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Original article

Prediction of violent crime on discharge from secure psychiatric hospitals: A clinical prediction rule (FoVOx)

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ABSTRACT

Background: Current approaches to assess violence risk in secure hospitals are resource intensive, limited by accuracy and authorship bias and may have reached a performance ceiling. This study seeks to develop scalable predictive models for violent offending following discharge from secure psychiatric hospitals.

Methods: We identified all patients discharged from secure hospitals in Sweden between January 1, 1992 and December 31, 2013. Using multiple Cox regression, pre-specified criminal, sociodemographic and clinical risk factors were included in a model that was tested for discrimination and calibration in the prediction of violent crime at 12 and 24 months post-discharge. Risk cut-offs were pre-specified at 5% (low vs. medium) and 20% (medium vs. high).

Results: We identified 2248 patients with 2933 discharges into community settings. We developed a 12-item model with good measures of calibration and discrimination (area under the curve = 0.77 at 12 and 24 months). At 24 months post-discharge, using the 5% cut-off, sensitivity was 96% and specificity was 21%. Positive and negative predictive values were 19% and 97%, respectively. Using the 20% cut-off, sensitivity was 55%, specificity 83% and the positive and negative predictive values were 37% and 91%, respectively. The model was used to develop a free online tool (FoVOx).

Interpretation: We have developed a prediction score in a Swedish cohort of patients discharged from secure hospitals that can assist in clinical decision-making. Scalable predictive models for violence risk are possible in specific patient groups and can free up clinical time for treatment and management. Further evaluation in other countries is needed.

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1. Background

While psychiatric inpatient numbers have continued to be reduced in Western countries in the last two decades [1,2], forensic psychiatry has seen the opposite trend where a recent overview found forensic psychiatric inpatient beds have increased steadily from 1990 to 2012 [3]. There are now over 7000 beds in England and Wales [4] costing about a fifth of the mental health budget in England and Wales goes to forensic psychiatric services [5]. Annual costs per are patient estimated at between €190,000 in low secure and €340,000 in high secure hospital [6].

One of the key justifications for such high costs has been that forensic psychiatric patients are at increased risk of repeat violence on release from hospital compared to general psychiatric patients and therefore their treatment should address a wide range of needs. A recent systematic review found studies from three European countries, showing high rates of violent offending following discharge from secure hospitals in England & Wales (7 studies; 1589 to 8403 per 100,000 person–years [7], Sweden (3 studies; 1041 to 3019 per 100,000 person–years), and Norway (one study; 486 per 100,000 person–years). Absolute risks of

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reconviction for grave offences (that could potentially attract life sentences) following discharge are around 7% within two years of discharge, as found in two recent representative studies from the UK [8,9].

Current approaches to reduce violence risk generally involve structured risk assessment tools allied to clinical decision-making, with over 90% of medium secure forensic units in England using one or more such tools [10] and their use is recorded as a key service outcome [11]. Such approaches are resource intensive and time consuming, taking around 16 person–hours for the first assessment [12] and many hours for subsequent ones, with limited accuracy [13], authorship bias in their reporting [14] and considerable variation in what constitutes 'high risk' [15], so that using such categorisations in current tools has questionable usefulness [16]. Furthermore, they are typically developed in non-psychiatric samples and their external validity is worse in forensic psychiatric populations [17]. Scalable tools in general psychiatry have been developed although not widely adopted [18,19].

Therefore, we have developed a simple, free, scalable tool to assess the risk of violence in patients discharged from secure and forensic psychiatric hospitals, using routinely collected data.

2. Methods

2.1. Study sample

We conducted a longitudinal cohort study of all individuals aged 15–65 discharged from secure and forensic psychiatric hospitals into the community between 1992 and 2013 through linkage of population-based registers in Sweden. The final study cohort consisted of all discharged individuals, with a single discharge for each patient, selected at random, with equal probability. Repeat discharges complicate model fitting and interpretation and were excluded. Each individual was followed from the day of discharge until first violent offending, death, emigration or end of follow-up [12 or 24 months post-discharge). If an individual was rehospitalised without a reoffence, this did not end follow-up as we included crimes committed during rehospitalisation. The study was approved by the Regional Ethics Committee at Karolinska Institutet.

2.2. Measurement of risk factors

Data from several national registers were linked to obtain information on risk factors, with unique personal identification numbers enabling accurate linkage [20]. Sociodemographic factors were obtained from the Total Population Register [21] and the Longitudinal Integration Database for Health Insurance and Social Studies [22]. From the National Crime Register, we obtained information on any previous violent crime conviction. In line with previous work, violent crime was defined as homicide, assault, robbery, arson, any sexual offence, or threats and harassment [23]. Serious violent crime was defined as homicide, aggravated assault, aggravated robbery, rape, sexual coercion or sexual exploitation. We identified diagnoses of psychiatric disorders and substance use disorders from the National Patient Register (see Appendix for all risk factor definitions).

2.3. Measurement of outcomes

Our primary outcome was the occurrence of violent offending within 24 months of discharge from hospital, with 12 months post-discharge a secondary outcome. Repeat offences by an individual within these two years were not considered. Conviction data were used because the Swedish criminal code determines that individuals are convicted as guilty regardless of mental disorder, although sentencing may be informed by mental disorder and no plea-bargaining is permitted at the conviction stage. Violent crime was defined as above.

2.4. Statistical methods

Statistical analysis was based on Cox regression, adjusting for risk factors as described below.

2.4.1. Adjustment for risk factors

Based on existing evidence into criminal history, sociodemographic and clinical factors [24,25], we grouped variables a priori on the anticipated strength of association with the outcome in decreasing levels of priority [26,27]. All variables were categorised in this way in a protocol before any statistical analysis was carried out (see below for description of variable groups). Table 1 specifies the group to which each variable was assigned. Measures of income and deprivation were transformed into deciles so that the final model can be generalised to populations in which different income and deprivation measures are used.

2.4.2. Risk factor groups

Group 1 consists of variables thought necessary to include in the statistical model regardless of statistical significance, in order to ensure face validity and to reduce the number of candidate predictors used in the variable selection procedure described below. For the majority of these risk factors, there was evidence from previous research of an association with the outcome measure. We drew on systematic reviews of risk factors for violence in patients with severe mental illness for this information [21].

Group 2 consists of variables thought likely to show an association with outcomes, but which are not required to be included to achieve face validity. These variables were included in a backwards stepwise selection procedure, with group 1 variables always retained in the model, such that they were sequentially rejected in order of *P*-value until no group 2 variables remained with *P*-values greater than 0.1.

Continuous variables were included in the model as linear terms as there was not strong evidence of departure from linearity between continuous variables and the log-odds of the outcome. Variables split into deciles were included as categorical variables. Interactions between risk factors were not considered.

2.4.3. Missing data

Missing data was imputed via multiple imputation using chained equations (with twenty imputations) using a regression model that used as explanatory variables all other risk factors that were candidates for inclusion in the model, and the outcome variable [28]. Estimates of coefficients in the final prediction rule were obtained by pooling across imputations, using standard methodology [29].

2.4.4. Internal validation and goodness of fit

The internal validity of the model was assessed using bootstrapping to assess its predictive accuracy [30]. Bootstrapping was used to create 100 samples drawn with replacement from the data set. Predictive accuracy was summarised using the following measures:

- the concordance index [31] to assess discrimination (ability of the model to distinguish between those who do and do not commit a violent crime, with a value of one meaning perfect discrimination);
- the Brier score [32] for calibration (model goodness of fit–whether the predicted risk is systematically off target, with zero

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