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Non-European migrants with schizophrenia spectrum disorders in Swiss forensic and general psychiatric care facilities – A comparative study using machine learning

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ABSTRACT

Personal history of migration poses an important risk factor for schizophrenia spectrum disorders (SSD), which are also associated with a higher rate of criminal behavior. To enhance care for migrants, a vulnerable and often stigmatized group in both general and forensic psychiatry, this study investigates clinical, therapeutic, and psychopathological differences between non-European migrants diagnosed with SSD treated in forensic and general psychiatric settings. The aim is to identify factors that may influence pathways into the criminal justice system and pose challenges for the therapeutic process, rather than directly predicting criminal behavior. We compared retrospectively obtained data of 52 general (GPP) and 104 forensic psychiatric (FPP) inpatients – all with a history of migration from non-European countries and treated in Zurich, Switzerland. To detect complex variable patterns, supervised machine learning models were applied to a training dataset. The best algorithm was then used to assess the predictive power of nine out of 174 possible predictor variables in a validation dataset. Two positive and negative syndrome scale (PANSS) items (uncooperativeness, poor impulse control) and the modified sum score upon discharge (mean 14.5 for GPP vs. 10.8 for FPP), previous treatments (more frequent treatment for GPP: inpatient 96% vs. 69%; outpatient 81% vs. 37%), medication strategies regarding antidepressants and antipsychotics, attendance to occupational therapy, and failed attempts of expanding patients' freedom influenced the model. The final model yielded satisfactory statistical properties (area under the curve (AUC) of 0.86 and balanced accuracy of 71.9%, including a specificity of 88.9%), demonstrating its strong predictive performance. General and forensic psychiatric inpatients with a non-European background diagnosed with SSD differ in various clinical variables. These findings may inform future psychiatric practices by identifying clinical and therapeutic variables that could support targeted interventions and potentially reduce the risk of criminal justice involvement among migrant patients with SSD.

1. Introduction

Worldwide migration has globally increased over time. According to the International Organization of Migration, a United Nations agency, the number of international migrants rose from approximately 170–280 million people between 2000 and 2022 [1]. While protective factors against mental disorders and resiliency are common in most migrants, several adverse influences such as poverty or enduring conflicts pose a major threat to their mental health [2,3]. Naturally, migrants form a heterogeneous group of individuals, and certain subgroups such as refugees are at higher risk of developing distinct psychiatric disorders like stress-related disorders following traumatizing events or even schizophrenia spectrum disorders (SSD) [3,4]. In general, history of migration is a risk factor for developing psychotic disorders and its association with developing psychosis has long been subject to research. A meta-analysis, whilst facing high heterogeneity concerning the studies

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included, showed an elevated risk of about 80% in first- and second-generation migrants of being diagnosed with a non-affective psychotic disorder (NAPD) in comparison to native individuals. Possible reasons for these findings are language and cultural barriers as well as isolation and exclusion [5]. There is also a higher risk of schizoaffective and psychotic affective disorders [6]. Another meta-analysis found that even after adjustment for socioeconomic status, the risk remained elevated. Moreover, migration from countries outside of Europe is associated with a further increased possibility of suffering from an NAPD (relative risk 2.94), whereas it is comparatively lower in migrants from other European countries (relative risk 1.88) [7]. Another risk factor for psychosis onset is the age at migration. It has been shown that migrants younger than 18 years are particularly vulnerable to develop a psychosis, with a nearly doubled risk compared to the native population [8]. In summary, history of migration constitutes a well investigated risk factor for psychotic disorders.

Several studies indicated that SSD are associated with more violent and criminal behavior compared to healthy controls, especially homicide. A large portion of additional risk is linked to comorbid substance use though [9]. That said, compared to healthy controls, individuals diagnosed with schizophrenia have been shown to yield an odds ratio of 1.2 to commit any violent crime. Once there is a comorbid substance use disorder, the adjusted odds ratio increased to 4.4 [10]. Other authors found that less than 5% of women and 25% of men affected by SSD committed any violent act over a 35-year span [11]. On a societal level, the linkage of migration and crime is controversial, and the discussion is often based on prejudices and misinformation while in fact there are studies in which no positive association could be found [12].

Depending on particular laws and regulations in different countries, offenders diagnosed with psychiatric disorders may be ordered to receive forensic psychiatric inpatient or outpatient treatment [13]. In many regions, for example in Denmark and southern Germany, individuals with a background of migration represent about one third of all inpatients in forensic psychiatry. In Switzerland, the percentage appears to be higher: about 55% of all inpatients were not born there [14–16]. In England, certain ethnic subgroups were also overrepresented in high-security psychiatric facilities [17]. In case a migrant offender is diagnosed with any psychiatric disorder, the chance of being subjected to court ordered inpatient treatment seems to be elevated compared to non-migrants [18]. Still, it remains unclear if the strong association of migration background and risk of suffering from an SSD is also linked to an elevated prevalence of criminal and violent behavior, as studies found no or only slightly elevated risks for ethnic minorities [19,20].

Another issue that has to be considered are language barriers in both general and forensic psychiatric settings, severely challenging the diagnostic and therapeutic process [21]. Patients' low language proficiency is even related to more compulsory interventions like involuntary admission, seclusion, restraint, or forced medication [22]. These problems can further be increased due to cultural differences [23].

Overall, the treatment of migrant individuals suffering from SSD faces many challenges, especially in the context of forensic psychiatry. Still, several characteristics of offenders diagnosed with SSD and a history of migration remain unclear. In order to optimally conceptualize the general and forensic psychiatric treatment process, as many features as possible have to be explored. Moreover, extended knowledge about peculiarities might help to foster existing prevention programs. Thus, patients' risk of becoming an offender during the course of their mental disorder might be attenuated in the future.

Previous work performed by our research group focused on the distinguishing characteristics of non-European and European migrants that were in forensic psychiatric treatment due to an underlying SSD using machine learning algorithms. In this study, the inclusion of merely five variables (dosage of antipsychotics, cultural background, childhood adversities, language barrier, low structured engagement in occupational therapy) facilitates a predictive power of 75%. Among others, psychiatric and criminal history as well as psychopathology did not contribute to the model [16].

The present study aims to identify clinical and therapeutic characteristics that distinguish non-European migrants diagnosed with SSD in forensic versus general psychiatric care. Using a machine learning approach, we focused on exploring variables that may indirectly influence pathways into the criminal justice system and that may pose challenges in the consecutive treatment. Thereby, the objective of informing preventative strategies and improving mental health services for this vulnerable population shall be achieved. Compared to conventional statistical methods, ML allows to include a larger number of variables and is better suited to uncover complex non-linear relationships between those variables [24].

2. Methods

2.1. Study population

The present study used data from a total of 740 female and male patients. One half (n = 370) consisted of offenders (forensic psychiatric patients, “FPP”) that were all ordered to court mandated treatment in the Center for Inpatient Forensic Therapy as part of the Department of Forensic Psychiatry due to lack of culpability. Another indication for the admission to this center was the treatment of acute symptoms while already being detained in penitentiaries. The other 370 patients (general psychiatric patients, “GPP”) received inpatient treatment in the Center of Integrative Psychiatry (CIP), a general adult psychiatric facility specialized in the rehabilitation of chronic cases. Both facilities are part of the University Hospital of Psychiatry Zurich, Switzerland. All individuals included in the analysis were admitted between 1982 and 2016 and had been diagnosed with SSD as listed in the ninth and tenth revision of the International Statistical Classification of Diseases (i.e., diagnoses in chapters 295.0 to 295.9 and F20.0 to F25.9, respectively) [25,26]. GPP were admitted either voluntarily or involuntarily, rare cases of court-mandated treatments within this facility were excluded. Patients born in Europe were also dropped out. Since SSD are chronic disorders with sometimes long courses of treatment, we considered the comparison of a cohort of forensic patients with those who were admitted to CIP as appropriate. Moreover, initial treatment was already set in most cases, and the symptomatology was usually on a level that does not require treatment on a ward specialized in acute exacerbations. Both study populations have been used in a variety of other analyses performed by our study group as part of a longtime project. Patients were recruited between 1982 and 2016. The mean length of stay was 84.25 weeks (SD = 109.46) for FPP and 5.31 weeks (SD = 3.73) for GPP, reflecting the different treatment mandates and objectives of the two settings.

2.2. Data collection

For all cases, more than 500 variables were retrospectively extracted from the patients' files through directed qualitative content analysis [27]. In order to obtain reliable results, two senior psychiatrists experienced in the field of forensic psychiatry extracted the data independently. Out of these variables, 174 variables were used for further analyses. We chose variables covering sociodemographic data, information about the current course of treatment documented by involved medical and assisting personnel, crime-related data, former treatments, substance use, and psychopathology. More precisely, the latter was depicted using a modified three-tier positive and negative syndrome scale (PANSS) including sum scores ranging from 0 to 60 [28]. The rating protocol was developed following research originally performed by Seifert and Nedopil [29]. A detailed definition of all included variables can be found in the supplementary material.

2.3. Data analysis with machine learning

We employed supervised machine learning (SML) for this study due to its ability to model complex, non-linear relationships and interactions between variables while directly optimizing for the classification of FPP and GPP. Unlike traditional statistical methods, SML can handle high-dimensional datasets and prioritize variables with the highest predictive value, making it well-suited for identifying patterns in psychiatric populations [30]. Specifically, SML was chosen because: (1) it accommodates the unbalanced group sizes in our sample through upsampling; (2) it allows exploratory analysis of 174 potential predictor variables without requiring a priori hypothesis specification; (3) it can capture complex interactions between clinical, therapeutic, and demographic variables that might be missed by traditional regression approaches; and (4) it automatically identifies and prioritizes the most informative variables while handling correlated predictors more robustly than traditional methods. Additionally, the use of nested resampling and train-test validation ensures predictive robustness and minimizes the risk of overfitting. This approach aligns with the study's goal of uncovering clinically relevant variables of forensic involvement in individuals with SSD.

In the following, the SML steps are briefly explained. Since the method overlaps with previous work, recurrences cannot be excluded. The outcome variable (y) "is not forensic" was dichotomized (true vs. untrue). "is not forensic" being true was defined as the positive class in further analysis. Software used for the analyses included R version 3.6.3. (R Project), MLR package v2.171 (Bischl, Munich, Germany), and MATLAB R2019a (MATLAB and Statistics Toolbox Release 2012).

First, variables lacking more than one third of values were not used for further analysis. This is important to facilitate accuracy [31]. The whole dataset was then split up into a training and validation dataset, which contained 70% and 30% of the cases, respectively. The training dataset was used for the following steps, while the validation dataset remained untouched in the first instance. Splitting up the dataset is a crucial method to avoid overfitting, a common problem in ML [32,33]. Missing values were then imputed using MLR package as stated above (i.e., mode for categorical and mean for continuous variables). As the outcome variable was unevenly distributed, we conducted a random upsampling at a rate of 2, which lead to a more balanced outcome. In order to spare computational resources and again to reduce the risk of

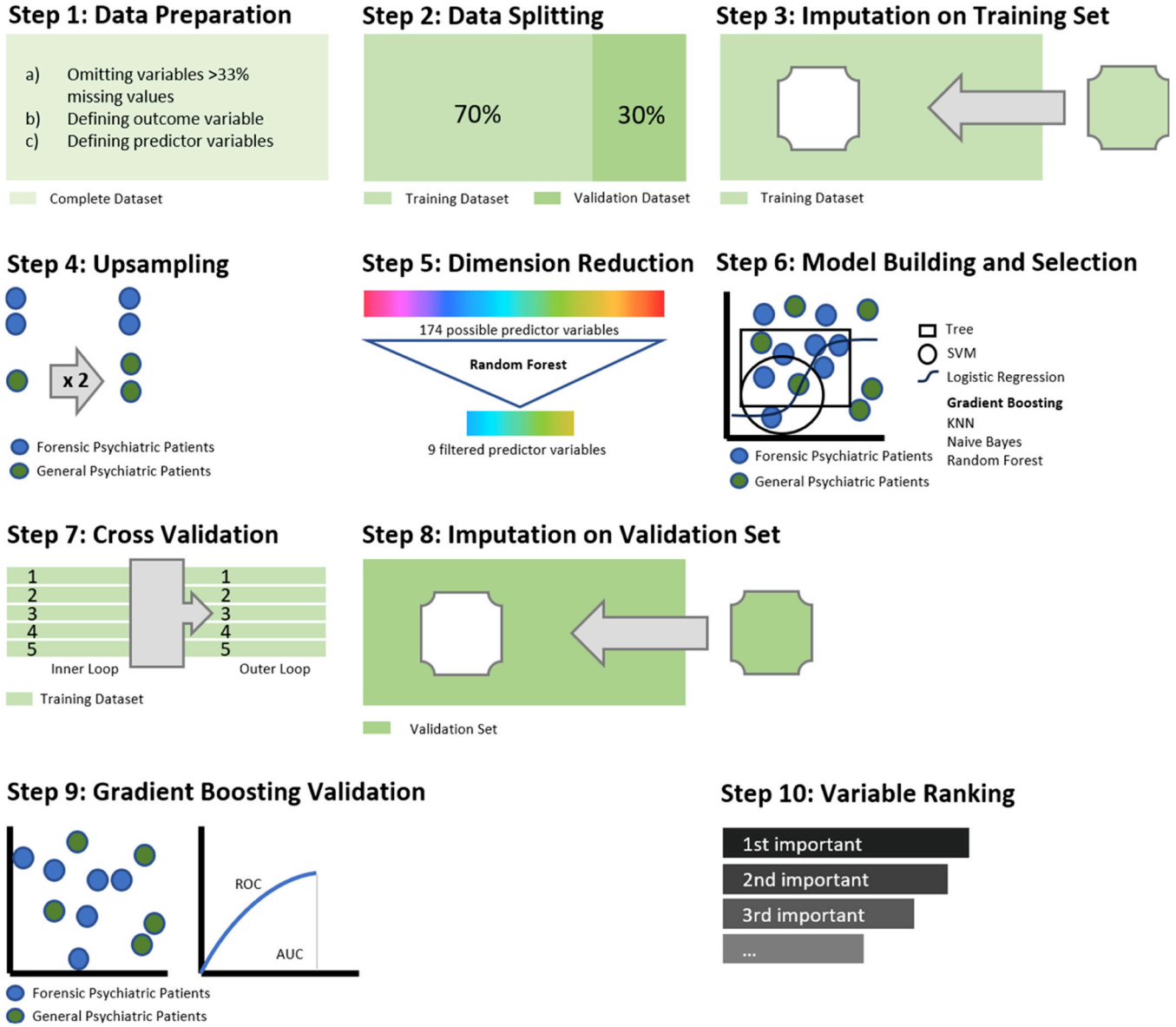

Fig. 1. Data preparation, machine learning model building and validation.

overfitting, a variable reduction was performed using a random forest algorithm. Thus, a variable was not included in the model if it failed to contribute more than 5% to the area under the curve (AUC). Now, having completed the data preparation, seven different algorithms were run on the training dataset. These included logistic regression, trees, random forest, support vector machines, gradient boosting, naïve Bayes, and k-nearest neighbor. The most suitable algorithm was then selected for further analysis, depending on performance measures like balanced accuracy (arithmetic mean of sensitivity and specificity) and the AUC of the receiver operating characteristics curve (ROC) – a parameter of the accuracy of fit. To attenuate additional overfitting, we created artificial subsamples via nested resampling. This concluded the training of the algorithms.

After having imputed missing values in the validation dataset using the same weights as in the training dataset, the final algorithm – i.e., gradient boosting – was now applied to the validation dataset in order to test the performance. The latter was evaluated using the same parameters as described for the model training. Moreover, the contributing variables were ranked according to their relative influence. For a graphical representation of all steps, please see Fig. 1.

3. Results

In total, 156 patients – all of whom were not natives of Europe – were included in the analysis. Exactly one third (n = 52) received general, the remaining two thirds forensic psychiatric inpatient treatment. As described in the method section, all individuals included had been diagnosed with some kind of SSD. The sample was relatively balanced, with similar mean ages and proportions of individuals of male sex. The vast majority was male, in their mid-thirties, and single at the time of admission (refer to Table 1). GPP slightly more often suffered from paranoid schizophrenia in particular, they also featured less comorbid substance use disorder. The duration of treatment differed substantially (mean 84.25 weeks for FPP, 5.31 for GPP).

We applied in total seven algorithms to the training dataset, the different performance parameters are shown in Table 2 (“Training model”). With an AUC of 0.9 and a balanced accuracy of 79%, gradient boosting proved to be the most sufficient algorithm, which is why it was chosen for further analysis. It has to be noted that the positive class was defined as “is not forensic”, sensitivity therefore identifies GPP while specificity identifies FPP.

Based on the training dataset, several variables appeared to be relevant. Accordingly, GPP had been more often in both inpatient and outpatient treatment prior to their admission to the referenced hospitalization. Moreover, they were more likely prescribed antipsychotic and antidepressant medication before and during hospitalization, respectively. GPP also showed less frequent attendance to occupational therapy, and the process of extending eligibilities to leave the ward failed more often. More differences between the two groups concerned the PANSS and its associated items: uncooperativeness and reduced impulse control were predominantly absent in FPP, and GPP suffered from a higher burden of symptoms upon discharge. For a comprehensive roundup, please see Table 3.

Regarding the importance of each variable, the adapted PANSS score upon discharge turned out to be most influential. In fact, this variable contributed more than half of the total influence, while the remaining eight accounted for the rest (see Fig. 2).

When applied to the validation dataset, the gradient boosting algorithm led to predominantly satisfying performance parameters (see Table 2, “Final Model”). Regarding the sensitivity, the model correctly identified 55% of general psychiatric patients. However, forensic patients were properly recognized in most cases (specificity of 88.9%), resulting in an acceptable balanced accuracy of 71.9%. The level of discrimination, as read with the AUC of 0.86, was satisfying, too [34].

Table 1
Basic data.

Variable description	Forensic psychiatric patients		General psychiatric patients	
	n/N (%)	mean (SD *)	n/N (%)	mean (SD*)
Age at admission		34.2 (10.2)		36.2 (12.2)
Sex category: male †	96/104 (92.3)		46/52 (88.5)	
Marital status: Single	73/102 (71.6)		38/52 (73.1)	
Diagnosis: Schizophrenia	75/104 (72.1)		41/51 (80.4)	
Comorbid Substance Use Disorder	75/104 (72.1)		26/49 (53.1)	
Comorbid Personality Disorder	8/104 (7.7)		4/47 (8.5)	
Adapted PANSS sum score at admission		25.03 (12.6)		23.75 (9.9)
Length of stay (weeks)		84.25 (109.46)		5.31 (3.73)

† as listed in patients' files
* SD = Standard deviation.

4. Discussion

While a personal history of migration has consistently been shown to be a risk factor for SSD [5–7], there is still little knowledge about the difference between non-European GPP and FPP. In particular, factors influencing the development of criminal behavior in SSD patients with a history of migration are widely unknown, as are specific needs of this population in the forensic vs. general psychiatric setting. With the current study, we aimed to narrow this gap in knowledge. However, this study was not intended, nor is it suited, to provide individual risk assessment or to predict offending behavior. The associations identified are descriptive and exploratory, reflecting differences in treatment processes and clinical characteristics between groups. Any interpretation beyond this clinical and service-related framework would exceed the scope and purpose of the research.

We applied SML to a sample of 156 individuals and found differences regarding psychopathology, mental health service use, medication strategies, and therapeutic process. The final ML model yielded satisfactory performance parameters, as indicated by a balanced accuracy of 71.9% and an AUC of 0.86.

4.1. Model defining features

The variable “adapted PANSS score upon discharge” was by far the most influential one. The original PANSS developed by Kay et al. features 30 items concerning positive, negative, and general symptoms, each rated from 1 to 7 [28]. Our adaptation uses the same items with values from 0 to 2 (subsequently, the sum scores range from 0 to 60). Upon discharge, GPP had a significantly higher sum score of 14.5, whereas FPP showed comparatively less symptoms with a sum score of 10.8. Regarding particular PANSS items upon discharge, “poor impulse control” and “uncooperativeness” turned out to be second and fourth most influential, respectively. While GPP showed more often substantially or at least slightly impaired impulse control (together more than half of this group), these symptoms were absent in about four out of five FPP. In addition, uncooperativeness was predominantly not or only discreetly pronounced in FPP, while about one third of GPP showed substantial uncooperativeness. These findings may be due to a couple of reasons. First, voluntarily admitted GPP may choose to decline further inpatient treatment. According to Swiss Civil Code Article 427, individuals are only subject to compulsory retention in case of imminent danger to themselves or others [35]. Since this threshold is set quite high, discharges occur even if the burden of disease is still substantial. Vice versa, FPP might remain hospitalized even in case imminent danger

Table 2
Machine learning models and performance in nested cross-validation applied to the training dataset (upper part). Final gradient boosting performance parameters applied to the validation dataset with 95% confidence intervals in parentheses (lower part).

	Statistical Procedure	Balanced Accuracy (%)	AUC*	Sensitivity (%)	Specificity (%)	PPV † (%)	NPV ‡ (%)
Training model	Logistic Regression	72.0	0.85	59.8	84.3	59.8	84.3
	Tree	65.5	0.69	53.3	77.6	51.4	78.4
	Random Forest	77.5	0.84	68.0	86.9	79.3	87.0
	Gradient Boosting	79.0	0.90	70.8	87.2	70.0	88.2
	KNN §	73.8	0.81	60.3	87.3	65.1	86.4
	SVM ((	81.3	0.87	74.1	88.5	72.1	89.6
	Naïve Bayes	81.1	0.86	74.8	87.4	72.7	89.3
Final model	**Gradient Boosting**	71.9	0.86	55.0	88.9	78.6	72.7
		(58.2–81.8)	(0.73–0.95)	(32.0 – 76.2)	(69.7 – 97.1)	(48.8 – 94.3)	(54.2 – 86.1)

† PPV = positive predictive value. ‡ NPV = negative predictive value. § KNN = k-nearest neighbors. ((SVM = support vector machines.
* AUC = area under the curve.

Table 3
Absolute and relative distribution of relevant predictor variables.

Variable code	Variable description	Forensic psychiatric patients n/N (%)*	General psychiatric patients n/N (%)*
PH18a	Outpatient psychiatric treatment(s) before current hospitalization	35/94 (37.2)	**39/48 (81.2)**
PH19a	Inpatient psychiatric treatment(s) before current hospitalization	66/96 (68.8)	**48/50 (96.0)**
PH23a	Any antipsychotic medication before current hospitalization	56/104 (53.8)	**46/49 (93.9)**
DZ12	Failures during opening	16/56 (28.6)	**28/45 (62.2)**
R9l	Antidepressants prescribed during current hospitalization	10/89 (11.2)	**20/52 (38.5)**
R17a	No attendance to occupational therapy during current hospitalization	5/102 (4.9)	**18/41 (43.9)**
PA53	Adapted PANSS † at discharge: Scale Uncooperativeness		
	Symptoms substantially	3/99 (3.0)	**14/44 (31.8)**
	Symptoms discreetly	**17/99 (17.2)**	7/44 (15.9)
	Symptoms absent	**79/99 (79.8)**	23/44 (52.3)
PA59	Adapted PANSS † at discharge: Scale Poor impulse control		
	Symptoms substantially	5/99 (5.1)	**14/44 (31.8)**
	Symptoms discreetly	14/99 (14.1)	**11/44 (25)**
	Symptoms absent	**80/99 (80.8)**	19/44 (43.2)
PA_D	Adapted PANSS † at discharge	10.8 (10.2)	**14.5 (11.1)**

† PANSS = positive and negative syndrome scale
* n/N (%): sample size with item present/whole sample size (percentage).

is absent since court-mandated orders are preset according to Swiss Criminal Code Article 59 [36]. Second, forensic treatments in Switzerland are scheduled for a period of up to five years with options of further prolongation (Swiss Criminal Code, Article 59) [36]. The median length of stay is 2.5 years, which in comparison to general psychiatry is much longer: hospitalizations of patients with SSD usually took up to two months (median of 33 days, GPP in this study: mean of 5.31 weeks) [37]. The FPP included in our study were hospitalized for 84.25 weeks (mean). Thus, the whole process of treatment is usually much longer and enables a thorough mitigation of symptoms [38]. One of the main tasks in forensic psychiatry generally is to reduce the risk of further crime committed by individuals suffering from mental disorders [39,40]. Given that, legal authorities may permit discharges from forensic treatment only in case of low burden of disease, and in many countries, including Switzerland, periods of probation can regularly be mandated [36,41]. On the other hand, thresholds to end hospitalizations of GPP, which so far have not committed a crime, may be much lower. These consideration might also explain the higher percentage of failures during opening, which were observed in nearly two thirds of all GPP but only in about one fourth of FPP. This item refers to any disobedience to agreements while on temporary leave from the ward. Again, legal authorities are highly involved in the process of expanding freedom of movement in case of forensic treatment. Due to the main goal, i.e., crime prevention, patients' personal freedom is often subordinate to security considerations, especially averting criminal offences during unauthorized leave [42]. In practice, FPP obtain rights to leave the ward later than GPP, and since authorities can withdraw already given rights, a deterring effect might refrain FPP from expanding their permitted freedom of movement. In a multinational study published in 2007, FPP and GPP diagnosed with SSD were compared at discharge and during a follow-up of two years. Similar to our findings, at least regarding the sum score, GPP suffered from more positive and negative symptoms, showed more aggressive behavior and lower scores of global functioning [43].

Besides mere psychopathological group differences, wider contextual and systemic factors such as language and cultural barriers have to be acknowledged. The former are often associated with a history of migration and low language proficiency has been shown to be connected to more severe psychiatric symptoms [44]. Of course, this finding accounts for both GPP and FPP migrants, but we cannot rule out that long-term forensic hospitalizations help acquiring more language proficiency, e.g., due to continued contact with personnel and other patients. As a consequence, existing barriers could alleviate over time, enabling a thorough treatment that includes more psychotherapeutic elements. These have already been shown to reduce risks of reoffending, and especially the marked PANSS item “poor impulse control” might react to cognitive behavioral interventions [45,46]. The similarity in PANSS scores at admission represents a methodological strength of our study, demonstrating that both groups entered treatment with comparable symptom severity. Several factors may explain this comparable symptom burden. Both populations represent chronic SSD cases reaching a critical threshold requiring inpatient treatment, whether triggered by psychiatric decompensation or an offence. Additionally, late referral to psychiatric services – a particular challenge for migrants facing language barriers and limited access to care – may result in similar symptom accumulation by hospitalization. Last, prior treatment history, while differing in frequency between groups (see below), may not necessarily translate into differences in acute symptom presentation at the point of admission. These findings underscore that pathways into forensic versus general psychiatric care are influenced by factors beyond symptom severity, such as social circumstances, support systems, and behavioral manifestations rather than illness intensity.

Our model includes four different items depicting inclusion in mental health services and medication strategies. GPP had more often received former outpatient and inpatient psychiatric treatment prior to the referenced hospitalization (item code PH18a and PH19a, respectively).

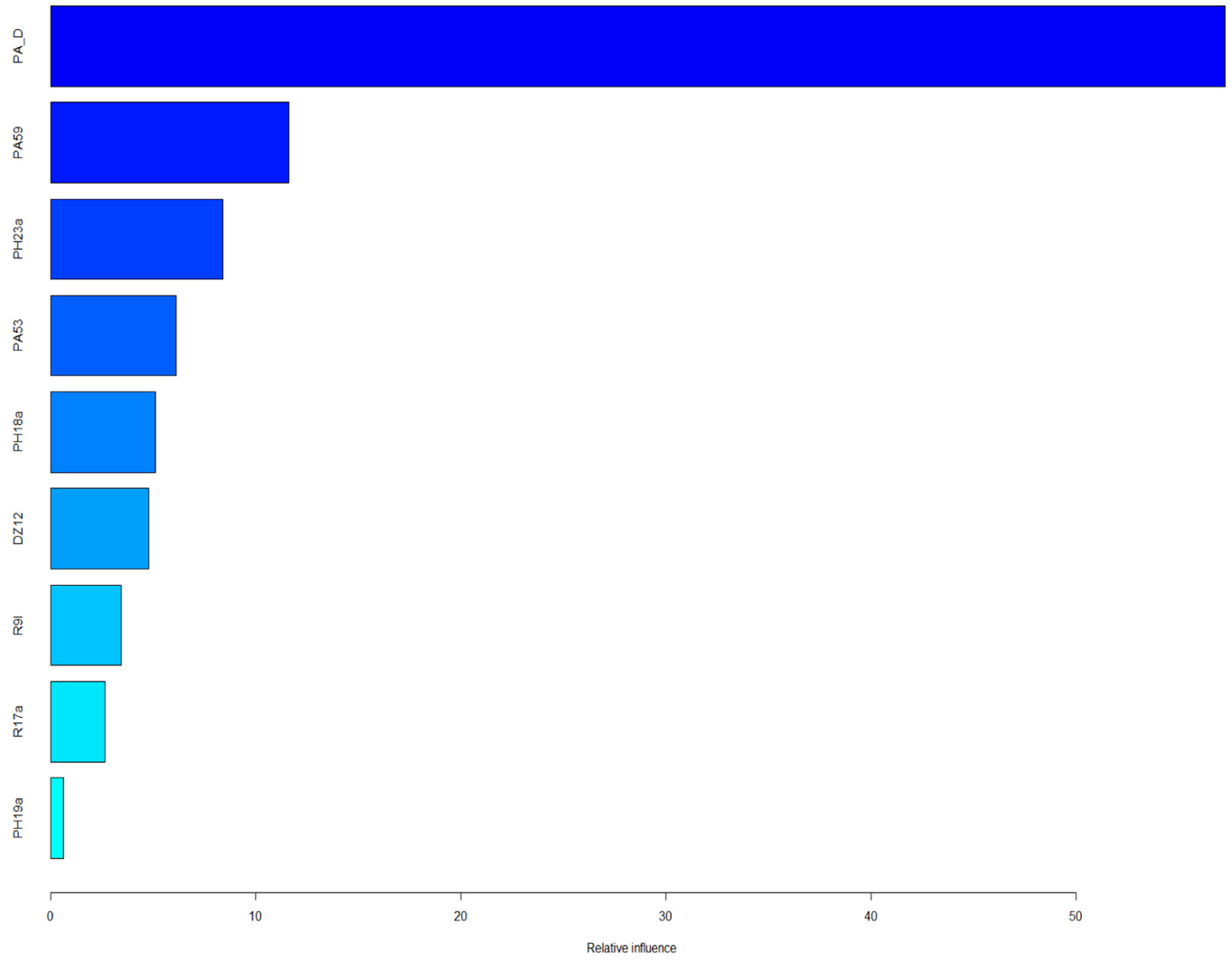

Fig. 2. Gradient boosting model variable importance and description. PA_D: adapted PANNS Score at discharge; PA59: adapted PANSS at discharge: Scale poor impulse control; PH23a: Any antipsychotic medication before current hospitalization; PA53: PANSS at discharge: Scale Uncooperativeness; PH18a: Outpatient psychiatric treatment(s) before current hospitalization; DZ12: Failures during opening; R9l: Antidepressants prescribed during current hospitalization; R17a: No attendance to occupational therapy during current hospitalization; PH23a: Inpatient psychiatric treatment(s) before current hospitalization.

Even though the majority of FPP had been in some kind of treatment before, GPP showed tremendously higher percentage of cases with previous integration in the mental health care system. They were additionally more likely to have had any kind of antipsychotic prescription before (PH23a). During the current stay, they also received an antidepressant more often (R91). In other words, FPP were less tightly integrated into existing mental health service structures. This might be attributable to several reasons. A 2011 review and meta-analysis found that about one third of all patients expressed some kind of violent behavior during their first episode of psychosis, with one sixth being serious events. The number of severe incidents remained rather small (<1%). In summation, a large proportion of first-episode patients commit any violent act [47]. Vice versa, large percentages of individuals suffering from psychosis that just had committed homicide or serious assaults are in their first-ever episode [48]. Aggregated with our results, the lower rate of former psychiatric treatment might be at least partially explained: some patients had so far been unremarkable and symptoms were rather mild, with the threshold for psychiatric treatment not yet reached. Subsequently, during their first episode, they committed a violent act leading to court-mandated forensic treatment. However, the fact that approximately 70% of FPP had received prior treatment raises important questions about treatment quality and continuity. Several factors may explain why previous treatment did not prevent criminal behavior: insufficient treatment intensity or duration, poor therapy adherence, treatment interruptions, and lack of care continuity – challenges particularly pronounced in migrant populations facing language barriers and limited social support networks. The sometimes fragmented nature of psychiatric care for migrants, often involving multiple providers without coordinated case management, may have further compromised treatment effectiveness. It has been shown that first-episode psychosis patients with any forensic history are at higher risk of withdrawing from further psychiatric treatment [49]. Notably, a multinational study featuring 158 former FPP diagnosed with an SSD found that nearly four in five of these (77.8%) had received inpatient treatment prior to their forensic hospitalization [50]. Other sources mention similar rates with up to 85% [51]. With about 69%, our FPP sample did not reach these proportions. We also found a lower percentage of former outpatient treatments (37% of FPP). Other sources stated nearly two thirds had been in contact with a psychiatrist or any caretaker within two months prior to the index offence [52]. Another multinational study directly comparing FPP and GPP patients with an SSD contrasts our results as the former had mostly already been in treatment during the time of the offence, although they also displayed weaker therapy adherence. The study sample included few migrants,

especially of non-European origin, though [53]. Regarding our study, the relatively small percentage of former treatments in general may therefore be related to the non-European migration history. It appears that there are still barriers preventing non-Europeans from entering the mental health services up to the point where a hospitalization is needed. This corroborates previous findings that specialized offers are needed, especially since migrants form no homogeneous group of individuals [3, 54,55]. We also would like to focus on previous findings of our working group based on the same dataset, revealing that nearly three quarters of FPP suffered from social isolation at the time of the index offence [56]. In case social networks are sparse or even not existent, patients are less likely to be motivated or assisted by significant others to seek psychiatric help.

Albeit its small effects, the use of antidepressants in SSD is a common method to treat depressive and negative symptoms [57]. The lower antidepressant prescription rate for FPP is potentially related to concerns regarding the increase of aggressive behavior or positive symptoms, although an association is still not provable [58–60]. This finding may also be due to the nature of forensic therapy: as stated above, the reduction of harmful behavior constitutes one of the main goals of forensic treatment besides the improvement of psychosis-related symptoms. The medication strategies are subsequently adapted to these goals, which may result in less use of agents addressing other than positive symptoms. Lastly, the longer duration of treatment could facilitate a thorough treatment process that involves more psychotherapeutic elements. Thereby, depressive symptoms, which are widely spread among FPP, could be treated using non-pharmacological methods [61,62].

"No attendance to occupational therapy" constituted as the second least influential variable, being found in about 44% of all GPP, but only in 5% of FPP. From our clinical experience in both treatment facilities, this stems most likely from structural differences. As the demand for accompanying therapies often surpasses the available services, patients have to wait some time to actually start this specific intervention. In case of forensic treatments, which are usually much longer than general psychiatric hospitalizations, individuals will eventually take part in specialized programs like occupational therapy, while GPP might already be scheduled for discharge before even starting. Moreover, attending all proposed therapies is potentially linked to a faster process of easing restrictions since the patient is then more likely perceived as cooperative, indirectly influencing decisions made by legal authorities. Participation may therefore be at least partially motivated externally. It should be noted that the item "problems at occupational therapy" is not part of the model, indicating no differences concerning compliance and commitment to therapy. In general, the importance of and research in occupational therapy in forensic settings has increased over the last couple of years. It aims at boosting mental and physical soundness through engagement in meaningful tasks and thereby fosters participation as well as perceived competence, responsibility, and freedom [63, 64]. Our findings regarding occupational therapy lead to two main conclusions. First, the fact that only 5% of FPP did not attend points out a thorough and diversified multidisciplinary approach to support non-European migrants in forensic inpatient treatment. Second, non-attendance was quite common in GPP, indicating a gap that should be closed in the near future.

4.2. Established risk factors without relevance to the final model

While substance use disorder was more prevalent in FPP compared to GPP (72.1% vs. 53.1%) – an important finding in line with existing literature identifying comorbid substance use as associated with a higher likelihood of offending behavior [9,10] – this difference warrants further discussion. Beyond its direct criminogenic effects through disinhibition and impaired judgment, substance use in migrant populations with SSD may also reflect underlying social marginalization and lack of integration. Previous findings from our working group revealed that nearly three quarters of FPP suffered from social isolation at the time of the index offence [56]. In this context, substance use may serve as both a maladaptive coping mechanism for social exclusion and as a marker for insufficient engagement with mental health services, as discussed above regarding treatment adherence [49]. The interplay between substance use, social isolation, and poor treatment integration may create a particularly high-risk constellation for criminal behavior in migrant patients with SSD. However, substance use did not emerge as a key predictor in the machine learning model, which may seem contradictory at first. Bearing in mind that the model was not designed with the intention to merely highlight risk factors for offending behavior, but to detect similarities and differences in clinical and treatment characteristics in FPP and GPP with migration background, the items defining the model do not necessarily resemble risk factors for offending behavior. It is also possible that the influence of substance use on the model is manifested in other items (e.g., reduced adherence to therapeutic interventions prior to the referenced hospitalization), or that its influence was reduced in the contextual framework of the full model through compensatory characteristics. This finding highlights the complex interplay of clinical and behavioral factors in understanding offending behavior in SSD patients.

The results also suggest that the identified clinical and treatment-related variables may positively influence the likelihood of committing crimes indirectly by shaping patients' functional capacities, social integration, and adherence to therapeutic interventions. For example, poor impulse control and lack of prior treatment may exacerbate vulnerabilities, increasing the risk of offending in individuals with SSD. They also highlight specific needs of offender populations with migration experience, which may differ from non-offenders. Further research is needed to investigate these pathways in greater depth, incorporating both clinical and criminological data.

4.3. Clinical and system implications

Regarding implications for clinical and forensic work, our findings suggest several concrete interventions. First, the substantially lower rates of prior psychiatric treatment in FPP highlight critical gaps in early detection and treatment continuity for migrants. Specialized outreach programs targeting migrant communities could improve early access to mental health services and prevent escalation to forensic involvement. These potentially include culturally adapted psychoeducation, multilingual crisis services, systematic screening in primary care, and shared case management incorporating language support and cultural mediators. Second, the higher symptom burden at discharge in GPP, particularly poor impulse control and uncooperativeness, suggests that current treatment durations may be insufficient for adequate stabilization. Extended treatment protocols with structured aftercare and outpatient follow-up could bridge the gap between inpatient care and community reintegration. Given the high rates of social isolation among FPP with SSD, integrating patients into comprehensive outpatient care networks with social support services – including assistance with housing, employment, and social integration – is crucial [56]. Additionally, ensuring access to occupational therapy, which was markedly lower in GPP, may enhance functional recovery and reduce forensic risk. Finally, coordinated care pathways bridging general and forensic psychiatric care, and migrant-focused organizations are essential. These findings are not only relevant for Switzerland but also resonate with challenges observed in international healthcare systems [65].

4.4. Strengths and limitations

The present study used a machine learning approach to exploratively, i.e., not hypothesis-guided, discover characteristics of non-European FPP and GPP. This method enabled to include a myriad of possibly influencing variables. To our knowledge, there currently is no similar study involving such a number of parameters. In order to

minimize the risk of overfitting and inaccuracies associated with multiple testing, we applied a nested-resampling approach, thus limiting hyperparameter search [33]. On the other hand, there are some limitations potentially impairing our study. The dataset comprised files of patients up to decades ago. Though this was necessary to obtain a sufficient amount of data, clinical practice has widely changed since then. And while the number of included patients seems to be adequate for forensic psychiatric studies, machine learning benefits from large amounts of data. In our study, sensitivity declined after applying the trained algorithm to the validation dataset. This might be explained by a case number too little. Nevertheless, the AUC remained more or less stable, and the specificity even rose. We therefore consider our model as performative. More important issues relate to the study groups. Our goal was to focus on non-European individuals with a history of migration, eventually improving mental health services offered to this group. However, the authors are aware that "non-European migrants" do obviously not form a homogeneous group but consist of different ethnicities with varying personal and cultural background. We also did not differentiate between time and various reasons of migration (e.g., age upon migration, forced migration due to conflicts). This again is mainly because of the limited amount of data, since a further fragmentation of our sample would have impeded the process of machine learning. Additionally, our study group consisted of mainly male patients, due to a paucity of data of female patients (8 female FPP, 6 GPP). The sample size was therefore insufficient to conduct meaningful separate analyses by gender. Even though this corresponds to many other studies investigating forensic treatments and the general demographics in penitentiary systems, the transferability of our current findings to female patients is limited [53,66]. Future studies should focus on populations of genders other than male. We would also like to point to the equally low portion of comorbid personality disorders, which regarding FPP differs from other studies [53]. Last, the similar PANSS scores at admission between both groups may also reflect sample-specific characteristics: our GPP cohort was recruited from a facility specialized in rehabilitation of chronic cases rather than acute psychiatric care, potentially selecting for patients with comparable chronicity and symptom severity to the FPP group. Transferability to non-chronic cases might therefore be impaired. Nevertheless, we consider our results to be helpful to examine similarities and differences as described above. Lastly, our data were retrospectively collected, leading to potential bias and missing values, although these issues were addressed by extensive and coordinated data collection and imputation. Further studies should include multiple treatment sites, resulting in more robust and larger datasets.

5. Conclusion

The present study aimed at exploring differences and similarities of GPP and FPP, both of non-European migration background and diagnosed with a SSD. A variety of variables was included in the machine learning analysis investigating a total of 156 patients. The final model features good performance parameters, as indicated by a balanced accuracy of 71.9% and an AUC of 0.86. We discovered in total nine different variables that significantly contributed to the model. In comparison to FPP, GPP had more often been supported by mental health services before their current hospitalization, had received more antipsychotics before and antidepressant currently, while they also scored higher on several PANSS items and sum score. They also attended less to occupational therapy and more often failed during the process of opening. In summation, these discovered peculiarities might help to further improve mental health services for migrants suffering from psychoses.

CRediT authorship contribution statement

Johannes Kirchebner: Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Andreas B. Hofmann:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Marc Dörner:** Writing – review & editing, Writing – original draft, Validation. **Lena Machetanz:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **Frank Stottmeister:** Writing – original draft, Conceptualization.

Ethical

This research project was reviewed and approved by the Ethics Committee Zurich under the reference number KEK-ZH-NR 2014–0480 (approval date: 05/19/2015). Patient consent was waived due to the retrospective design, for which formal consent is not necessarily required in the Canton of Zurich, Switzerland.

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Declaration of Competing Interest

The authors declare no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.forsciint.2026.112976.

Data Availability

The following supporting information can be downloaded at: https://www.researchgate.net/publication/363044110_Coding_protocol_Pathways_into_delinquency_in_offenders_suffering_from_schizophrenia_spectrum_disorders?_sg%5B0%5D= -ouv9n-TZGVYwLNz-NA2bbNtfTtmeQNdhhSQ-LYjjNDxDMyLjcB4vguIZNi9ybfdR_-BWL5X_anlM8pT205mWVZhQ0SQHmrjOyBkLTY4C.CsUdT-XjnI56I52UGGdJCVu5RF529xxsJdoeMgg6niRGe915la0jtcoQq1bpRUMolGL8TNd8w6wt3rMM3mDZpA&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InByb2ZpbGUiLCJwYWdlIjoicHJvZmlsZSIsInByZXZpb3VzUGFnZSI6InByb2ZpbGUiLCJwb3NpdGlvbiI6InBhZ2VDb250ZW50In19

The datasets used for the current study as well as a detailed list of all variables (including definitions and references) are available from the corresponding author on reasonable request.

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