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Workload reduction through automated documentation in intensive and intermediate care - a monocentric observational study

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Abstract. – OBJECTIVE: The global coronavirus pandemic has placed an unprecedented and enormous burden on health systems worldwide. In addition to a shortage of resources, nurses were also confronted with high levels of sick leave and an increasing exodus from the profession. Automating documentation obligations is an effective way of reducing the burden on the workplace.

PATIENTS AND METHODS: The study was conducted at a tertiary university hospital. The time required for the manual documentation of administered medication and dose changes of syringe and infusion pumps was recorded using the patient data management system (PDMS) representing all intensive and intermediate care wards (n = 6). Subsequently, all medication administration – grouped into five classes – was evaluated from January 1st, 2019, until December 31st, 2022.

RESULTS: A total of 1,373,340 drug applications were studied, treating 32,499 patients. Data were obtained from ICUs (68%) and IMC wards (32%). This corresponds to an overall time of 2,901 ± 233 hours per year. Based on publicly known national rates for intensive care nurses, an annual financial expenditure of approximately 83,300 € (~ USD 89,300) per year was estimated.

CONCLUSIONS: A non-negligible part of the daily working time in the medical sector is spent on documentation duties. This aggravates the high workload, which has increased in recent years. Automated documentation systems can lead to considerable relief and the possibility of focusing primarily on the patient and on other core competencies and activities. This is even more important, as available staff will be a key resource in patient care for the foreseeable future.

Key Words:
Economic development, Healthcare economics, Employee workload, Digital signal processing, User computer interface.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic acted as a focal point for the already existing and increasing difficulties in recruiting sufficient nurses for critically ill patients. The problems can be seen in various aspects of human resource management, as well as in working conditions. One major issue is the ratio of intensive care staff to patients. The currently recommended ratio is, depending on the condition of the patients and the hospital level of care, 1:1 or 1:2, but in many medical institutions, the ratio is much higher, leading to overworked and stressed staff[1-3]. This has an undeniable impact on the observed patient mortality as well as burnout risks and the mental health of staff[4,5]. The COVID-19 pandemic has worsened the level of stress for healthcare workers, leading to an increase in burnout[6]. Another important issue of modern critical care is the tension between increasingly multimorbid patients and demographic changes[7]. As the population ages, the number of patients with multiple chronic conditions who require complex critical care increases[8]. This places additional demands on intensive care staff, who must have specialized knowledge and skills to care for these kinds of patients. In addition to these challenges, there is a widespread shortage of intensive care nurses, making it difficult to fill vacancies. Some of the reasons for this shortage include low pay, high stress, and lack of job satisfaction as well as appreciation[9]. As a result, many nurses leave their profession or opt to work in less demanding sectors. All these issues have led to a shortage of nurses in intensive care units (ICUs), which in turn affects the quality of care provided to critically ill patients[10]. More specifically, for several years, there has been a trend towards overload in the demand for ICU

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beds and available ICU capacities, mainly driven by the lack of qualified staff available[11]. Internationally, this is leading to a lack of available treatment capacities despite the increasing need for ICU therapy; for example, the Critical Care Professional Societies published a white paper on the "Critical Medicine Crisis" in 2004[12]. The resulting difficulties in addressing public health needs adequately made it onto the political agenda years ago without any real change in staffing levels becoming apparent[13]. A shortage of nurses, short training periods, and high-stress levels also increase the risk of hygiene problems, especially linked to germs spreading[14]. The acquisition of staff from countries outside the EU or the US cannot and should not be a long-term solution due to a shortage in the countries of origin. Problems due to linguistic barriers and different qualifications in various countries underline this tension in staff recruitment[15].

The majority of critically ill patients require complex, differentiated medication therapy using Infusomat® Space pumps (infusion pumps produced by B. Braun, Melsungen, Germany) and syringe pumps. The preparation of the medications, loading of the infusion pumps, operation and adjustment of the flow rates, and bolus administration according to the patient's needs are very demanding[16]. As a result, preparing and administering these medications can be quite time-consuming, as it requires specialized knowledge and skills. One of the main challenges is the documentation of these medications[17]. The documentation must be accurate and complete, as it has legal and forensic impact[18]. It must include the correct time of administration, the correct dosage, the name of the medication, and the patient's vital signs[19,20]. This process can take a considerable amount of time, which reduces the time available for patient care. Additionally, the use of syringe pumps and the administration of medications require constant monitoring and adjustment[21]. This can be a substantial burden on nursing staff, as this requires constant attention and can lead to fatigue and burnout.

A modern digital patient documentation management system (PDMS) can be of help but must meet several requirements to be effective. These include ease of use, data security, legal compliance, real-time data, and interoperability. Modern systems should be integrated with other systems and devices, such as electronic health records, vital sign monitors, and infusion pumps, to ensure continuity of care. Unfortunately, this is usually not the case. End users, such as nurses, continue to play a crucial role in the use of digital PDMS. They are responsible for entering and updating patient information, such as medication flow rates and vital signs. They are also responsible for ensuring the accuracy and completeness of the data entered. A user-friendly system with high interoperability can help reduce workload and ensure completeness and accuracy of data. Accordingly, a thoughtful digitalization strategy is revolutionizing patient care in the critical care sector[22]. In addition, suitable anonymization mechanisms generate datasets for research purposes to improve treatment in ICUs; thus, databases such as MIMIC-III provide the basis for validating and investigating numerous issues in modern intensive care[23]. The quality of the datasets is clearly improved by digital data transmission with few complications.

To grasp the potential of a completely digital data transfer, we intended to evaluate the time workload caused by time-consuming manual documentation in several interdisciplinary intensive care and intermediate care units (IMCs) of a tertiary university hospital and to detect potential savings through automated recording.

Patients and Methods

This is a prospective observational study at a tertiary university hospital. The protocol was approved by the institutional Ethics Committee (IRB of the University Hospital Frankfurt, Theodor-Stern-Kai 7, 60590 Frankfurt, Germany; #2022-995), and a waiver of written informed consent was approved[24].

This study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and was conducted in accordance with the Declaration of Helsinki[25].

Patient Population and Data Collection

During the observation period from January 1, 2019, to December 31, 2022, all patients older than 18 who were treated in one of the university intensive care or intermediate care units were included in this study. To obtain a dataset that was as homogeneous as possible, the data of all operating intensive care units participating in the care of critically ill adults were included. The sample thus included patients from all internal medicine departments, as well as all neurological

and neurosurgical patients and those from the entire spectrum of modern surgical departments, including cardiac surgery.

All documented changes, initiations, and terminations in syringe pumps and infusion pumps were extracted from the patient data management system (PDMS) Metavision (Version 5.4, iMDsoft, Tel Aviv, Israel). Data were stored in a Microsoft Excel pivot table (Version 365, Microsoft Corp., Redmond, USA) with restricted access. Data extraction was carried out for neurosurgical, neurological, internal and surgical intensive care and intermediate care wards. Overall, the entire spectrum of modern intensive medical care at a tertiary university center was covered.

A differentiated evaluation was carried out for each month, and status changes were defined for the abovementioned devices (documentation of a newly prescribed or re-prescribed medication *via* syringe pumps and changes in the delivery rate of the syringe pumps).

Furthermore, five medication categories were generated, consisting of catecholamines, sedatives, anti-infectives, nutrition, and (grouped) other medications *via* syringe pumps and infusion pumps as appropriate. In addition, the patient occupancy rates of the study wards were taken into account within the month under investigation. The data were extracted by the in-house data integration center according to the defined endpoints, the number of new syringe pumps documented, and dose changes.

To evaluate the aspect of time savings, an observation of the nursing staff on all examined wards was carried out. This involved capturing whether the computers on which data changes were recorded manually were in an already open PDMS (Status I), followed by the necessity of PDMS authentication (Status II) up to the completely locked user workstation and PDMS (Status III). In addition, the time needed to walk from the syringe pump/infusion system to the corresponding PC and the documentation time needed were recorded. There were 150 measurements at each station for all possible combinations of data acquired.

Statistical Analysis

No statistical power calculation was conducted prior to this study. The sample size was based on the maximum number of records available from the collection period. The categorical variables were presented as counts and percentages. The variables that were not normally distributed are described as medians [interquartile range, IQR (25/75)]. Differences between pharmacological groups and wards were assessed using Fisher's exact test for categorical variables, while the Mann-Whitney U test and the Student's *t*-test were used for continuous variables, as appropriate.

All statistical tests were two-tailed, and results with $p < 0.05$ were considered statistically significant. All calculations/analyses were performed with SPSS (Version 29, IBM Corp., Armonk, NY, USA).

Results

We recorded data on the treatment of 32,499 patients admitted to the ICUs and IMCs of our tertiary university center between 2019 and 2022. There was a slight decrease in ICU occupancy with a simultaneous increase in IMC occupancy in terms of new admissions. The median monthly occupancy was 685 (IQR 628/742) patients requiring monitoring, with a slight upward trend (1.09% annual increase in occupancy) over the study period. During the observation period, a median monthly documented 27,889 manual changes in syringe pump rates were recorded. A detectable seasonal fluctuation of the documented interactions, e.g., in the winter season, could not be determined from the available data, but a slight nonsignificant increase in simultaneous COVID-19 waves was observed. In total, 1,373,340 individual records were registered, 68.0% of which were allocated to ICUs and 32.0% to IMCs. In addition, the records were categorized according to the predefined pharmaceutical groups, as shown in Figure 1.

To document the time needed for continued syringe pump use without a dosage change, a dosage change, and to pause and resume syringe pump use, separate working time expenditures were recorded. The results revealed that the PC's status (locked/unlocked) at the workstation had a significant influence on the documentation time needed ($p < 0.001$). The shortest processing time was found at a PC workstation with an already open PDMS (Status I), followed by the necessity of PDMS authentication (Status II) up to the completely locked user workstation and PDMS (Status III) with an over 300% greater time expenditure (Table I).

Furthermore, the data showed a significant difference in the use of catecholamines, sedatives, and nutrition between the ward types, with

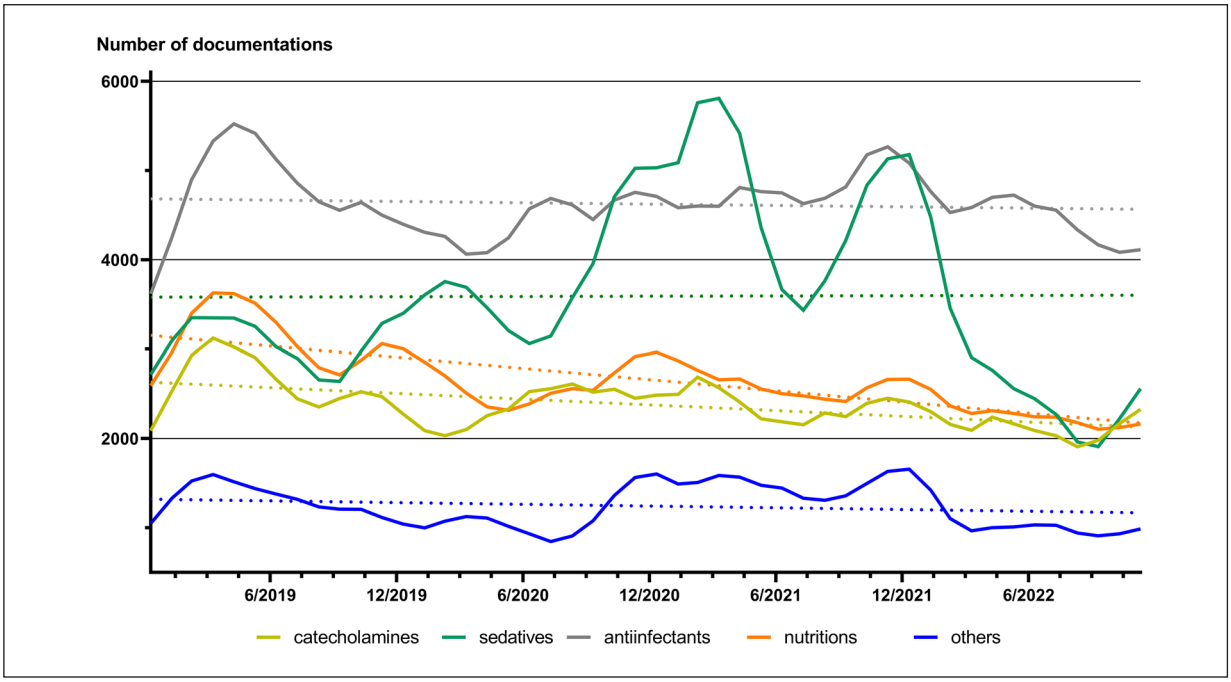

Figure 1. New syringe pump documentation over time. Graphical visualization of newly documented syringe pumps during the observation period, separated according to the predefined groups. Showing the linear trend over the study period in dashed lines of the corresponding colour.

significantly higher use in ICUs than in IMCs ($p < 0.001$). These differences were not observed for anti-infectives (Figure 2).

By offsetting the required staff work hours with the documented procedures, taking into account the observed PC statuses, an annual average work effort of 2,901 ± 233 hours was calculated, corresponding to 1.5 full-time equivalent positions. Taking into account the level of care, we determined a time expenditure of 35 ± 5 minutes per patient cared for during their stay in the ICU and 18 ± 2 minutes in the IMC. Based on publicly known national rates for intensive care nurses, an annual financial expenditure of approximately 83,300 € (~ USD 89,300) per year was estimated, which corresponded to average documentation costs of 16.69 ± 4.72 € (~ USD 17.90 ± 5.06) per intensive care patient and 8.55 ± 3.22 € (~ USD 9.17 ± 3.45) per intermediate care patient.

Discussion

The future of medicine is indisputably determined by an increasing digitalization process[26-28]. A fully digital data transfer of infusion and syringe pump data could have a considerable impact on the compliance and workload of intensive care staff. Manual documentation does not result in any advantage for the care of critically ill patients; in contrast, valuable time

Table I. Required working time for the considered operations.

Considered operation	PC Status I	PC Status II	PC Status III
Unchanged/resumed [sec.]	13.10 ± 2.63	30.40 ± 6.98	45.43 ± 9.96
Stopped/paused/changed [sec.]	12.73 ± 2.64	28.42 ± 5.48	46.85 ± 13.73

Tabular overview of the mean time (± SD) intervals measured for the execution of the documentation with regard to the different states in which the PC workstation was found. Status I: PC workstation with open PDMS system, Status II necessity of PDMS authentication, Status III completely locked user workstation and PDMS. sec, seconds, SD, standard deviation.

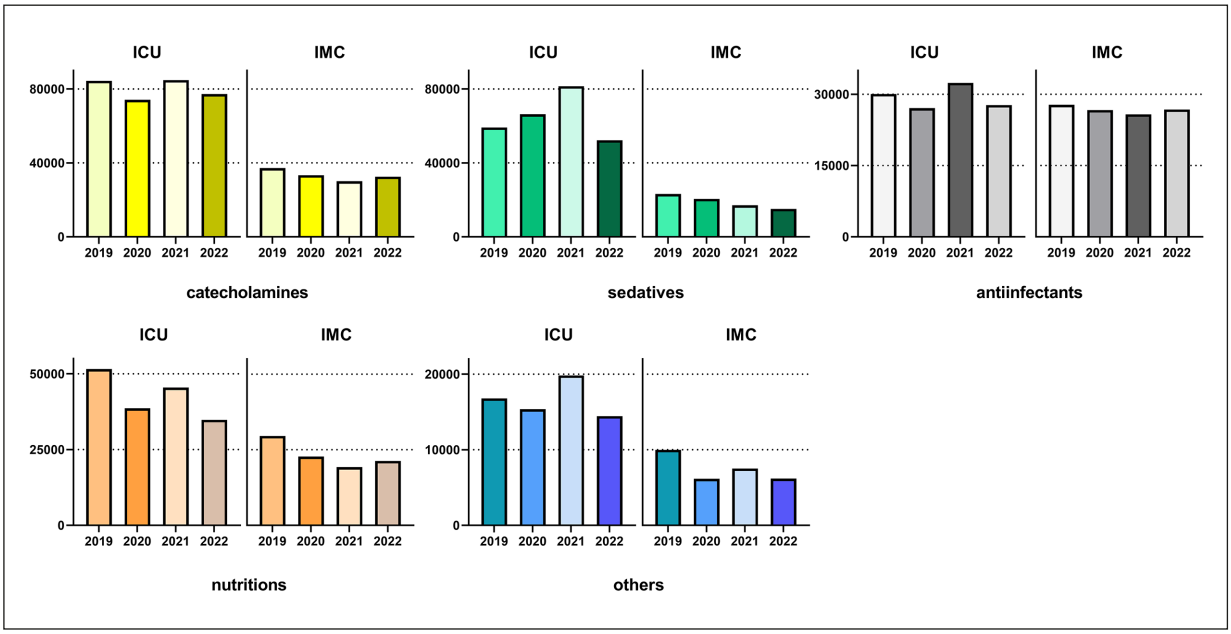

Figure 2. Documented actions within the monitoring wards. Illustration of the recorded data entries in the five selected categories in comparison of ICU and IMC over the study period. ICU, intensive care unit; IMC, intermediate care unit.

is lost for patient care to meet these digitizable forensic requirements. Accordingly, one of the main benefits of a complete digital data transfer would be the time that is freed up for additional patient care, regardless of whether an ICU works with paper-based documentation or has implemented a digital data transfer solution for some aspects of its care. An expansion of the digital data transfer of syringe pump settings and changes to a PDMS would substantially reduce the workload of nursing staff by eliminating the need for manual documentation. This could free up time for staff to focus on other aspects of patient care, such as monitoring vital signs and providing emotional support[29]. Another benefit is the increased forensic security of the data. With a digital system, the data would be more secure and less prone to errors or tampering[30]. Such data should also be easily accessible and retrievable, making it easier to review and analyze patient information. Automated data transfer can also improve the accuracy and completeness of patient records and information, reducing the risk of errors or omissions. This may result in improved patient outcomes and help staff make more informed decisions. Overall, a fully digital data transfer of infusion pump data could have a positive impact on the compliance of intensive care staff by reducing workload and increasing the accuracy, completeness, and security of patient information. This would enable staff to provide more efficient care to critically ill patients. As demographic changes are expected to lead to an increasing number of multimorbid and neurocognitively vulnerable patients being admitted to the ICU within the next few years, it is anticipated that care will become more time-consuming, and solutions such as digital data transmission can help to meet the demands of such patients[31].

Regardless of the digital transfer of syringe pump data, a considerable amount of time was spent due to the state of the computer interface. The enormous amount of time needed for the necessary authorization of individual access to the system and PDMS appears to be in urgent need of improvement in view of the great documentation effort that is still needed. A chip-based login to the existing terminals, as some centers have established, appears to be a relevant approach for improvement to minimize the needed lead time of corresponding documentation. In addition, the risk of third-party use of foreign user interfaces could be reduced by a more uncomplicated authentication procedure.

Even if the absolute sums of attributable costs appear marginal compared to the total costs of intensive care therapy, the costs subsume them-

selves over the years, and in times of growing economic pressure, this has relevant potential[32]. In particular, the implementation costs are one-time costs, which depreciate against the financial expenditure we calculated over a few years. Additionally, the costs of working time, as well as the number of work steps to be documented, will tend to increase further[33]. The social impact of an increasing exodus of medical specialists from their fields due to excessive workload is a growing problem of immense proportions, threatening the ability to provide proper health care services. The improvement of working conditions and the work-economical design of the working environment are relevant factors in staff satisfaction. However, the aforementioned factors of economization and increasing employee satisfaction due to improved working conditions are not necessarily contradictory; the example we provide is a good example of this. These simple steps should be quickly implemented to avoid the progressive migration from healthcare professions. In this context, the mental health of the staff providing care should be prioritized. The tension that arises from legally compliant documentation and corresponding possible errors in this process cannot be dismissed entirely. As this no longer has to be performed manually, this concern can be reduced, and if possible, the mental tension of the staff providing care can be reduced. However, it remains questionable how pronounced the described effect of negative mental impairment through this type of documentation is; for this purpose, more differentiated observational studies are needed.

In addition to the financial cost-benefit ratio, a decisive factor is that reduced documentation obligations free up the capacities of highly specialized nursing staff for direct patient care.

In the future, a self-administering smart pump could be a further step; initial studies[34] have already been conducted on closed-loop concepts of this kind. With regard to diabetes mellitus type I, there are promising results in this respect, whereas, with regard to catecholamines, there have not yet been any publishable studies due to insufficient study quality[34,35]. However, such algorithm-based closed-loop drug administration has the potential to improve patient outcomes, although there are also risks associated with its use. Importantly, self-adjusting syringe pumps pose risks that need to be eliminated even prior to trial-based use. In particular, specific therapy targets, compromised organ function, or measurement errors could otherwise have fatal consequences. However, due to the complexity needed for the development and legal approval of such a pump, it is unlikely that there will be any market launch in the coming years.

Limitations

This study had certain limitations, particularly due to its monocentric character. In addition, it was expected that the use of a different registration procedure or a different program for data input would result in deviations from the values we determined despite the similar manual documentation procedure. Furthermore, the COVID-19 pandemic was included in the dataset we included; although this reflected the general reality of the past years in the healthcare system, this may have led to errors due to the median long length of stay with equally high sedation requirements of the patients[36]. Although the syringe pumps of major manufacturers have had gateways for data transfer to a PDMS for many years, this cannot be assumed to generally apply to all syringe pumps, especially older pumps[37].

Conclusions

The implementation of a complete digital data transfer of syringe pump data in patient documentation offers both monetary and clinical advantages and seems to be inevitable in only a few years. This is particularly important in view of the growing shortage of qualified staff and the increase in the number of patients.

Conflict of Interest

K.Z. received honoraria for participation in advisory board meetings for Haemone-tics and Vifor and received speaker fees from CSL Behring, Masimo, Pharmacosmos, Boston Scientific, Salus, iSEP, Edwards, and GE Healthcare. He is the Principal Investigator of the EU-Horizon 2020 project ENVISION (Intelligent plug-and-play digital tool for real-time surveillance of COVID-19 patients and smart decision-making in Intensive Care Units) and Horizon Europe 2021 project COVend (Biomarker and AI-supported FX06 therapy to prevent progression from mild and moderate to severe stages of COVID-19).

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The other authors declare that there are no conflicts of interest.

Ethics Approval
The protocol was approved by the institutional Ethics Committee (IRB of the University Hospital Frankfurt, Theodor-Stern-Kai 7, 60590 Frankfurt, Germany; #2022-995). The study was conducted in accordance with the Declaration of Helsinki and its later amendments.

Informed Consent
The institutional Ethics Committee decided in favor of a waiver, as the required data were completely anonymized and made available to the study team by the corresponding data integration center of the hospital without any traceability.

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Authors' Contributions
Conceptualization, A.N.F. and F.J.R.; methodology, A.N.F., J.L., and F.J.R.; software, A.N.F. and F.J.R.; validation, A.N.F., J.L., V.N., K.Z., and F.J.R.; formal analysis, A.N.F., J.L., K.Z. and F.J.R.; investigation, A.N.F., J.L. and F.J.R.; resources, A.N.F. and F.J.R.; data curation, A.N.F., J.L., V.N. and F.J.R.; writing—original draft preparation, A.N.F. and F.J.R.; writing—review and editing, A.N.F., J.L., V.N., K.Z. and F.J.R.; visualization, A.N.F.; supervision, A.N.F., K.Z., and F.J.R.; project administration, A.N.F. and F.J.R.; funding acquisition, n/a. All authors have read and agreed to the published version of the manuscript.

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Data Availability
The data cannot be shared publicly. Due to national data protection laws, the datasets generated and/or analyzed during the current study are not publicly available but are available upon reasonable request from the corresponding author or *via* the data protection officer of the University Hospital of Frankfurt [Datenschutz@kgu.de (www.kgu.de, accessed on 19 March 2023)].

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