Title: A Retrospective Cohort Study Mapping Real-World Psychosis Care Pathways and Guideline Adherence Using Integrated Electronic Health Records

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KC conducted the document review, assisted in developing the coding categorisation framework, analysed the data, and wrote the manuscript with input from all authors. KC also serves as the guarantor for this work. BL developed and tested the coding categorisation framework, prepared the results, assisted with the document review and data analysis, and wrote the manuscript with input from all authors. WW is a principal investigator and co-led the project conceptualisation, oversaw the development of the patient journey model, and provided feedback and editorial input on the manuscript. AB contributed expertise in the use of routinely collected data to assess and interpret variations in health service quality and safety and provided feedback and editorial input on the manuscript. RW contributed clinical expertise and contextual interpretation, including shaping the idealised patient journey, informing the coding framework and categorisation process, and contributing to data analysis, interpretation and manuscript drafting. TW contributed dataset expertise, including identifying and decoding tables and variables in the dataset, checking the coding framework and categorisation process, and provided feedback and editorial input on the manuscript. QG contributed to interpretation and revision of the manuscript. PA is a principal investigator, co-led project conceptualisation, and provided both clinical and dataset expertise and contributed to the manuscript.

ABSTRACT

Objectives: To develop a systematic, data-driven approach to map patient journeys and apply this to care pathways, assessing alignment with published guidance and highlighting potential areas to improve service delivery, using the case study of first diagnosis of psychosis.
Design: Using document review, an idealised patient journey was developed. Event data were extracted from electronic health records using a systematic process to map real-world patient journeys across care settings.
Setting: North West London's de-identified integrated care records system (Discover).
Participants: 3,219 (mean age 37 years; 55% men) adult patients (18 to 64) registered in North West London in December 2024, with a first episode of psychosis recorded between 2016 and 2019.
Main outcomes: Mapping full patient journeys, including care transitions and service contacts (i.e. psychiatric admissions, EIP involvement, and GP management). Comparison of real-world pathways against NICE guidelines.
Results: Case identification yielded demographic trends comparable with national and local level data. Two-thirds of cases had their diagnosis first recorded in primary care, with many already attending secondary care services (i.e. records may not reflect where diagnosis was clinically established). Only 18% had a clearly identifiable record of an early intervention in psychosis (EIP) service, and the recorded duration of EIP involvement varied widely. Psychiatric admission, readmission, and use of crisis and emergency services were frequent. A large proportion of patient records showed no recorded healthcare contact within either 30 days or 6 months following the index admission. The patient journey models highlighted the complexity and heterogeneity of psychosis care and were difficult to manage and visualise using available models (process maps and matrices).
Conclusions: Real-world patient journeys in psychosis, as represented in electronic medical records, appear to diverge widely from NICE-recommended care, particularly around diagnosis, EIP service provision, and post-discharge follow-up. Interpretability is likely limited by incomplete and inconsistent recording, with ambiguities posing a challenge to utilisation and interpretation of this data to reliably inform clinical decision-making, service evaluation, and policy. This work points to the need for more advanced analytical tools (i.e. artificial intelligence and optimisation) to better interpret and use patient journey data.

BOX

What is already known on this topic
Psychosis is a complex and severe mental disorder. A range of clinical guidelines and quality standards published by NICE, NHS England and the Royal College of Psychiatrists outline idealised patient pathways for psychosis care in the UK. The use of electronic medical records presents an opportunity to more effectively map and assess patient journeys across the whole care pathway.
What this study adds
This study developed a systematic approach to modelling patient journeys and demonstrated the feasibility of constructing patient journey models from heterogeneous linked healthcare data. It explored the potential for modelling to support service evaluation and care quality improvement

in complex health conditions, such as psychosis. Patient journeys reconstructed from electronic medical records revealed frequent apparent deviations from guideline recommended pathways in routine health record data. For instance, only a minority of patients had clearly recorded EIP care, and many appeared to have shorter recorded durations of service contact than recommended. Some of these deviations are likely due to data limitations, while others may indicate areas for service improvement.

How this study might affect research, policy or practice

Routine data can be used to develop patient journey models in mental healthcare, identify service gaps, and areas for quality improvement; however, recording practices remain a barrier. The journey timelines we developed provide a strong foundation for understanding patient pathways and outcomes for psychosis and possibly other diagnoses. New approaches are needed to accommodate, analyse, and visualise complex, incomplete, and "messy" health data to support effective decision-making.

INTRODUCTION

Patients with mental health conditions often experience a complex series of interactions with the healthcare system, or a journey, involving multiple contacts, referrals, and interventions across services over time [1]. Often, these journeys are not well understood or described. They may vary widely, even for the same condition, and may reveal delays in diagnosis, gaps in provision, problems with continuity or other unmet needs [2, 3]. Ideally, such journeys should follow evidence-based guidelines such as those developed by the UK's National Institute for Health and Care Excellence (NICE). However, individual preferences and values may also influence the course of care, which may reflect patient-centred or person-focused approaches, rather than substandard provision [2].

Mapping patient journeys has become a well-established method for understanding variation and improving service design [4, 5]. Within healthcare, this has historically been done using qualitative and quantitative methodologies, including interviews, patient records, and observational techniques, as well as process mapping methodology, with an increasing focus on incorporating the patient's perspective in mapping exercises [5]. However, the application of these methods to complex conditions or across the whole system is not well established.

Electronic medical records (EMRs) provide the opportunity to apply data-driven methods to reconstruct patient journeys at scale. Healthcare datasets and systems are multifaceted and dynamic, often contain incomplete, overlapping or duplicative data, and contain a broader range of event types [6, 7]. For instance, start or end at different points in the healthcare system, span long time periods, or include data points across levels of care or in different settings. As such, they are not optimised for pathway analysis [8]. In the UK, despite standardised coding systems, healthcare data is complicated by variable practices across multiple EMR systems [9, 10]. These challenges make it difficult to produce clinically meaningful models of patient journeys in mental health and beyond. There are clear benefits if patient pathway analysis can be done.

Psychotic disorders provide a significant test case for journey-based analytics. Psychosis is a severe mental disorder, with estimated lifetime prevalence of 1.5-3.5% and an incidence of 31.7 per 100,000 in the UK [11-13]. It carries substantial morbidity and premature mortality of 15–20

years, with estimated annual costs to the NHS of £2 billion. There is known to be variation in patient journeys for people who experience psychosis, some of which could be clinically unwarranted [14]. Outcomes are similarly variable, with a subgroup of individuals developing treatment-resistant symptoms, 10–20% of cases, that account for a disproportionate share of psychiatric service utilisation and healthcare costs [15, 16]. Early diagnosis and treatment are consistently associated with improved outcomes and reduced costs [17-19]. Input from Early Intervention in Psychosis (EIP) services, designed to deliver comprehensive, time-limited packages of treatment for early psychosis, is recommended in multiple national-level guidelines [20, 21], and has been consistently shown to improve outcomes. However, access to and duration of EIP services are variable [22]. Transition points (i.e. out of EIP services) are critical moments of care, which if not properly managed can lead to negative outcomes [23, 24].

Analysing real-world patient journeys across the full care pathway for people with psychosis may, therefore, provide unique insights into the quality, safety, and organisation of care, as well as highlighting opportunities for service improvement.

METHODS

Objectives

This study aimed to use routine linked health records to map the real-world care pathways of people following a first diagnosis of psychosis. In doing so, we aimed to develop a systematic approach to modelling patient journeys for individuals with complex health conditions. After first demonstrating the feasibility of constructing patient journey models from heterogeneous linked healthcare data, we aimed to compare these models with guideline-defined care pathways, identifying potential gaps and exploring the potential for our modelling to support service evaluation and quality improvement, both in psychosis care and potentially in other complex conditions in the future.

Setting and data source

We used individual-level linked adult healthcare records from the Discover research platform (Discover) [25, 26], which is a de-identified research database based on the Whole Systems Integrated Care (WSIC) database used for direct patient care in North West London (NWL) (online supplementary text).

All data extraction was carried out in the databases using Snowflake SQL. Python was used to characterise patient journey models, representing them as high-dimensional timelines or structured data frames suitable for analysis. Process mining was performed using the R-based package bupaR (1.1.0) on the prepared journey models [27].

Inclusion and exclusion

Patients registered with a General Practice in North West London as of December 2024 were identified. Of those, patients aged 18 to 64 in 2016 with records indicating first episode of

psychosis, termed first recorded diagnosis of psychosis, as defined by the earliest recorded diagnosis of psychosis (psychosis or psychosis related ICD-10 or SNOMED/READ codes) and use of secondary care mental health services for psychosis or EIP specific services between January 2016 and December 2019 were included in the analysis. Patients' records were analysed through December 2024. The age range corresponds to the management of the first episode of psychosis pathway for adults. The date range was restricted to 2016-2019 to ensure that patient records could be pulled from all data tables within Discover, as the data has varying temporal coverage in each of the tables included in the analysis, and to ensure that the patient journey would be sufficiently long for the analysis.

Data prior to this timeframe were reviewed to ensure that patients with a historic record of psychosis care were excluded. Due to the distinct nature of their clinical pathways and service use, patients who received Child and Adolescent Mental Health Services (CAMHS), Older People's Mental Health Services (OPMHS), or perinatal services were excluded (online supplemental figure 1).

Idealised patient journey model development

An evidence synthesis document review was undertaken to construct an idealised, guideline-derived patient journey for the assessment, diagnosis, and management of psychosis. The review focused on UK specific psychosis related clinical best practices and quality of care guidance [2, 20, 21, 28]. The expected patient journey was mapped using basic process mapping techniques and a flow chart focused on the diagnosis of the first episode of psychosis and the subsequent treatment pathways created using Microsoft Visio. The output was checked by a clinical academic psychiatrist with expertise in psychotic disorders.

Patient journey model development from electronic health records

Mapping patient journeys from raw health records is challenging due to their structure. To address this, we developed a systematic process mining method to construct patient journeys across care settings. A detailed description of this process is given in the supplementary material. In summary, it involved:

1. **Data cleaning and filtering**: Identifying mental health-related activities across primary and secondary care records and filtering and refining for psychosis-related events based on clinical guidelines and clinical knowledge of services and recording techniques.
2. **Normalisation and unification**: Identifying coding inconsistencies, including terminology variation and coding formats, and consolidating events within and across tables into a unified and consistent format, for example, locating EIP services under referrals, discharge notes, and service label codes.
3. **Categorisation:** Grouping activities in line with a simple idealised patient journey (Figure 1) to reduce model complexity and increase interpretability, such as grouping medications into (non-clozapine) antipsychotics, clozapine, and other psychotropics or

combining GP records corresponding to the annual health check for people with severe mental health conditions.

4. **Event log creation and consolidation:** Merging and reformatting patient journey data into an event log, in line with process mining methodology. Managing duplicate services, events recorded in more than one table, and overlapping services and events from different sources occurring concurrently by applying heuristics to reduce redundancy and produce clinically interpretable timelines.
5. **Iterative refinement based on guidelines and clinical feedback:** Ensuring real-world applicability and alignment with guideline-based care by refining the model through multiple iterations involving clinician review and feedback.
6. **Timeline summarisation and process mining:** Conducting process mining to visualise the complexity of the full patient journey and subsequently apply edge filtering to simplify the process map for analysis, emphasising key transitions.

These steps allowed us to transform raw, heterogeneous data (online supplementary figure 2) into structured timelines representing each patient's care pathway to compare against the idealised patient journey, quality of care standards and benchmarking data. Full details of the six-step process, including coding framework and software used, are provided in the online supplement (online supplementary 3a and 3b).

Patient and public involvement

Public contributors chosen based on their use of NWL healthcare services or connection to the NWL community were involved at the identification and prioritization, analysis and interpretation, and evaluation stages of this study. Initial consultations undertaken during the Imperial Biomedical Research Centre (BRC) funding reapplication helped identify research priorities and informed research question refinement. The results, including patient journey models, were presented to the Imperial BRC Digital Health Community Partners to assess their acceptability, understandability, and usefulness. Their input informed refinements to study outputs and future research plans. We intend to further disseminate the results to patients with lived experience of psychosis to further understand the patient journey models and how to apply them to analysis using advanced analytical tools and service and guideline improvement activities. As this study used secondary data stored in a secure environment, no recruitment or data collection was undertaken.

RESULTS

Patient characteristics

Our search retrieved 19,080 patients aged 18-64 with a recorded diagnosis of psychosis during the study period (out of a population of 1.83 million). Of these, 3,219 met the inclusion and exclusion criteria of adult patients with a first diagnosis of psychosis and not accessing specialised service pathways during the study period (online supplemental figure 1), corresponding to an incidence rate of 38 per 100,000 person-years. The mean age of the included

patients was 37.4 years (SD = 12.2); 55% were men (Table 1). Compared with the underlying population, psychosis was more commonly diagnosed among Black or Black British individuals and those aged 25 to 34, and less common among older (55-64) and younger adults (18-24).

Table 1: Sociodemographic summary of patients aged 18–64 with a diagnosis of psychosis registered in Northwest London

	Cases (n = 3219)		**Population (k) (n = 1.83 million)**	
	n	**%**	**n**	**%**
Gender				
Female	1447	45.0	851	46.6
Male	1772	55.0	975	53.4
Other	0	0.0	<0.1	0.0
Unknown	0	0.0	<0.1	0.0
Age group				
18 – 24	584	18.1	423	23.2
25 – 34	895	27.8	529	29.0
35 – 44	752	23.4	390	21.4
45 – 54	632	19.6	295	16.2
55 – 64	356	11.1	187	10.2
Ethnicity				
White	1307	40.6	754	41.3
Asian or Asian British	703	21.8	518	28.4
Black or Black British	508	15.8	145	7.9
Other ethnic groups	391	12.2	212	11.6
Mixed	151	4.7	56	3.1
Unknown	159	4.9	138	7.6

Idealised patient journey model

The idealised patient journey based on clinical guidelines is shown in Figure 1. Upon referral, patients with symptoms that merit evaluation for possible psychosis are assessed by a specialist mental health provider with training in at-risk mental health states, typically as part of the outpatient or inpatient service provision and less commonly in A&E or by crisis services. As such, a referral or transfer of service (i.e. from primary care to EIP) may be required. Patients who do not meet the diagnostic threshold for psychosis may be followed up by the At Risk Mental Health Service (ARMS), with some patients ultimately being diagnosed with psychosis. Following a diagnosis of psychosis, a proportion of patients will require initial inpatient treatment prior to EIP. All patients should be offered EIP input, which is intended to be time-limited for a period of three years. Patients are then either discharged to primary care or transferred to ongoing specialist care treatment, where clinically indicated. Primary care management of psychosis should include an annual physical health check. Ongoing specialist

care treatment should continue until symptoms are adequately controlled, potentially on a long-term basis. Specialist treatment typically involves a community mental health team (CMHT) delivering various interventions tailored to the patient's needs, which may include social care interventions and input from a rehabilitation service. Readmissions and index admission at a later stage of the journey may occur and should be followed by a referral and transfer of care to EIP, ongoing specialist care, or primary care. Acute events (A&E attendances and use of crisis services) may occur at any stage of the journey [20, 28]. For simplicity of presentation, these were excluded from the idealised model.

Upon diagnosis, patients should be offered a non-clozapine antipsychotic medication. In a small proportion of patients, medication might not be offered or delayed (i.e. mild, brief, or self-limiting psychotic symptoms). Medication reviews occur at regular and increasing intervals as the patient stabilises, and changes may be made based on the effectiveness of the drug and its side effects. Clozapine should be offered to those with treatment-resistant symptoms, defined by not responding adequately to two other medications [20, 28].

Applying process mining to patient journeys for psychosis

When process mining was run for all cases, the patient journey model process map proved difficult to interpret (online supplemental figure 4). This complexity arises because each trace represents an individual patient journey spanning multiple service providers, resulting in a much higher degree of variation in transition patterns compared with standard business or clinical processes. After implementing the cleaning and edge filtering, we obtained a much clearer view of the major transitions (Figure 2).

We also used a transition matrix (Figure 3) as an alternate way to visualise patient journeys, summarising the probabilities of moving from one event to another. Each cell represents the proportion of patients transitioning event-to-event, or the next step in event, across all patient pathways; thereby, providing an aggregated view of common pathways and transition probabilities and enabling clearer interpretation of common transition patterns and dominant pathways (i.e. the next point of contact after an inpatient admission or transitions between year of EIP service), as well as less likely pathways.

Interpreting and analysing the patient journey for psychosis

Analysis of the patient journey pathways provided insights into real-world patient journey models for a new diagnosis of psychosis compared against the idealised patient journey and guideline-based care.

Diagnosis recording

The earliest recorded diagnosis of psychosis captured in EMRs was most often in primary care (67.8%), followed by outpatient (19.6%), inpatient (7.6%), and EIP services (5.0%). However, many patients' records indicated they had already been seen in secondary care: in the two months before diagnosis, 23.1% had a GP referral to mental health services, 40.7% attended an outpatient clinic, 23.4% were admitted as inpatients, 13.4% presented to A&E, and 5.0%

accessed crisis services, but no diagnosis of psychosis was captured (online supplemental figures 5a and 5b).

EIP service input

We observed a surprisingly small number of records (18.0%) with clearly identifiable EIP labels. Among those without an EIP record, 61.6% had other outpatient mental health activity within the EIP qualifying period of three years (online supplemental figure 6). The recorded duration of EIP input also varied. Among those with EIP records, 31.6% appeared to be discharged to primary care within the first year, and a further 24.5% of those still accessing EIP services by year two. Of those completing three years, 45.1% remained in EIP care for at least another year.

Inpatient care

Inpatient data was reviewed and filtered for psychosis-related primary or secondary diagnoses. Overall, 43.3% of patients had a psychiatric admission. The mean length of stay was 53.6 days and median 30 days (IQR 44 days). Readmission rates were 17.4% at 30 days and 43.8% at six months. Thirty-eight per cent of participants were not seen by any provider for mental health-related care within 30 days, dropping to 18.4% of participants by 6 months. Among patients who were seen, the most common next contact within 30 days and six months were outpatient services (25.0% and 30.5% respectively) and GPs (16.1% and 23.4% respectively), although substantial proportions returned to crisis services (16.9% and 21.3%) or A&E (2.3% and 3.7%) (online supplemental figure 7).

Emergency and crisis care

A&E attendances were recorded for 32.6% of patients, with a median of two visits (range 1–256). One-quarter of patients (25.8%) had crisis service contacts, with frequent repeat use (median, 6.5 contacts; range 1–224).

DISCUSSION

In this study we conducted a comprehensive analysis of large, real-world datasets to examine patient journeys for people with psychosis. We developed and tested a novel systematic approach for cleaning, unifying, and structuring heterogeneous records into clinically interpretable journeys, with iterative clinician input. We demonstrated the feasibility of constructing journeys using this approach for psychosis from routine, linked EMRs. This process showed that routine data can yield important information about care pathways, with potential future applications for modelling other complex health conditions.

We identified 3,219 first recorded diagnoses of psychosis in North West London over a four-year period, with an incidence rate comparable to previous reports [11-13], indicating that our methodology correctly identified and captured new incident cases. As expected, diagnoses were more common among men and individuals from Black ethnic backgrounds.

Process mining and the accompanying visualisations identified several findings that are notable in relation to current clinical guidance. These include the earliest record of diagnosis, access to

and duration of EIP services, and access to outpatient services after an inpatient admission, all of which are worthy of further investigation, both to confirm their validity and identify the reasons underlying these variations.

Guidelines specify that diagnosis must be established by a trained mental health professional, typically a psychiatrist, in secondary care settings (outpatient, inpatient, or, in rare instances, A&E) [20, 28]. The earliest recorded diagnosis in our data was most seen in primary care records. This finding reflects where diagnoses are recorded within accessible datasets rather than where they are necessarily made clinically. Our analysis of the events preceding the earliest recorded diagnosis suggests that many patients had already been seen by secondary mental health services. This, along with recording practices in outpatient settings and data surfacing within Discover (i.e. lack of detailed diagnosis codes in the mental health table), suggest that diagnoses may not have been adequately captured in electronic records, until communicated to GPs (i.e. in clinic or discharge letters). The discrepancy highlights the challenges of relying on routine records to monitor adherence to standards. The risk of delayed or unclearlydocumented diagnosis introduces uncertainty about the exact timing and nature of diagnoses for a population where timely identification of issues and intervention is an important predictor of prognosis [28]. It also highlights the potential for omissions in health records and miscommunication between primary and secondary care, which is known to be a significant issue for this population [29].

In the UK, multiple guidelines specify that EIP input should be provided to all people with a first episode or presentation of psychosis [20, 28], with current iterations increasingly removing potential barriers such as age cutoffs, diagnostic categories or duration of untreated psychosis. A clearly identifiable record of EIP care was present in 18.0% of cases. We noted that a further 61.6% of people did have additional outpatient mental health records during the qualifying EIP period. Due to variability in additional information (i.e. incomplete location and service name data or lack of service type variables) it was not possible to say definitively whether these represented input from EIP or other services (e.g. generic CMHTs). As such, this finding may reflect incomplete identification of EIP activity within the dataset, rather than absence of EIP involvement. This may limit interpretation of alignment with guideline-recommended care, and warrants further exploration into how outpatient and community services are represented and captured in routine health records.

Current guidelines indicate that EIP services should support people with an optimum treatment package of three years as standard, avoiding premature transition to alternative services, whilst considering individual needs [28]. Similarly, although there are recommendations that services should have the capacity to consider extending input beyond three years [20], this is widely understood to apply only in exceptional circumstances to allocate resources effectively. However, our data indicate substantial variation in the duration of EIP input, with large numbers of patients who appear to receive significantly less than three years input and a smaller but meaningful number who appear to receive more. It is difficult to determine the root cause of this variable duration, with possible explanations including difficulties with engagement, variation in service delivery, and differences in how care is recorded, reflecting a combination of clinical complexity, service configuration, and limitations in data capture. These results are worth examining in further detail, including a deep dive into patient characteristics and trajectories,

especially as they have implications for funding, provision of real-world evidence-informed care, and equity of access alongside accurate data recording.

Finally, while rates of hospital admissions, 30-day and 6-month readmissions were similar to those reported elsewhere [30], access to follow-up mental health services deviated from the guidelines, with only 42.5% of patients being seen within 30 days and 56.6% by 6 months [28]. Records of remaining patients showed either no contact (38.3% and 18.4% respectively) or emergency or crisis services (19.2% and 25.0%) as their next point of contact after discharge. Although absence of recorded follow-up does not necessarily indicate absence of care, this pattern suggests possible gaps in planned follow-up and the possibility of loss to care at a critical and high-risk stage, which warrants further analysis [31].

Taken together, these findings suggest that the real-world delivery of psychosis care may diverge from guideline-defined pathways. Some of this variation is likely to reflect limitations of the available data, particularly inconsistent recording across settings, missing data and differences in coding practice. However, the patterns observed also highlight areas where there may be true variation in service quality and the structure of care delivery. They suggest that data capture and surfacing should be reviewed in line with guidelines to improve the accuracy and usefulness of routinely collected data to monitor care.

Our study has some limitations. Traditional visual representations became too complex to allow for meaningful interpretation. Data cleaning and edge filtering helped clarify key transitions but reduced the resolution of our analysis compared with more comprehensive categorisations. Further, we were unable to accurately assess a substantial number of measures outlined in the quality of service guidelines due to data not being present in the version of Discover used for analysis. Although more comprehensive datasets aligned to the Mental Health Services Data Set are now available, they are further truncated, do not yet cover all service types, and currently are only populated for child and adolescent mental health services. Finally, coding practices varied across providers: for instance, data from GPs, inpatient, and A&E are coded using formal systems (e.g. SNOMED, ICD-10). However, data from community services, outpatient care, and social care use categorical labels (e.g. appointment, treatment), which are less specific. Medical codes can be overly detailed or include irrelevant information, while categorical terms are often too broad or ambiguous, leading to multiple possible interpretations. Missing data is common. The size of the dataset, diverse data types and distribution across many different database tables further compound the analytical complexity and complicate interpretation. Data on prescribing antipsychotic medication presented a particular challenge. Our secondary care analyses, especially for outpatient appointments, lacked detailed prescribing codes, and the mental health table lacks a variable for prescribing. As such, we were only able to report on the GP prescribing table. While there was clear evidence of prescribing across the full patient journey present in the GP records (i.e. patients with a record of EIP services also having a record of concurrent antipsychotic medication prescribing (Figure 3)), we would not expect these records to be a full and accurate representation of all prescribing across the full patient journey. This limits our ability to draw conclusions about prescribing practices and their compliance with the guidelines.

The multi-dimensional journey timeline developed in this study provides a structured foundation for analysing complex care pathways. Our findings show that psychosis patient journeys are long, heterogeneous, and irregular in timing and service composition, making them difficult to compare using conventional summary statistics or process-mining visualisations alone. A natural next step is therefore the development of analytical methods that can compare complete trajectories, identify pathway patterns across patients, and quantify deviation from recommended care processes while preserving longitudinal structure. Such methods are needed because existing statistical approaches typically reduce journeys to fixed features, while process-mining techniques focus on common transitions rather than calibrated, whole-journey comparisons. Addressing this challenge requires both transparent modelling of event structure and appropriate computational tools. Optimisation methods can enable scalable comparison across large populations, and AI-based approaches may assist in handling complex or partially unstructured records. Together with clearly defined event categories and robust data governance, these elements form a coherent framework for rigorous and interpretable evaluation of care pathways.

CLINICAL IMPLICATIONS

The Department of Health and Social Care has identified digital transformation as a top priority in health care service delivery, with a key focus on improving access to and use of digital technology to improve access to and use of electronic medical records data, as well as using routine health outcome data to support clinical decision making, and national and local priority setting and funding decision-making [32-35]. Our approach to using electronic medical records to map and analyse patient journeys across the health system shows promise for analysing patient journeys for both specific conditions and comorbidities, illuminating how care is delivered in practice and where it diverges from recommended standards.

However, a key finding of this study is the limited ability of current routine data to fully represent complex mental health care trajectories. For psychosis, our approach identified probable gaps in recording diagnoses, the presence and nature of EIP input, and revealed an apparent heavy reliance on crisis care. Our findings do highlight areas where services may be falling short of best practice. However, they suggests that there are issues with the way the data is collected and aggregated, which may misrepresent clinical reality and perpetuate existing gaps in care. As such, relying on this data to make decisions about clinical practice or allocating limited healthcare resources should be approached with caution and triangulated with clinical and service user insights.

Advanced analytical tools present an opportunity to address some of these concerns when applied with the input of key stakeholders, including clinicians, data analysts, service users and carers. This in combination with improved data capture and surfacing, journey-based modelling could become a valuable tool for monitoring adherence to clinical guidelines, identifying service gaps, improving efficiency and enhancing care for people with a psychosis diagnosis.

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ETHICS STATEMENT

Access to the Discover dataset was granted by the Discover Data Access Sub-group in July 2023. No reference numbers are given by this committee. All data was fully de-identified, as such ethics committee review was not required based on UK Health Research Authority guidance. Patient consent for publication is not required.

DATA AVAILABILITY

The WSIC / Discover data that support the findings of this study are available from Imperial College Partners, but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. De-identified data may be accessible for research purposes or service evaluation through application to the North West London Data Access Sub-group.

COMPETING INTERESTS

The authors have read and understood the BMJ Group policy on declaration of interests and have no interests to declare.

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LEGEND

Figure 1: Idealised patient journey model

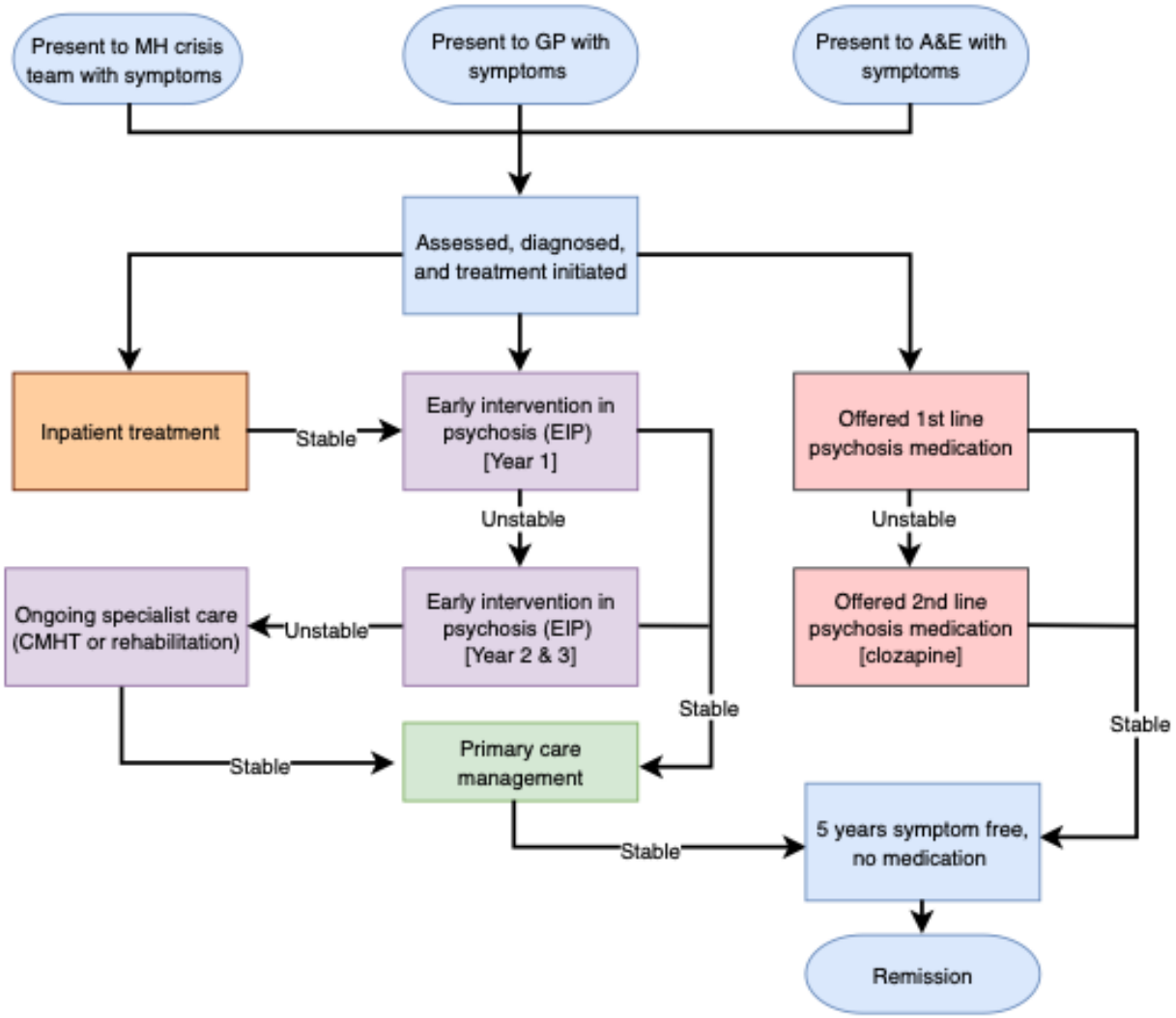


Figure 2: Cleaned and edge-filtered process map, showing only transitions with a probability greater than 0.15.

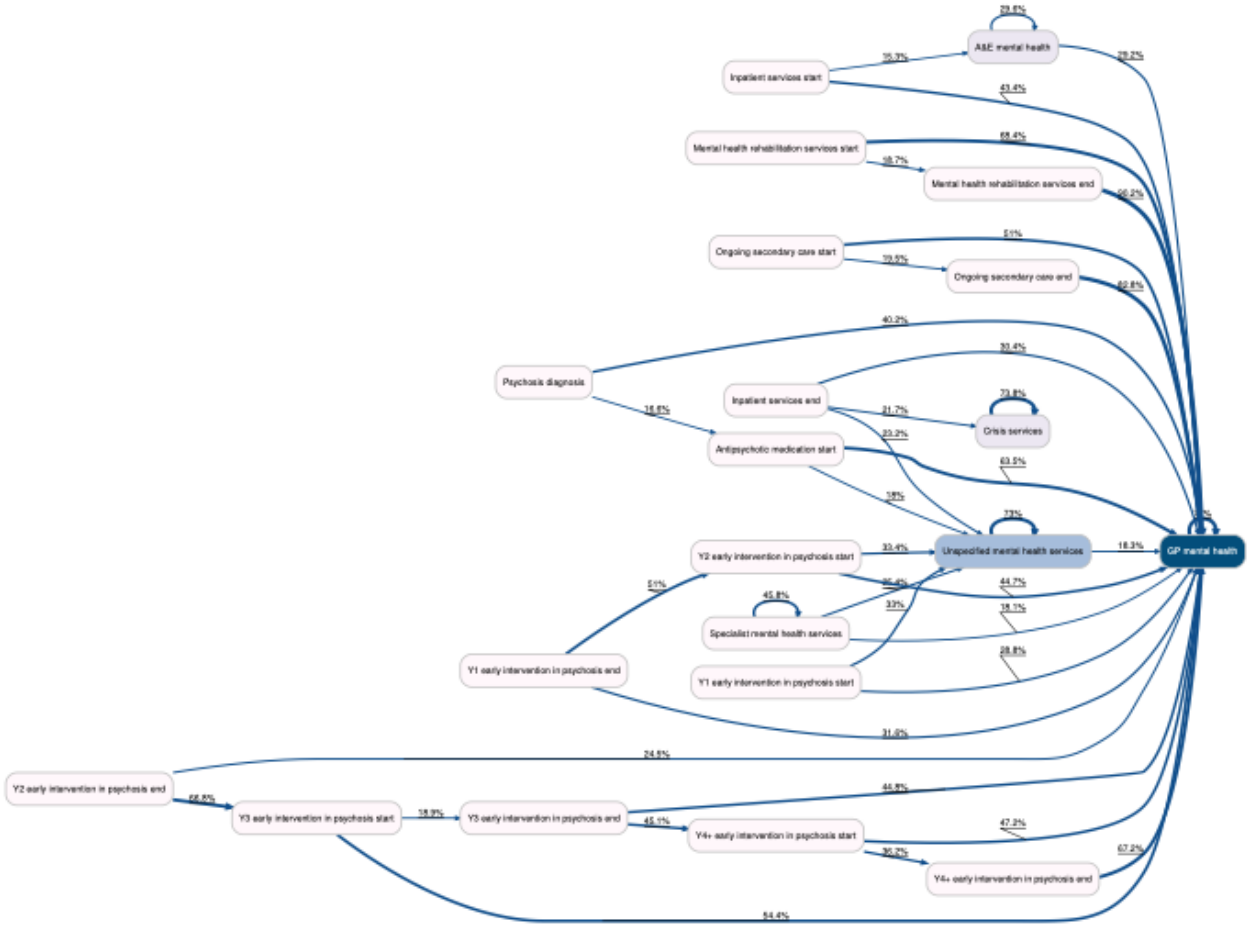
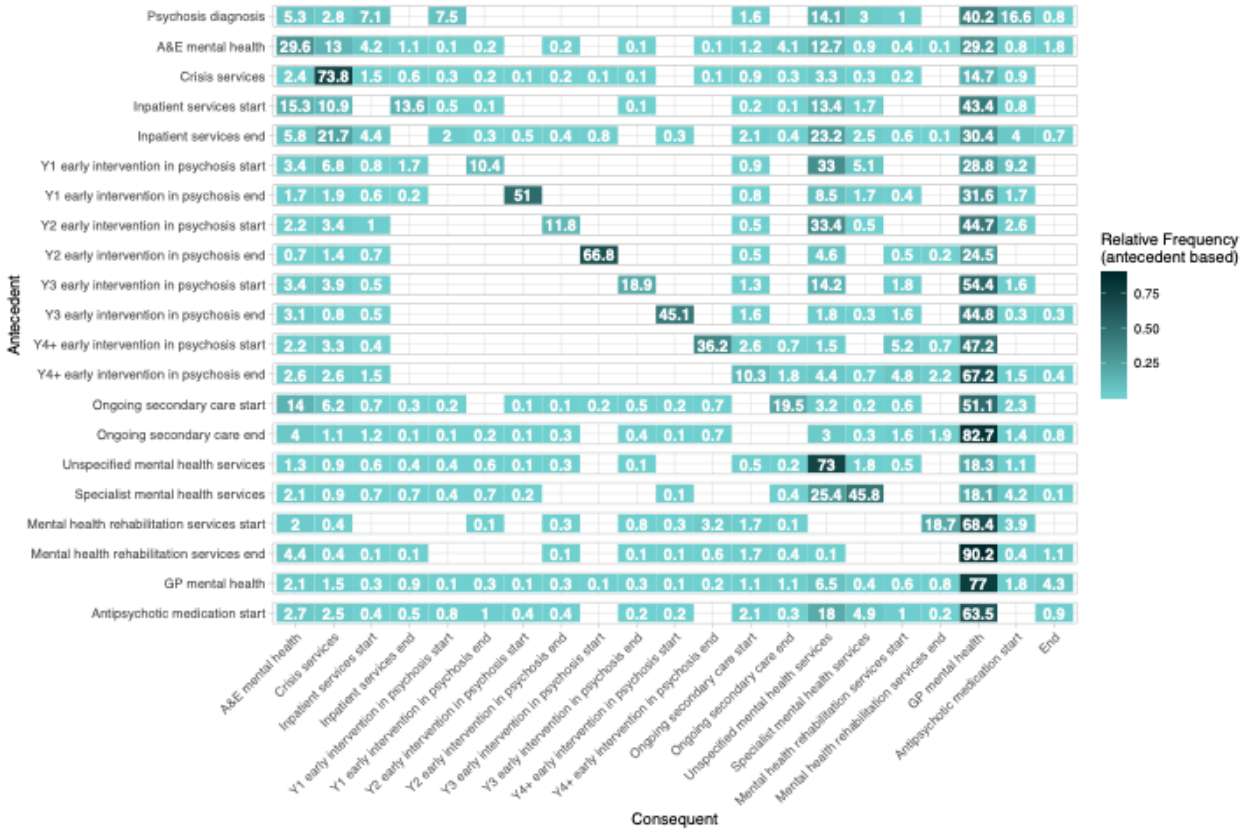


Figure 3: Transition matrix summarising the likelihood of transitions from starting events (vertical axis) to subsequent events (horizontal axis).



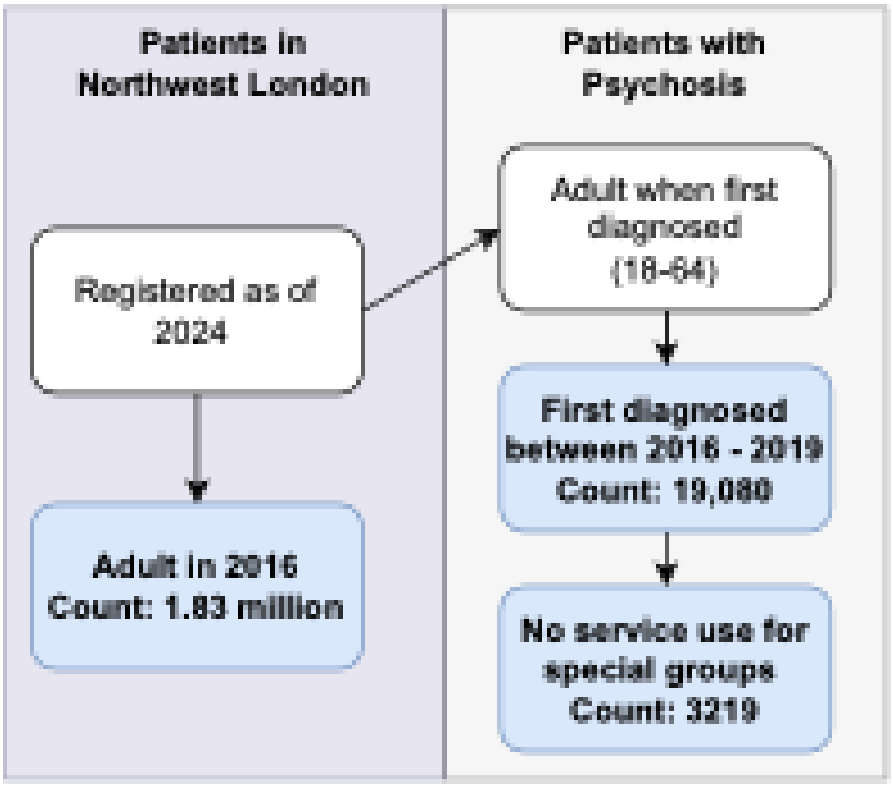
SUPPLEMENTARY MATERIALS

Contents

Supplementary Text: Detailed description of the study setting

NWL operates psychosis care within one Integrated Care System (ICS) that coordinates regional primary and secondary services. Within this system, the region is supported by six major acute hospital trusts, and 18 out-of-area providers, which provide the broader secondary-care environment for mental-health pathways, and two NHS Trusts which are a part of the Mental Health Provider Collaborative set up to deliver mental health services. NWL operates six EIP services. NHS NWL has approximately 350 GP practices organised into 45 Primary Care Networks (PCNs) [1,2]. The Discover research platform is a de-identified research database covering the described setting.

Supplementary Figure 1: Case identification diagram



Supplementary Figure 2: List of Discovery data tables included for analysis

Table	Data range (Years)	Brief description of table
did.GP_events_c	2015 - Present	All events/procedures/diagnosis for GP
did.GP_prescription_c	2015 - Present	All initial or repeat prescriptions ordered by GP
did.sus_apcepisode	1992 - Present	All events/procedures/diagnosis for one hospital admission
did.sus_apcspell	1992 - Present	Multiple episodes for one hospital admission
did.sus_op	2015 - Present	All outpatient visits including procedure code (ICD-10)
did.sus_AE	2015 - Present	All A&E visits, including the diagnosis code (A&E specific code)
did.mentalhealth_pld	2015 - 2022	All mental health related events, including outpatient/community, social care/rehabilitation, A&E, and inpatient
did.community_pld	2015 - Present	All mental health related events, including outpatient/community, social care/rehabilitation. Currently coded using a very limited coding

dbo.mh_liasionpsychiatry	2021 - Present	All A&E visits related to mental health and/or a patient who has a mental health condition
did.GP_events	1955 - Present	Uncleaned GP records used to cross reference and exclude any patients who received care for psychosis prior to 2016.

Supplementary Figure 3a: Detailed methodology applied to develop the patient journey model development from electronic medical records

The following steps were used to develop the patient journey model.

1. **Cleaning and filtering:** Data were cleaned and filtered to include only mental health related activities. Data included a wide range of variables (e.g. service team and service category) to ensure events and activities were not inadvertently excluded due to data quality issues. Secondary care data are recorded using International Classification of Diseases – 10[1] code or service term. GP tables presented unique challenges, as they use the 'Systematised Nomenclature of Medicine Clinical Terms' Terms (SNOMED-CT) coding system. Each visit could include hundreds of codes, making it difficult to identify and interpret key activities. To account for redundant and low-relevance information, events were filtered using clinical guidelines (e.g. quality standards for EIP services) [3] and refined based on clinical knowledge of the services and recording techniques.
2. **Normalisation and unification:** Activities were often recorded in different formats or under different coding systems. For example, EIP services appeared under referral codes, discharge notes, or service activity labels. The normalisation step detected such overlaps and consolidated them together with the related concepts or activities such as subservices. For instance, assertive outreach was then interpreted as a subcomponent of early intervention. This step ensured that each event within a given table was recorded in a unique and consistent form.
3. **Categorisation:** Activities were categorised into groups in line with a simple idealised patient journey (Figure 1). One example was the classification of prescription medications, which was divided into three categories: (a) first line antipsychotic medications, (b) second line antipsychotic medications, namely clozapine, a specific agent uniquely licensed for treatment-resistant psychosis in the UK context, and (c) other psychotropic medications not specific to the treatment of psychosis (such as antidepressants). This step was required to reduce model complexity and aid in interpretability. However, it introduces a risk of information loss. This step was implemented using a reference table (online supplemental figure 1), which can be easily updated or revised based on evolving criteria.
4. **Event log creation and consolidation:** Records were first ordered by start and end date. For events that occurred on the same day and lacking inherent sequencing, a heuristic sequence was applied based on clinical knowledge. They were then reviewed to identify duplicate services, or events recorded in more than one table (e.g. an outpatient clinic

[1] The ICD is the standard medical classification system in the United Kingdom. ICD-10 was superseded by ICD-11 in 2022. However, ICD-10 codes are still used in WSIC data, and, therefore, used for this analysis.

appointment recorded in both outpatient and GP records), and overlapping services, or events from different sources occurring concurrently (e.g. a GP appointment during an inpatient admission). These were also managed by applying heuristics. This significantly reduced redundancy and surfacing clinically meaningful activities.

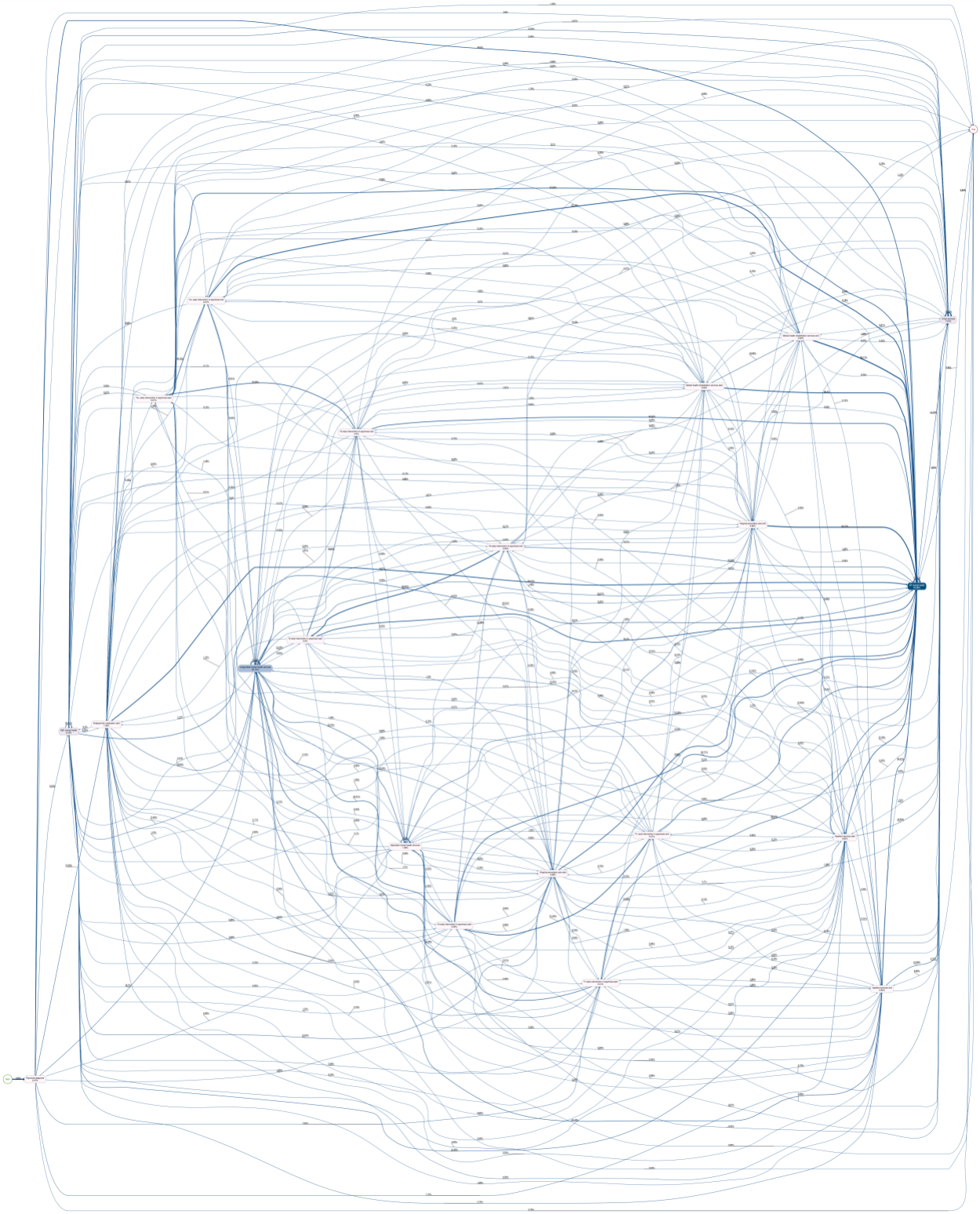
5. **Iterative refinement based on guidelines and clinical feedback:** To ensure real-world applicability and alignment with guideline-based care, the model was refined through multiple iterations involving clinician review and feedback.
6. **Timeline summarisation and process mining:** Unlike traditional event sequences, patient journeys for psychosis can span extended time periods, contain overlapping services, and exhibit diverse transition patterns. To represent this complexity, a multi-dimensional timeline model that integrates timeline elements with event sequences was used. When applying this to multiple patients, the differences in patient journeys made the process map visualisation too complex to be meaningful. Additional cleaning and edge filtering was conducted to simplify the process map and emphasise key transitions in the plot, making them stand out within the broader context.

Supplementary Figure 3b: Coding framework

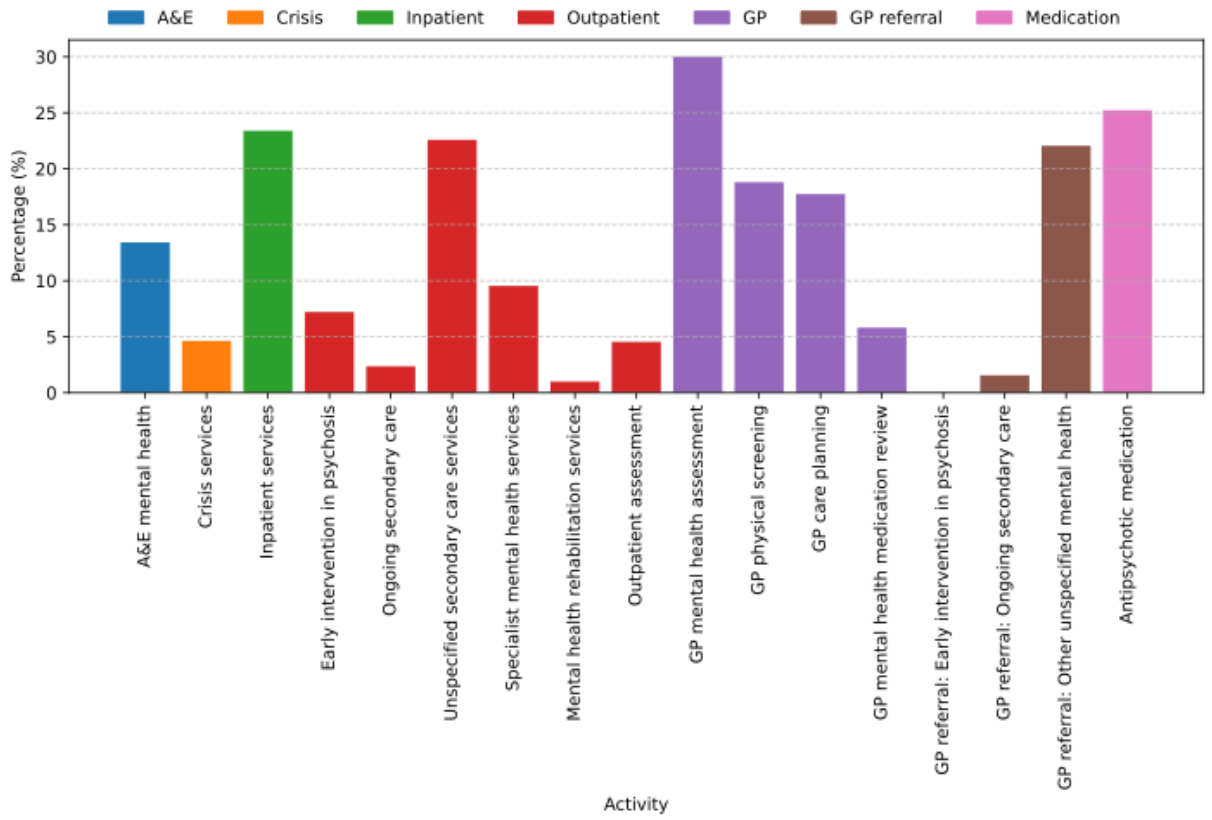
Patient journey plot/Service	Event/Care level	Discover Table
Pre-diagnosis, at risk of psychosis	ARMS	GP_events
Diagnosis	GP SNOMED code FEP	GP_events
	EIP (specifically designated service)	sus_op, mentalhealth
	A&E diagnosis code	sus_AE
	ICD-10 codes (inpatient or outpatient)	sus_apcspell, sus_apcepisode, sus_op
Inpatient	ICD-10 codes (F20 with specific psychosis terms)	sus_apcspell, sus_apcepisode
	Suspected case of psychosis (F28 and F29)	sus_apcspell, sus_apcepisode
	Any acute care term	mentalhealth
	Specialist inpatient mental health services (forensics, PICU)	mentalhealth
EIP (outpatient)	EIS or EIP (specifically designated service, service team, or combination of terms)	mentalhealth, Community
	Specialist teams assertive outreach	mentalhealth
Ongoing MH service (outpatient)	Community mental health team/CMHT	mentalhealth, community
Unspecified mental health appointment (outpatient)	General terms (Community/Community 1st/ Community Fup, Outpatient/Outpatient 1st/Outpatient Fup/OPS, Adult/Adult Fup, 1st appointment, Follow-up/Fup, Review, Treatment, Consultation, Assessment and Treatment etc)	mentalhealth, sus_op, community
	Primary and Planned Mental Health Care	mentalhealth
	Unplanned contact (emergency visit but not AE)	mentalhealth
	Specialist teams other (adult)	mentalhealth
Rehabilitation (community)	Rehab or rehabilitation (with or without location), excluding elder care or CAMHS	mentalhealth, community
	Community and recovery mental health services (cmht for rehab)	mentalhealth
	Mental health day care	mentalhealth

MH: Other (outpatient)	MH: Other (outpatient)	mentalhealth
GP	Physical health reviews and/or combined clinical indicators for physical health review Medication review GP Mental health assessment/care plan reviews	GP_events GP_events GP_events
GP Unclassified	GP referral (mental health related services) GP discharge (mental health related services)	GP_events GP_events
A&E	A&E	mentalhealth, liaisonpsychiatry, sus_AE, community
Crisis	Crisis	mentalhealth
Medications (Prescribing)	Category 1: Antipsychotic medication (1st line) Category 2: Antipsychotic medication - Clozapine (2nd line) Category 3: General psychiatric medication	GP_prescription GP_prescription GP_prescription
Excluded	Child and Adolescent Mental Health Services (CAMHS) Older People's Mental Health Services (OPMHS), elder and/or elder care Perinatal mental health services	N/A

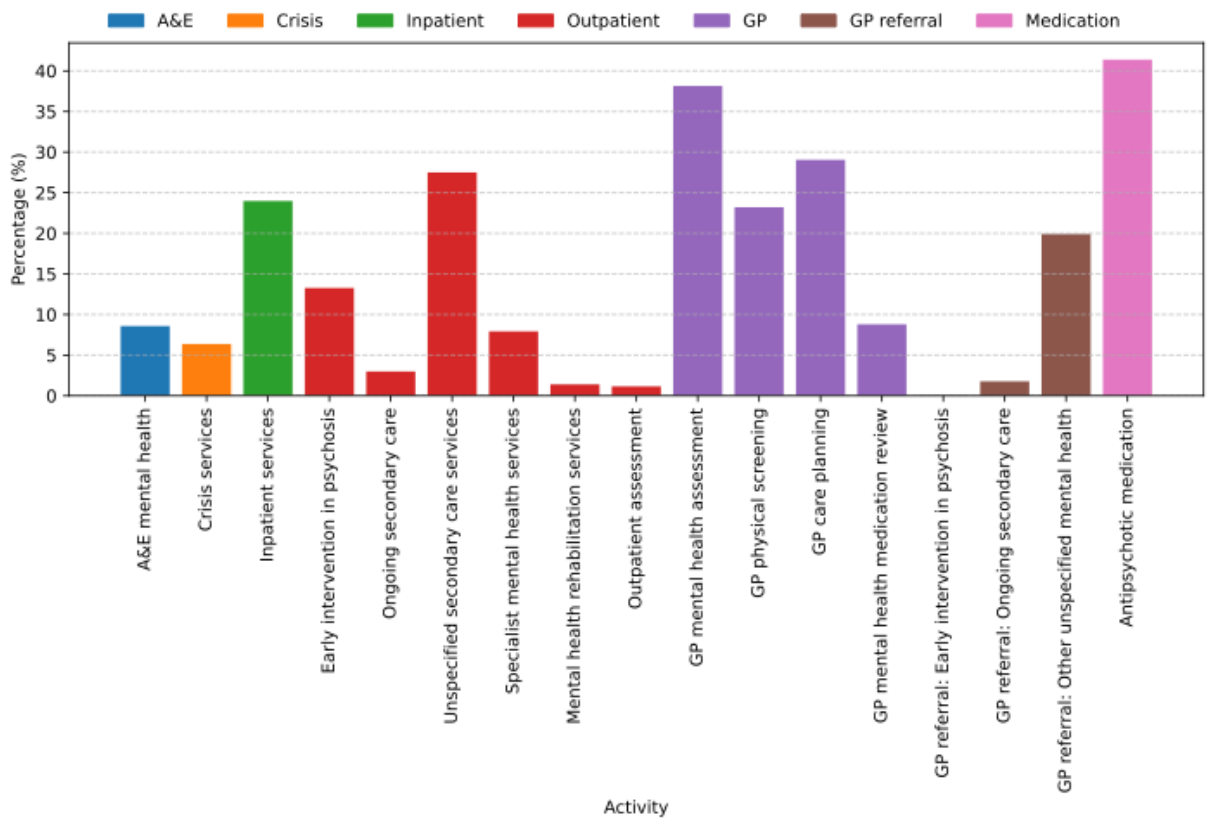
Supplementary Figure 4: Visualisation of the patient journey for all patients



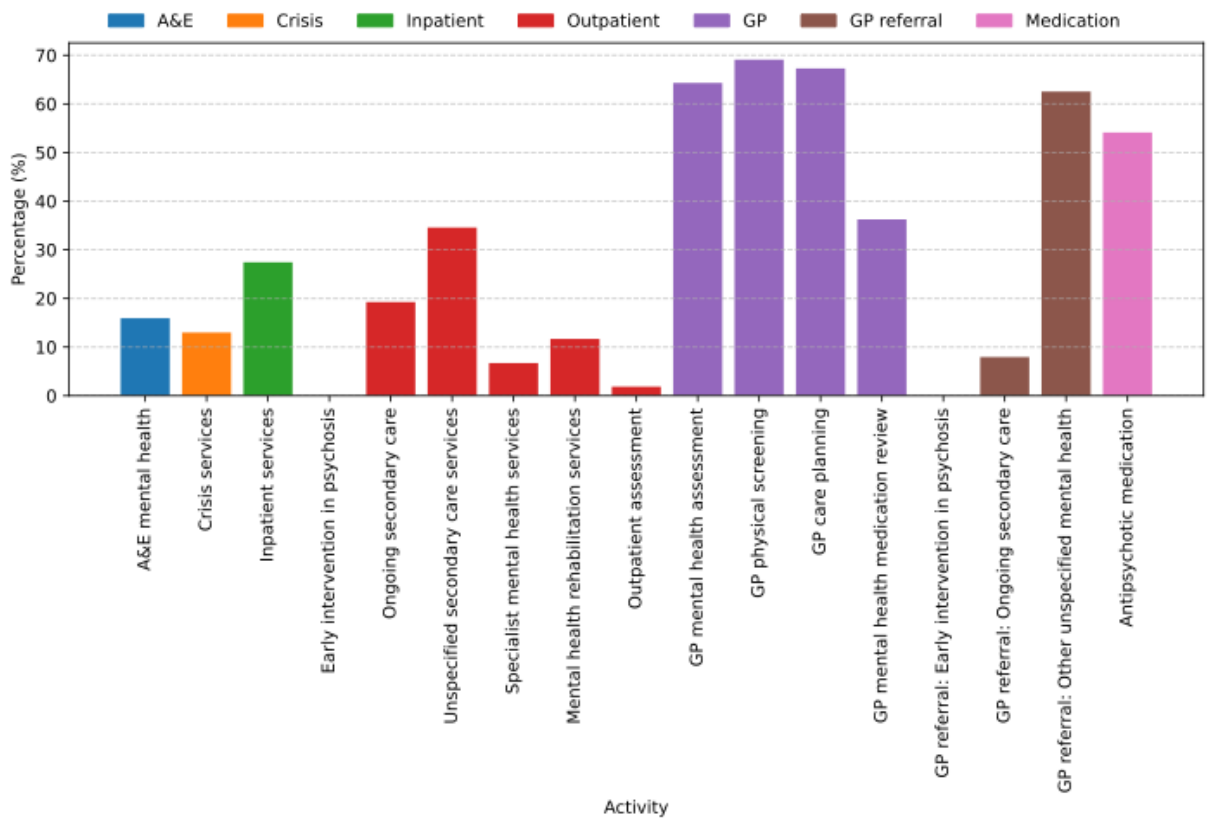
Supplementary Figure 5a: Events occurring during the 2 months prior first diagnosis of psychosis



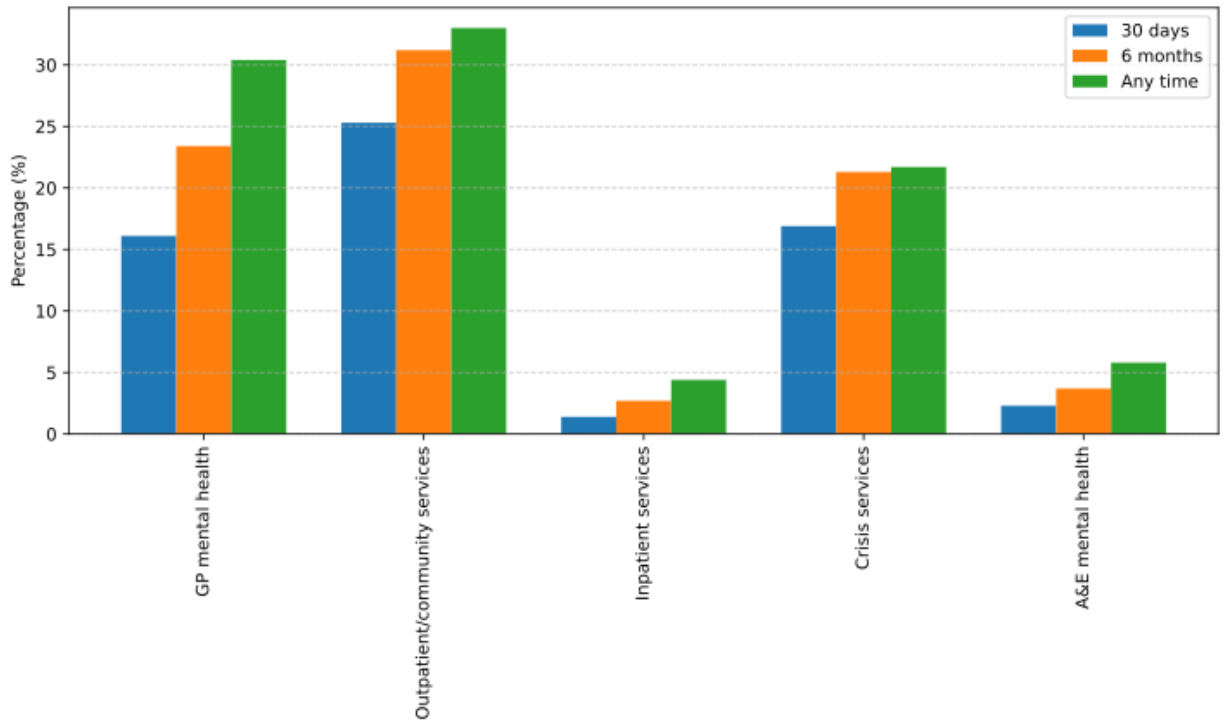
Supplementary Figure 5b: Events occurring during the 2 months after first diagnosis of psychosis



Supplementary Figure 6: Distribution of events in the 3 year period after psychosis diagnosis for patients with no recorded of EIP involvement



Supplementary Figure 7: Percent of patients seen by service provider as next point of contact 30 days, 6-months, and any time after an inpatient hospital stay.



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