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Staff Management with AI: Predicting the Nursing Workload

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Abstract. The effective management of human resources in nursing is fundamental to ensuring high-quality care. The necessary staffing levels can be derived from the nursing-related health status. Our approach is based on the use of artificial intelligence (AI) and machine learning (ML) to recognize key workload-driving predictors from routine clinical data in the first step and derive recommendations for staffing levels in the second step. The study was a multi-center study with data provided by three hospitals. The SPI (Self Care Index = sum score of 10 functional/cognitive items of the epaAC) was identified as a strong predictor of nursing workload. The SPI alone explains the variance in workload minutes with an adjusted R2 of 40% to 66%. With the addition of further predictors such as "fatigue" or "pain intensity", the adjusted R2 can be increased by up to 17%. The resulting model can be used as a foundation for data-based personnel controlling using AI-based prediction models.

Keywords. Staff Management, Nursing Workload, epaAC, Self-Care Index SPI, Machine Learning, Prediction Model, Clinical Decision Support

1. Introduction

Today, personnel resources, such as staff pools, are often managed using abstract key figures such as fixed nurse-patient ratios, sick leave, bed occupancy or overload reports. The actual needs of patients are usually not considered. However, the shortage of skilled nursing staff in many countries calls for flexible solutions instead of rigid guidelines. Fortunately, there is a data source just waiting to be tapped into: In everyday clinical practice, electronic documentation generates a lot of routine data on nursing-related health status, patient capabilities, risk profiles, interventions, medical diagnoses, vital signs, etc. These data should be analyzed and used secondarily to control clinical processes using key performance indicators.

The epaSYSTEM[2] [1, 2] including epaAC provides a structured nursing language for all steps of the care process (assessment, diagnoses, goals, outcomes as well as decision support for suitable nursing interventions); only the classification of the nursing interventions themselves is carried out using a subsystem (usually LEP[3]). With over 1,300 healthcare providers, mostly hospitals, in German-speaking countries

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[2] epaSYSTEM = System for Efficient Nursing Care Analysis, abbreviated from the German-language *System für effiziente PflegeAnalyse*

[3] LEP = Documentation of Nursing Activities, abbreviated from the German-language *Leistungserfassung in der Pflege*

(DE-AT-CH-LIE-LUX), the combination of epaSYSTEM and LEP is the most frequently used standardized language for nursing (data on nursing-related health status, intervention data).

The nursing care derived from the patient's nursing-related health status triggers workload for the nursing staff, which can be expressed in LEP minutes. Nursing workload is understood here as the totality of the nursing activities actually performed [3]. According to Bartholomeyczik et al [4], workload can be explained by characteristics that are independent of the time required to perform the activities, such as restricted mobility or limitations in personal hygiene skills, or in short: on the basis of impairments in the nursing-relevant health status.

The basic idea of the research project outlined here was to develop a solution that makes it possible to predict the nursing workload directly based on the routine data of the nursing process and other (medical and organizational) data. Based on this, an innovative approach to personnel planning was to be developed, as called for by experts [e. g. 3, 4, 5].

The aim of the study [6] was to identify predictors that can predict the nursing workload. Among other aspects, it was investigated which data from the assessment of patients' nursing-related state of health ("nursing needs", measured with epaAC) can serve as predictors for the nursing workload (measured with LEP minutes) in acute inpatient care.

Two central questions can be derived from this:

1. Which characteristics are suitable for predicting higher or lower nursing workload?
2. How well can the variance in care minutes spent be explained?

Previous studies have already investigated the relationship between the variables of nursing-related health status of patients (measured with the SPI[4] of the epaAC[5]) and nursing workload (expressed in LEP minutes). It was shown that, firstly, there is a significant correlation between the two variables and secondly, that information from the patient's nursing-related health status can be used for workload grouping [7]: The total LEP minutes per case and day were grouped into minute intervals of 20, 40 and 100 minutes. Logistic regression was used to calculate the probability that the patient's status (measured using SPI) predicts the correct LEP minute group. The best practice-relevant results were obtained for the group of 40-minute intervals in the category "interventions/minutes triggered by nursing care needs".

Hunstein [1] showed a clear correlation between the patient's nursing related health status (measured using the SPI) and documented interventions due to impairments in self-care ability, as well as a non-correlation with interventions that can be assigned to the area of assistance with medical diagnostics and therapy. There is a clear correlation between the distribution of LEP minutes of a day and the SPI of the same day. The (negative) slope of the correlation points in the expected direction: the more patients are impaired in their ability to care for themselves, the higher the nursing workload in LEP minutes. The LEP minutes resulting from assistance with medical therapy and

[4] The SPI (Self Care Index, abbreviated from the German language *SelbstPflegeIndex*) is a global measure for the complexity of nursing care needs. The SPI is a sum score of ten 4-point scaled items, where the value 1 stands for no ability/maximum impairment and the value 4 for full ability/no impairment. Therefore, the SPI has a range between 10 points (no self-care ability) and 40 points (full self-care ability).

[5] epaAC = nursing assessment tool for AcuteCare (abbreviated from the German-language *effiziente Pflege-Analyse AcuteCare*

diagnostics clearly show that – as expected – there is no correlation between the SPI and the workload concerning medical therapeutic tasks.

2. Methods

Firstly, relevant characteristics were extracted from the routine clinical data that could potentially influence the nursing workload. These include demographic information, medical variables, nursing-related health status, nursing interventions and other factors.

Four ML algorithms (random forest, gradient boosting, linear boosting, and lasso regression) were calculated based on mass data (37,316 epaAC assessments and 1.1 million LEP interventions from three clinics in Germany and Switzerland) using statistical methods from the knowledge discovery in database process (KDD). The data was modelled using several statistical models and subgroups. The relevant predictors were determined using the variable Importance per variable of the used ML algorithms. A linear regression was calculated for the selected predictors to determine the variance elucidation for each model.

Validation samples from the available data were used to evaluate the performance of the models. Predictions from the developed models were compared with the actual nursing workload and various evaluation metrics such as accuracy, sensitivity and specificity were calculated. In addition, we performed a cross-validation to check the robustness and generalizability of our model.

3. Results

Research question 1: When calculating the overall data set, the variables "clinic" and "medical department" were identified as important predictors of nursing workload. As these two variables are not patient-inherent characteristics and the importance of institutional and structural framework conditions is emphasized in the literature (e.g. [8]), the data were divided into subgroups accordingly.

For the cases of the subgroup “medical department: Surgery”, there are predictors such as pain intensity, history of falls and fatigue that cannot be explained per se by the SPI, but can rather be attributed to illness or medical/therapeutic triggers (e.g. surgeries).

In the comparison of the three clinics, both consistent and different predictors were also identified. When looking at the clinic-specific predictors, predictors such as illness or medical/therapeutic triggers were again found in Clinic 1 (specializing in trauma surgery). In Clinic 3 (high number of patients in internal medicine and geriatrics), on the other hand, predictors from the areas of personal hygiene and clothing were predominantly identified.

Research question 2: The SPI itself explains the variance in nursing minutes with an adjusted R2 of 40% to 66% (depending on the respective subgroup). With the addition of further predictors such as "fatigue" or "pain intensity", the adjusted R2 can be increased by up to 17% depending on the respective model or subgroup. The highest variance clarification with an adjusted R2 of 71% was achieved in the subgroup "Clinic 3 - Department of Internal Medicine". An adjusted R2 of 58% was calculated for the overall data set.

When comparing the medical departments, it clearly shows that the "Department of Internal Medicine", with an adjusted R2 of 63%, explains the variance in nursing minutes more strongly than the "Department of Surgery".

After it became clear that the SPI can be regarded as a central predictor of nursing workload, various preliminary models were created for subsequent studies (which have already been initiated) for predicting nursing workload in LEP minutes using the SPI value. As an example, Figure 1 shows the results stratified according to interventions from the nursing "self-directed area" of the overall data set.

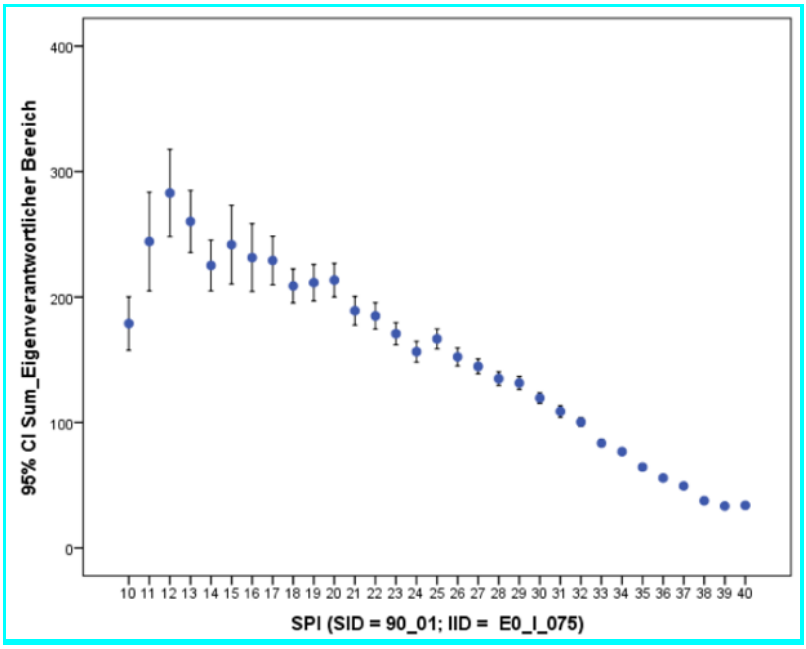

Figure 1. Mean of total LEP minutes per SPI value (excluding time spent on assistance with medical therapy and diagnostics as well as for instruction and advice). From: [6]

As can be seen, the nursing workload is not linearly dependent on the impairment of the nursing-related health status (operationalized by the SPI). While the nursing workload increases almost linearly with low and moderate impairment, there is a noticeable decrease with maximum impairment (SPI <12). This reflects practical experience: a patient for whom residual abilities are to be restored through nursing therapy is more complex to care for than a patient who does not have these abilities.

4. Discussion

As shown the epaAC contains predictors for forecasting the nursing workload caused by the need for care. The SPI value was identified as a strong predictor of nursing workload in almost all models. It was concluded that the SPI can be used as an estimator for a higher or lower nursing workload. Nevertheless, the prediction values vary in different settings. One explanation is that the reasons for nursing interventions e.g. in the context of a surgical department are additionally influenced by the medical

services provided (e.g. surgeries) while in internal medicine the proportion of patients with a general need for care is higher. Therefore it can be assumed that, especially in surgery, the consideration of other variables such as medical diagnoses or medical procedures will further improve the prediction of nursing workload.

To assess the nursing workload per case, the workload resulting from assistance with medical therapy and diagnostics as well as for instruction and advice must be added. To calculate the total nursing workload to run the ward properly, the non-case-related workload (e.g. education, organization of staff and ward) must also be considered.

In the next step, further predictors, such as the medical treatment, must be added to the model to minimize the variance and predict the total workload. The prediction horizon (e.g. expected nursing workload for the next 24 or 48 hours) must also be determined.

In addition to the purely quantitative prediction of the nursing workload, we are working on an extension of the model regarding the following possible applications:

– Management of specific specialist nursing teams (e.g. dementia counselling)
– Management of staff in terms of a skill and grade mix (i.e. the right staff with the right qualifications at the right time)
– Managing the use of materials (e.g. anti-decubitus mattresses)
– Control of bed occupancy already on the admission ward

5. Conclusion

The future lies in the increased use of AI, embedded in digital workflows, to be able to distribute scarce resources accurately, comprehensibly, and in accordance with the capacity utilization, skill mix and the patient's nursing needs.

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