full-time physicians (net total) desired 14.5					
Public holidays/year		11											
Rest allowance in %		19.5											
Working hours without break per day (h)		8.4											
Standard weekly hours of full-time employee (FE) in h		42											
Gross annual time per full-time employee FE (h)		2192											
Net annual time per full-time employee FE (h) (without public holidays, holidays, illness)		1691											
Shift	Days	Type	Start	End	Break h	Working hours without break h	Physician/shift	Demand physicians/wk		Demand physicians/yr			
								Workdays/wk (n)	Workhours/wk	Workdays/yr (n)	Workhours/yr net	Core time full-time employee/yr net	Standby duty full-time employees/yr net
a. m. shift	Weekday		7:15	16:09	0.5	8.4	3	5	126	250	6300	3.7	
p. m. shift	Weekday		13:30	22:24	0.5	8.4	2	5	84	250	4200	2.5	
x shift	Weekday		0:00	0:00				5	0	250	0	0	
a. m. shift	Weekday		7:15	16:09	0.5	8.4	0	2	0	104	0	0	
p. m. shift	Weekday		0:00	0:00				2	0	104	0	0	
x shift	Weekday		0:00	0:00				2	0	104	0	0	
a. m. shift	Public holiday		7:15	16:09	0.5	8.4	2			11	184.8	0.1	
p. m. shift	Public holiday		0:00	0:00			2			11	0	0	
x shift	Public holiday		0:00	0:00			2			11	0	0	
Standby duty	Weekday	1	0:00	0:00	0			5	0.0	250	0		0
Standby duty	Weekend	1	0:00	0:00	0			2	0.0	104	0		0
Standby duty	Public holiday	1	0:00	0:00	0					11	0		0
Standby duty	Weekday	2	16:09	8:00	0	15.85	2	5	158.5	250	7925		4.7
Standby duty	Weekend	2	7:15	8:00	0	24.75	2	2	99	104	5148		3
Standby duty	Public holiday	2	7:15	8:00	0	24.75	2			11	544.5		0.3
Senior physician	Weekend /public holiday		8:00	10:00	0	2	1	2	4	115	230		0.1
Inhouse special duty			0:00	0:00					0		0		0
Sum									261.5		24532.3	6.3	8.2
Sum core time, standby duty + special duties full-time employees net													14.5
Net demand											-21.7		0

CME: Continuing medical education; FE: Full-time employee; LS: Leadership; PT: Postgraduate training; SA: Staff appraisal.

at the owner's expense, to interested stakeholders by BDA/DGAI^[10]. The tool is widespread all over Germany in university and non-university hospitals and has been

fine-tuned through the years since 2008, reflecting and integrating the feedback of the users. However, studies reflecting improved outcomes or better productivity

have not been performed. Feedback to BDA/DGAI revealed that personnel calculations were effectuated in around 1/3 of the users, transposed partially in 1/3, and not accepted in 1/3. Unfortunately, there is no in total or representative scientific evaluation of personnel staffing in non-university and university hospitals all over Germany which could reflect the gap between the calculations done by the tool and the actual personnel staffing of the ICUs. Moreover, whether staffing differences from basic and regular care up to maximal care hospitals result in better productivity or improved outcome in Germany is still a matter of debate. However, quality of care, length of stay and mortality in ICUs has been reported to be highly dependent on organisational structures, personnel staffing and qualification of physicians^[9,14,15]. Reductions in personnel staffing are counterproductive if safety for patients and staff, and efficiency of processes decline^[16-19], and/or the costs for materials increase^[18,20]. Furthermore, it has to be taken into account that optimal reduction in errors is expected with a 85% average utilisation of an ICU with 100% of personnel staffing^[19]. To achieve optimal quality, physician staffing has been claimed as follows^[5,21]: The ICU has to be under a qualified, uniform, physician organised guidance, *e.g.*, by a physician of a specialty which has intensive care medicine as an integrated part, such as anaesthesia, surgery, internal medicine, and who has special certification in intensive care medicine. The leader of the ICU should not be in other duties in his hospital, devoted full-time or at least 75% of time to intensive care^[5,21].

To find out whether timings for tasks are realistic, in the ICU personnel staffing tool, we proceeded as follows. To determine duration of tasks to be performed, estimations by experts' opinion (10 leaders of ICUs), a survey in 200 ICUs in Germany (practitioning ICU physicians), and real time measurements on a surgical and a medical university and a non-university interdisciplinary ICU of a basic and regular care hospital have been compared^[22]. In 20%, expert opinion survey and measured times were consistent. Differences, such as higher values for daily routine in the basic care non-university hospital, may be explained by different process operations on the various wards. Thus, necessary time requirements depend on the comparability of basic prerequisites, process operations, structural and legal conditions. Therefore, cited timings for tasks can serve as an indication for time requirements, however, have to be verified, at best with real time measurements in the own structural conditions and process operations.

Tasks beyond the ICU, such as initial trauma care, care for in-hospital emergencies or engagement as external emergency physician, should not be incorporated in the staffing calculation of the ICU, but calculated separately. Quantitative and qualitative cornerstones for personnel requirement of physicians in anaesthesia reflecting recent legal rights of patients in Germany, meeting legal demands of therapeutic quality, and, thus, serving patient safety, have been published in 2015 by the German Society of Anesthesiologists (BDA) and the German Society of

Anesthesiology and Intensive Care Medicine (DGAI)^[23]. Subsequently, the current Excel-based calculation tool version (2015) regarding physician staffing in anaesthesia has been published, especially reflecting recent laws governing physician's working conditions and competence in the field of anaesthesia, as well as demands of strengthened legal rights of patients, patient care and safety^[24].

CONCLUSION

Workload-oriented models of physician staffing with generalizable items taking into account quality, efficiency of processes, legal, educational, controlling, local, organisational and economic aspects, differentiating basic effort, additional effort, and non patient-oriented tasks, may help to justify realistic personnel staffing demands. Modular calculation models may serve to individualise generalizable aspects to various types of hospitals, process operations, structural and legal conditions, as well as funding and refunding systems, resulting in broadly use and acceptance by various stakeholders all around the world. In the future, it should be evaluated whether this model may lead to improvement of patient safety and quality of management.

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