INVITED REVIEWS

‘Big data’ in mental health research: current status and emerging possibilities

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Abstract

Purpose ‘Big data’ are accumulating in a multitude of domains and offer novel opportunities for research. The role of these resources in mental health investigations remains relatively unexplored, although a number of datasets are in use and supporting a range of projects. We sought to review big data resources and their use in mental health research to characterise applications to date and consider directions for innovation in future.

Methods A narrative review.

Results Clear disparities were evident in geographic regions covered and in the disorders and interventions receiving most attention.

Discussion We discuss the strengths and weaknesses of the use of different types of data and the challenges of big data in general. Current research output from big data is still predominantly determined by the information and resources available and there is a need to reverse the situation so that big data platforms are more driven by the needs of clinical services and service users.

Keywords Big data · Mental disorders · Epidemiology · Electronic health records

Introduction

‘Big data’ resources for research have attracted increasing interest across healthcare, but applications in mental health have remained relatively limited to date. Big data challenges are traditionally characterised as those of volume (size of datasets), velocity (rapid, ‘real-time’ acquisition of data), and variety (multiple sources and types), with ‘variability’ and ‘veracity’ more recently added to reflect the unreliability of information arising from some sources [1]. There are numerous examples of different sources of big data which might be utilised for health research, including those derived from large biological sample collections, complex investigations (e.g. imaging), devices, and social media. With growing accessibility to large volumes of data accumulating in routine clinical practice following the shift of medical records from paper to electronic formats, clinical notes are also potential big data resources for researchers. There has been a long history of using routine data in mental health research, from the earliest studies of asylum records through the growth of the ‘case register’ in the mid- to late twentieth century. However, larger volumes of information are now accumulating in electronic format than would have been conceivable 20–30 years ago, which potentially transforms data-based investigations. We feel that it is timely to review the information resources being used for big data research, their current scope and coverage, and the nature of the research emerging.

Method

In a narrative literature review, we sought to ascertain and collate studies where big data approaches had been used in research on mental illness and treatment. Aiming at a
representative rather than exhaustive list, the authors used recent reviews [2–10] to extract names of projects to use as key words for a Google Scholar search, adding also the requirement for the terms “mental health” or “psychiatry” for non-specialist sources, restricted to those since 2009. Where no relevant papers were returned, a simple web search for the project was also carried out to check for name changes and non-academic outputs. Forward bibliographic searching was also carried out to identify papers that had cited the reviews above, in an attempt to identify more recent projects. The authors included projects that demonstrated a reach in terms of massed healthcare data, and papers that had used big data approaches for mental health research. Our review was limited to English-language papers, and quantitative and qualitative studies about opinion regarding use of healthcare data were not included. Information was extracted on the name of the project (where given), the database used, the data sources for the database, and the geographical setting. The studies themselves were categorised into disease- or medication-specific, or other topics.

Results

Data resources identified and their international distribution are summarised in Table 1. In all, we identified 84 examples of databases that had been used to provide big data answers to mental health research questions, of which 24 are specific to mental health and related topics. Geographically, most data resources were found in the United States, with few specific national resources identified outside North America and northern/western Europe. However, there were a number of examples found of multinational and multi-continent collaborative resources, centred mostly on neurodegenerative or neurodevelopmental disorders. What should also be evident from Table 1 is the large number of databases being used for mental health research which are not themselves specific to mental health over and above any other specialty.

Distributions of identified reports by disorder and nature of research are summarised in Table 2 with examples, although it is important to bear in mind that percentages refer to studies identified in this review which will not have been exhaustive; they are included for illustrative purposes and inferences regarding the total literature should be appropriately circumspect. The disorders covered in the papers we identified show that big data resources had been used most commonly to research unipolar depression and dementia, followed by schizophreniform and autism spectrum disorders, and relatively uncommon output on bipolar disorder, substance use disorders and neurodevelopmental disorders. For most disorders, the output was reasonably equally split between epidemiological/aetiological research and analyses of treatments and outcomes. The distributions of medication-reporting publications are summarised in Fig. 1 and indicate a predominant focus on antipsychotic and antidepressant agents, with relatively few publications on mood stabilisers or treatments for dementia. Specific examples of papers on medication and other topics are given in Table 3. Beyond medication profiles and safety, there were a number of papers on suicide, service use and user characteristics. Few of the research studies that we found were directly focused on mental health policy, but their findings often have important policy implications. A more detailed narrative of the types of questions addressed forms the focus for discussion of the topic.

Discussion

A wide variety of big data resources are emerging as platforms for mental health research, and it is inevitable that the characteristics of these resources will shape the questions addressed, particularly data availability. At one end, there are databases that take full clinical data directly from the electronic health record (EHR) at primary care or hospital level; some databases are populated from specific patient-level information provided by health service staff for the process of research or surveillance; some make secondary use of unmodified administrative data; some rely on patient report. Some studies transcend boundaries by making use of massed service-level data—such as the European Observatory of Health Systems and Policies—or combine findings from different databases—such as the Psychiatric Genomics Consortium. We have sought in this review to provide a snapshot of big data resources which are now becoming available for clinical/epidemiological mental health research and the way in which these have been used to date. It would be difficult to guarantee comprehensiveness in coverage due to limitations in our search methodology, the fast pace of current development in this field, the under-acknowledgement of the role of databases, and the nature of much of the research (i.e. not published in peer-review/indexed journals). In addition, the data resources themselves do not exist within tightly definable boundaries. For example: general healthcare databases may contain mental health relevant information but may not have been used for research within this field; many biological databases might be classifiable as ‘big data’ because of the density of information contained; and there is no clear point at which information from a large survey, or series of surveys, or cohort study, becomes large and detailed enough to be called ‘big data’. We have referenced resources that have access to large numbers of individuals, and have sought to
| Region/nation                        | Database                                                                 | Mental health specific? | Description                                                                                           | Example publication |
|-------------------------------------|---------------------------------------------------------------------------|-------------------------|-------------------------------------------------------------------------------------------------------|---------------------|
| Middle East, Asia and Australasia   | Clalit Health Services                                                   | No                      | National. Covers 55% Israeli population                                                              | Hammerman et al. [77]|
| Middle East                         | Israeli Psychiatric Case register                                        | Yes                     | National. Secondary care psychiatry. Since 1950                                                      | Lichtenberg et al. [78]|
| Far East                            | Hong Kong Hospital Authority                                             | No                      | Covers 95% secondary care in HK                                                                        | Cheung et al. [79]  |
| Thailand                            | National Health Insurance Database                                       | No                      | National. Covers 96% Taiwan population                                                               | Chen et al. [81]    |
| Australia                           | Mental Health National Outcomes and Casemix                               | Yes                     | National. Secondary care psychiatry. Since 2003                                                       | Burgess et al. [47] |
| Western Australia admin              |                                                                           | No                      | Regional (3.7 m people). Mental health sub-group. Up to 50 years data                                | Lawrence et al. [82]|
| Multi-country (Asia)                | Pan-Asian SNP Consortium (HUGO)                                          | No                      | Research database                                                                                     | Ngamphiw et al. [83]|
| Europe                              |                                                                           |                         |                                                                                                       |                     |
| Western Europe                      | Asturias Cumulative Psychiatric Case Register (RACPAS)                   | Yes                     | Spain. Regional (1 m people). Secondary care psychiatry                                                | Bobes et al. [84]   |
| Gmünder Ersatz-Kasse (GEK)          |                                                                           | No                      | Germany. National. Large health insurer (6% population, around 5 m people)                            | Sauer et al. [85]   |
| German Research Network on Depression/ DGPPN-BADO | Yes                                                                 |                          | BADO is national minimum data set for inpatient psychiatry. Depression network from 10 heterogeneous hospitals | von Wolff et al. [48]|
| Health Search Database              |                                                                           | No                      | Italy. National. Primary care data (1.5% population, around 1 m people)                               | Sultana et al. [86] |
| Marseille/French National Health Insurance Fund | No                                                                      |                          | Regional. Prescription data                                                                           | Bocquier et al. [87]|
| Regensburg Hospital/DGPPN-BADO       |                                                                           | Yes                     | Germany. Local. BADO is minimum data set from psychiatric inpatients                                  | Frick et al. [88]   |
| South Verona Community-Based Mental Health Service | Yes                                                                 |                          | Italy. Local. Secondary care psychiatry. 25 years+ of data                                            | Donisi et al. [89]  |
| Zurich/Swiss psychiatric case register |                                                                           | Yes                     | Regional. Secondary care psychiatry. 25 years+ of data                                               | Lay et al. [90]     |
| United Kingdom                      | Clinical Practice Research Data link (CPRD), formerly General Practice Research Database (GPRD) | No                      | National sample primary care providers. Some data open access (NIHR.ac.uk)                           | Margulis et al. [91]|
| Clinical Record Interactive Search (CRIS) |                                                                           | Yes                     | Local secondary care psychiatrist. South London and Maudsley Biomedical Research Centre (SLaM BRC) Case Register. 200,000+ people | Perera et al. [20]  |
| Generation Scotland                 |                                                                           | No                      | Regional (Scotland). Research database. Family based cohort                                          | Fernandez-Pujals et al. [92]|
| GRiST                               |                                                                           | Yes                     | Multiple locations, primary and secondary care psychiatry. Mental health risk assessment software     | Buckingham [50]     |
| Public Health England Mental Health Dementia and Neurology Intelligence Network | Yes                                                                 |                          | Regional (England), 22 ‘indicators’ from mixed administrative sources                                 | Wilkinson et al. [93]|
| QResearch GP database               |                                                                           | No                      | National sample primary care providers. 600 practices, around 12 m people                           | Coupland et al. [94]|
| The Health Improvement Network (THIN)|                                                                           | No                      | National sample primary care providers. 10 m people. 600 practices, broadly representative of population | Osborn et al. [36]  |
| UK Biobank                          |                                                                           | No                      | National sample 500,000 volunteers. Research database                                               | Smith et al. [58]   |
| Secure Anonymised Information Linkage (SAIL) | No                                                                      |                          | Linked data from a range of healthcare sources covering Wales (population 3 m)                      | John et al. [95]    |
| PsyCymru                             |                                                                           | Yes                     | An e-cohort of around 12,000 psychosis cases in Wales linked to SAIL data                             | Lloyd et al. [96]   |
| Scandinavia                         | Danish Psychiatric Central Research Register                              | Yes                     | National. Secondary care psychiatry with extensive national linkage                                   | Munk-Jorgensen and Ostergaard [97]|
| deCODE Iceland                      |                                                                           | No                      | National opt-in commercial/research database                                                          | Thorgerisson et al. [98]|
| Finnish Hospital Discharge Register  |                                                                           | No                      | National. Inpatients. Linked to other national registers                                              | Haukka et al. [100] |
| Region/nation | Database | Mental health specific? | Description | Example publication |
|---------------|----------|-------------------------|-------------|---------------------|
| Mid-Netherlands | Psychiatric Care Register | Yes | Regional—Utrecht and surrounding areas, population 760 k. Secondary care psychiatry | Braam et al. [101] |
| Norwegian Patient Register | Yes | National. Secondary care psychiatry. Linked to other national registers | Evensen et al. [102] |
| Odense University Pharmaco-epidemiologic Database | No | Denmark. Local prescription database with linkage | Hansen et al. [103] |
| Hungarian National Health Insurance Fund | No | National. Prescription-with-indication database | Katona et al. [104] |
| Eastern Europe | European Observatory on Health Systems and Policies | No | Health services. Produces country-based reports | Dlouhy and Barták [105] |
| European Prevention of Alzheimer’s Dementia (EPAD) project | Yes | A European Innovation Medicines Initiative | Ritchie et al. [106] |
| European Autism Interventions | Yes | A European Innovation Medicines Initiative | Murphy and Spoooren [107] |
| Nordic population-based prescription database | No | Pharmaco-epidemiology using databases from five countries | Zoëga et al. [108] |
| PROTECT-EU | No | Pharmaco-vigilence using databases in three countries | Requena et al. [109] |
| Refinement | Yes | Mental health services. Population data and service inventory | Sfetcu et al. [56] |
| America | Canadian Chronic Disease Surveillance System (CCDSS) | Yes | National. Will specifically monitor excess mortality in people with psychiatric diagnosis | Lesage et al. [110] |
| Canadian Primary Care Sentinel Surveillance Network | No | National sample primary care providers | Wong et al. [35] |
| OntarioMD | No | Regional, primary care providers | Hwang et al. [111] |
| Ontario Mental Health Reporting System | Yes | Regional, based on interRAI MH dataset for psychiatric inpatients | Perlman et al. [112] |
| Saskatchewan Health Databases | No | Regional, multisource. 25 years+ of data | Meng et al. [113] |
| 23andMe | No | National. Commercial genotyping database, self-report | Tung et al. [114] |
| Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilisation Project (HCUP) | No | National sample hospital care providers. Databases and software through Federal-State-Industry partnership | Smith et al. [115] |
| Alzheimer’s Disease Genetic Consortium | Yes | Distributed network of sample of healthcare providers | McDavid et al. [116] |
| CDC data surveillance systems, including national ambulatory care survey | No | National. A number of monitoring systems and surveys | Offson et al. [117] |
| Data QUEST | No | Sample of 15 primary care providers in five states | Estiri et al. [118] |
| Electronic medical records and genomics network (eMERGE) | No | Distributed network of five leading academic medical centres for biobanking, includes Alzheimer’s cohorts | Kho et al. [40] |
| Group Health Research Institute (GHRI) | No | Healthcare management organization (HMO). HMO network member | Lin et al. [119] |
| Health Plan Employer Data and Information Set (HEDIS) | No | National. Set of performance measures used by most health plans in USA. Managed by National Committee for Quality Assurance (NCQA) | Clark et al. [120] |
| Informatics for integrating biology and the bedside (2b2) | No | Local secondary care. Biobank affiliated with Harvard Medical Schools | Perlis et al. [26] |
| U.S. Food and Drug Administration (FDA) Mini-Sentinel, including Innovation in Medical Evidence Development and Surveillance (IMEDS) | No | National (currently sample) medication-based database, aiming to create active monitoring system | Raebel et al. [121] |
| Kaiser Permanente, including KP Research Program on Genes, Environment and Health (RGEH) | No | Regional sample. HMO based in Northern California, 3.4 m insured | Young et al. [122] |
| Mayo Clinic | No | Local secondary care provider. Based in Minnesota, also contributes to Olmsted County/Rochester projects | Sohn et al. [123] |
| MarketScan Research Database | No | National sample. Commercial claims and encounters database from mix of providers | Watkins et al. [124] |
| Region/nation                  | Database                                                    | Mental health specific? | Description                                                                 | Example publication                      |
|-------------------------------|-------------------------------------------------------------|-------------------------|-----------------------------------------------------------------------------|------------------------------------------|
| Medicaid & Medicare data      | No                                                          | National sample. Government reimbursed healthcare activity. Data accessed through CMS.gov or a variety of platforms, including MarketScan and HEDIS | Medicaid Medical Directors Learning Network [125]                           |
| Mental Health Research Network at Health Care Systems Research Network, formerly HMO research network | No                                                          | National sample. Distributed network of up to 17 HMOs with virtual data warehouse. Potentially 11 m population in 11 states | Ahmedani et al. [126]                    |
| Multiparameter Intelligent Monitoring in Intensive Care (MIMIC) | No                                                          | Local critically ill. ICU patients in Massachesets teaching hospitals | Ghassemi et al. [127]                   |
| National Prescription Audit (NPA) and National Disease and Therapeutic Index (NDTI) | No                                                          | National sample. Commercial medication-focused databases from IMS Institute for Healthcare Informatics | Alexander et al. [128]                  |
| New York Presbyterian         | No                                                          | Local. Single hospital. 30 years+ of data                        | Melamed et al. [129]                   |
| Palo Alto Medical Foundation (PAMF) | No                                      | Regional. Single HMO. HMO network member                        | Goyal et al. [130]                     |
| Partners Healthcare           | No                                                          | Regional. Single HMO. Feeds into i2b2                           | Castro et al. [131]                    |
| PharMetrics Patient-Centric Database, now merged with IMS databases | No                                                          | National sample. Pharmacy and encounter data 14 m people        | Berger et al. [132]                     |
| Penn Longitudinal Database    | Yes                                                         | Regional. Public mental health use (secondary care) in Philadelphia. Also part of collaborative perinatal project | Connolly Gibbons et al. [133]          |
| Shared Health Information Network (SHRINE) | No                                      | Multiple sites. Secondary care. Collaboration between Harvard and University of California hospitals | Kohane [134]                           |
| Scalable Partnering Network (SPAN) for Comparative Effectiveness Research (CER) | No                                      | National sample. Project providing linkage between nine HMOs and two community partners | Toh et al. [38]                        |
| Stanford Translational Research Integrated Database Environment (STRIDE) | No                                                          | Local. Data from healthcare provider. Data on 2 m people since 1994 | Raj et al. [135]                        |
| Texas Department of Criminal Justice | No                                      | Local database of prisoners                                     | Bailleugeon et al. [136]               |
| University of Michigan Health System data warehouse | No                                      | Local secondary healthcare provider. Uses Electronic Medical Record Search Engine (EMERSE) | Hanauer et al. [137]                    |
| Vanderbilt University Biorepository—BioVU | No                                      | Local secondary care provider. Genomics, select health metrics and EHR | Crawford et al. [138]                  |
| Veterans Affairs Database     | No                                                          | National specialist provider for veterans. Provides healthcare for aprox 14 m, has smaller biobank | Bauer et al. [139]                     |
| Multi-continent               |                                                             |                                                                      |                                             |
| Aetionomy                     | Yes                                                         | Neurodegenerative diseases. Under European Innovative Medicines Initiative, aligned with EPAD in Europe and GAP in North America | Hofmann-Apitius et al. [140]            |
| Asian Pharmacoepidemiology Network (AsPEN) | No                                      | Eight cohorts in distributed network model: six countries, four continents, 200 m people | Pratt et al. [141]                     |
| Enhancing NeuroImaging Genetics through Meta-Analysis (ENIGMA) | Yes                                                      | Sets of research cohorts. 70 institutions taking part              | Thompson et al. [60]                    |
| Global Burden of Disease (GBD)/WHO mental health survey | No                                                          | Estimates of morbidity for 187 countries                         | Whiteford et al. [57]                   |
| Genetic Consortium for Anorexia Nervosa | Yes                                                    | Up to 30 datasets for GWAS                                       | Reichborn-Kjernerud et al. [142]        |
| Health Care Quality Indicators (HCQI) for OECD countries | No                                                          | Comparative data on national health systems                      | Moran and Jacobs[143]                   |
| IMS Prescribing Insights database | No                                      | Medication-based database. Presence in 30 countries               | Wong et al. [144]                      |
| Psychiatric Genomic Consortium | Yes                                                     | Has a number of working groups for specific disorders and cross-disorder group | Cross-Disorder Group of the Psychiatric Genomics [59] |
| International Genomics of Alzheimer’s Project (I-GAP) | Yes                                                      | Including existing genetic consortia and other cohorts            | Lambert et al. [145]                    |
provide examples that are broadly representative of emerging information available. For example, we have cited administrative data registries with linked death certification records to investigate mortality in mental disorders, and we have described these as big data; however, there is no qualitative difference between this and the linkage of the large Norwegian HUNT survey of over 60,000 community residents to national data on mortality and occupation-related outcomes [11, 12], which tends to be described instead as a large cohort study rather than ‘big data’. Similarly, this review did not attempt to cover large cohort studies with an emphasis on original data collection rather than reliant on administrative data (e.g. in a UK context, cohorts such as ALSPAC, Whitehall, or the 1946, 1957 or 1970 birth cohorts)—whose boundaries with big data are inevitably indistinct. Big data resources, thus, tend to be defined by the challenges faced by the data and their interpretation, as will now be described, rather than solely by the size or complexity of a database.

**Big data and the five V’s**

Big data resources are often characterised by ‘Vs’: originally three (volume, velocity and variety), now five (adding

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**Table 1** continued

| Region/nation | Database | Mental health specific? | Description | Example publication |
|---------------|----------|-------------------------|-------------|---------------------|
|               | Sequenced Treatment Alternatives to Relieve Depression (STAR*D) | Yes | Whilst this international study was not “big data”, in terms of using hybrid EHR and manual methods, it develops techniques to be used for observational research in big data | Garriock et al. [146] |
|               | WHO Global Health Observatory Data Repository | No | Special topics covered, including mental health and suicide | WHO [147] |

**Table 2** Example topics in papers discussing mental illness epidemiology, treatment and outcome

| Disorder (% of papers) | Descriptive epidemiology and service use | Risk factors, comorbidities and genetics | Treatment and prognosis | Physical health, pregnancy, mortality |
|------------------------|-----------------------------------------|------------------------------------------|-------------------------|--------------------------------------|
| All disorders (10 %)   | Manson [148] | Roque et al. [150] | Cross-Disorder Group of the Psychiatric Genomics [59] | Donisi et al. [89] | Perini et al. [151] | Lawrence et al. [82] |
| Severe mental illness (5 %) | Lyalina et al. [152] | Kyaga et al. [153] | Steinberg et al. [154] | Perlman et al. [112] | Matheson et al. [155] | Wangel et al. [156] |
| Dementia (9 %) | Knopman et al. [24] | Exalto et al. [158] | van den Bussche et al. [159] | Rait et al. [160] |
| Substance use disorder (2 %) | Bonn-Miller et al. [161] | Nesvig [162] | Mark et al. [163] |
| Schizophrenia (6 %) | Okkels et al. [164] | Harper et al. [165] | Stroup et al. [166] | Gal et al. [167] | Vigod et al. [168] |
| Bipolar disorder (2 %) | Castro et al. [169] | Schaefer et al. [170] | Hayes et al. [171] | Lee and Lin [172] |
| Depressive disorders (11 %) | Hoffmann et al. [173] | Hanauer et al. [137] | Morkem et al. [34] | Musliner et al. [175] |
| Anxiety and somatoform disorders (2 %) | Walters et al. [75] | Lacourt et al. [176] | Sandelin et al. [177] | Frayne et al. [178] |
| Eating disorders (1 %) | Micali et al. [179] | Reichborn-Kjennerudet al. [142] |
| Post-partum mental disorders (2 %) | Polachek et al. [180] | Goyal et al. [130] |
| Intellectual disabilities (1 %) | Sprung et al. [181] | Alexander et al. [182] |
| Autism/Autism Spectrum Disorder (ASD) (6 %) | Kohane [134] | Hsu et al. [183] | Murphy and Spoor [107] |
| Other neuro-developmental disorders (4 %) | Surén et al. [185] | Leivonen et al. [186] | Hoffmannanet al. [187] |
variability and veracity), but with the potential for further expansion (e.g. visualisation and value: http://dataconomy.com/seven-vs-big-data/). Taking the five V’s as the most common current characterisation, it is worthwhile considering each in turn as it applies to the mental health relevant databases described here:

1. The examples we identified exemplify ‘volume’ in the large number of cases represented and, in many instances, the quantity of information on each person represented. This particularly applies to healthcare data which are linked to high-compute biological datasets (e.g. from ‘omics’ and imaging) and to those which include the full electronic health record—i.e. which contain both large case numbers and large amounts of detail on each case. While small compared to many ‘big data’ resources, electronic health records represent a step-change in volume compared to the administrative databases previously relied on for analysis.

2. ‘Velocity’ may be a feature of electronic health records databases if these accumulate in real time, although is less relevant to static and/or periodically updated sets, and depends on the way in which a database is used. At the moment most research use has been observational, using historic data extractions and therefore not encountering the velocity challenge, even in ‘live’ (i.e. continually accumulating) databases. This will change once interventions start being developed which rely on real-time data feeds from health records, and will be challenge not only for hardware (e.g. the demands on central or local processing hubs) but also for designing appropriately agile software to enable such processing.

3. ‘Variety’ has also been less relevant to date because most analyses are still focusing on relatively stereotyped datasets drawn from original or derived structured fields; however, this is changing with increasing interest in natural language processing to derive information from text—whether relatively simple information extraction applications to render pre-defined constructs available as structured fields, or more complex whole-text analytics (e.g. investigating subtle changes in health records text as a potential predictor of adverse events such as suicidal behaviour https://slamtwigops.

Table 3 Examples of other topics appearing in multiple papers

| Topic (% of papers) | Example papers |
|---------------------|----------------|
| Medication prescription 6 % | Sultana et al. [86] |
|                      | John et al. [95] |
|                      | Abdullah-Koolmees et al. [188] |
|                      | Hartz et al. [189] |
| Medication safety and adverse drug reactions 13 % | Chung et al. [190] |
|                      | Eriksson et al. [191] |
|                      | Castro et al. [131] |
| Medication safety in older adults | Hwang et al. [111] |
|                      | Huybrechts et al. [54] |
| Medication safety during pregnancy | Hviid et al. [192] |
|                      | Palmsten et al. [193] |
| Suicide and self-injury 5 % | Stewart et al. [194] |
|                      | Simon et al. [195] |
| Mental health admissions 4 % | Frick et al. [88] |
|                      | Bardach et al. [196] |
| Patient characteristics 4 % | Koopmans et al. [197] |
|                      | Oram et al. [198] |
| Mental Health Services Quality 3 % | Moran and Jacobs [143] |

Fig. 1 The relative number of papers found reporting on different classes of medication (57 papers on medication in total)
Variability is used to describe the phenomenon of data whose meaning is constantly changing. Within health records, data fields clearly do change over time in the way information is entered, although this is generally at a pace which is manageable. Text fields in health records may present more of a challenge, as there are likely to be more rapid and less manageable changes in the ways clinicians record information, although this is likely to be negligible compared to the rapid evolution in social media and the language used there (and thus in any development of shared records with the facility for accommodating patient-entered information).

Veracity is perhaps the most important challenge in the use of any administrative database for research, simply because source data have not generally been collected with research in mind and thus it is important to be aware of factors influencing the recording of information or not, and the accuracy with which this is carried out. The veracity challenge will be considered later in this discussion, having first reviewed the data resources available.

Electronic health records

EHRs present novel opportunities for research because of the very large volumes of information which naturally accrue and, unlike paper-based records, are accessible without prohibitively time-consuming data entry. Considering volume of information, there is a major distinction between databases using only structured fields, and those using the free text [13, 14]. Structured data such as age, sex, diagnosis, and dates of service-level events (admissions, discharges, etc.) are routinely entered by clinical or administrative staff, can be made readily available for research use, and are relatively easily de-identified for data governance requirements. However, the fact that structured information is more readily available for analysis does not make it any more valid or accurate than unstructured information. Clinical uncertainties can be poorly translated into codes [15–17], and the sustainability of imposed structured data entry in routine clinical care (e.g. through embedded checklists and scales in the EHR) remains to be established. Free text is typically extensive in case note fields and uploaded correspondence for mental health EHRs, but less accessible for analysis, and less easily anonymised; however, text-contained information is potentially the most valuable for research despite the inconvenience of having to design mechanisms for extracting the information.

To make better use of the whole record, text mining tools have attracted increasing interest as a means of facilitating research with free text alongside the structured record [18–21]. This can increase sensitivity for record identification; for example, Vanderbilt University Medical Centre found that extraction of diagnosis of dementia from structured fields identified 38 % of cases found by manual notes review, whereas 91 % of these were identified through a free text information extraction application [22]. However, it should be noted that even searching the free text for a diagnosis will only give an accurate indication of the numbers of people identified with a disorder, which may be a substantial underestimate of community cases. For example, Mayo Clinic analyses found that, of people identified in research studies as having definite dementia or autism spectrum disorder, around 70 and 50 %, respectively, had any note of such in their EHR [23, 24].

A key potential advantage of using information derived from EHR free text is the quantity of phenotypic data beyond a diagnosis, both in terms of patients’ mental health—such as symptom profile [25] or treatment responsiveness [26]—and the context in which a disorder is occurring [27]. This can be used for highlighting patients who have inclusion criteria for recruitment into observational or interventional studies, or can be used to investigate treatment response directly within the database: all relevant for the development of personalised medicine [28, 29]. Furthermore, phenotypic signatures of direct clinical relevance, such as “high suicide risk” or “vulnerable to depression”, might be fed back in real time via the EHR to alert the treating clinician [30, 31], coupled with decision support software or information resources. Free text can also be mined to define groups or outcomes that are too rare to be studied conventionally—such as the use of Khat in South-East London [32] or neuroleptic malignant syndrome [33].

Primary Care EHRs are potentially valuable for investigating the wider health of people with common or severe mental illnesses. Examples include Canadian longitudinal research into changes in the diagnosis and treatment of depression [34, 35], or the use of a UK general practice database to investigate the risk of cardiovascular disease in people with severe mental illness and to derive a risk prediction model for this outcome [36]. While some countries benefit from large healthcare providers with
associated data resources (e.g. National Health Service data in the UK, and the Taiwan National Health Insurance Research Database), others, such as the USA, have brought together healthcare providers in ‘virtual networks’ [37, 38]. Anonymised data derived from each provider’s EHRs can be brought together with tools such as the Health Care Systems Research Network’s online integration tool “PopMedNet” for research, or to compare practices, such as the benchmarking of psychotropic prescribing [39]. There are also EHR-genomic consortia, such as eMerge—a collaboration of Marshfield, Mayo Clinic, Northwestern, Group Health and Vanderbilt—which hosts some dementia cohorts [40].

It is important that the governance of these EHR databases and projects is planned to balance the concerns of patients and the needs of researchers. Full anonymization may not be possible for projects requiring phenotypic details [41]; other protections such as limited access and firewalls must therefore be considered so as not to lose “social licence” for these types of projects [42–44]. Both researchers and patients should have input to the next generation of data repositories and projects to shape them towards the kinds of questions that remain outstanding, such as capturing traits as well as diseases for research compatible with the USA’s National Institute of Mental Health Research Domain Criteria (RDoC) paradigm [45, 46].

Case registers involving de novo data collection

Specialist databases form registries of people in contact with the mental health system, or have evolved from this to offer surveillance of both service users and the services themselves [6]. While it is possible to create and maintain such a register solely with electronic health records, many involve the collection of specific data, usually requested from the service providers. These databases are a helpful resource for research into patterns of service use and their individual and societal determinants. Some databases, such as the Mental Health National Outcomes and Casemix Collection in Australia and the DGPPN-BADO in Germany have made efforts to include valid measures of outcome for service users, which helps them monitor improvement [47, 48] and also for research, such as into treatments for depression in Germany. There are also examples of more specialised registries: a database in the Netherlands recording seclusion and restraint episodes looking for insights to drive service improvement [49]; and the GRiST mental health data set in the UK, which deals with risk assessment and aims to use the data to become a decision support tool [50, 51].

Administrative databases

We identified a number of examples of projects making secondary use of large-volume administrative data to draw conclusions about healthcare use through diagnoses on hospital discharge notifications, billing for procedures, or prescriptions. Some of these databases are long established, such as the Swedish population-based registers; while the expansion of Medicaid, and the requirement for billing with ICD-codes, combined with incentives for “meaningful use” of information technology [52], has led to large accumulations of new data resources. This information tends to be used to describe treated prevalences of disorders, patterns of prescribing, and comparisons of ‘real-world’ treatment with recommendations. Where data include both prescriptions and incident diagnosis, this can also be useful in pharmacovigilance, using retrospective cohort or nested case–control studies to investigate adverse events [53], such as differences in the safety of different antipsychotics in older patients examined using Medicaid billing data for nursing home residents [54]. Such data can also be used to describe treatment costs—which may have a specific focus, such as a US investigation of the cost of non-compliance in bipolar disorder [55], or a broader scope, such as an EU project investigating whether the financing of health services in different EU countries affects the quality of mental healthcare [56].

Surveys and biobanks

In most circumstances, surveys and interviews are not practical for assembling big data resources; however, the WHO Global Burden of Disease programme uses standardised mental health surveys (based on the Composite Diagnostic Interview—CIDI) carried out at intervals by local research teams in member countries [57], and could be claimed to come closest to being a ‘big data’ survey in the mental health field. Large samples have also been achieved by some biobanks, such as UK Biobank, which already has self-report data for 500,000 [58] and is looking to improve its mental health phenotyping through an online questionnaire based on the CIDI-short form. Genome Wide Association Studies (GWAS) for complex disorders require large independent datasets of genomes, therefore it makes sense for researchers on projects such as UK Biobank to co-operate with others. The international Psychiatric Genomics Consortium (PGC) is a means to achieve this, sharing both datasets and expertise [59]. International research collaborations have also allowed the leveraging of neuroimaging taking place in different locations through the ENIGMA program [60].
Record linkage

All of the above databases can be given new dimensions when data from other sources are linked at the level of the individual [3, 9]. This is facilitated in countries with a unique identification number for its residents, such as many of the Nordic countries: for example, allowing researchers using Sweden’s population-based registers to link reports of death by suicide to records of psychiatric and medical diagnoses, periods of sickness absence from work, and unemployment [61–65]. Danish records that link also to parents and siblings have been used to investigate potential risk factors for schizophrenia, such as family history, season of birth, urban living, and trauma to mother during pregnancy [66–68]. A number of observational studies have investigated the safety of psychotropic medication in pregnancy, but in Western Australia this approach has been taken one step further by assembling and following an e-cohort of children born to mothers who have schizophrenia, using health and social service administrative registers alone; associations with obstetric complications and subsequent intellectual disability have already been reported [69, 70].

Data veracity

Although it might be assumed that cohorts assembled through researcher interviews are preferable to those derived from administrative data, it is important to recognise that each research method has strengths and limitations. Research interviews do provide potentially highly accurate information about a person’s status at a particular time; however, conventional research projects are limited, and not just in the numbers of cases who can be interviewed and examined. They may also poorly capture variability or trajectories in health status over time (especially as recollection of episodes of mental disorder has been found to be so poor [71]) which may be better characterised from administrative data than retrospective interview. Furthermore, even highly trained interviewers might have difficulty ascertaining phenomena like physical signs or relatively rare symptoms, which may be better identified from clinician-derived text in health records.

Conversely, as previously discussed, a veracity challenge for all healthcare databases is that information used has not, generally, been collected for research reasons; therefore, data are vulnerable to influence from forces other than the underlying patterns of disease, and hence the incentives for record-keeping need to be taken into account (sometimes considered under a ‘data provenance’ heading). One important issue concerns diagnosis, as many studies rely on recorded diagnostic information and frequently do not have any further information on the disorder under investigation beyond this. However, many mental disorders do not result in a documented diagnosis because the person does not report the disorder to a healthcare practitioner, because the practitioner does not identify the disorder, or because they do not assign or record a diagnosis. For example, in 2009 it was estimated that one-third of all people living in England with dementia had received a formal diagnosis [72]. Since then, political pressure, availability of medication and other factors have changed the culture surrounding the making and recording of a dementia diagnosis. Registers of people with dementia kept by all GPs in primary care have consequently been increasing in size by an average of 8% per year [73]—a change that does not reflect changing epidemiology of the disease. Primary Care diagnosis rates of anxiety and depression in the UK have also been found not to be representative of disease trends [74, 75]; however, a team at the Secure Anonymised Information Linkage Databank in Wales found that combining diagnosis and symptom terms appeared to be more reflective, which suggests the wisdom of working with people who are familiar with the data source being used [76].
information that happens to be available and accessible in these data resources. For example, the fact that healthcare databases are used so extensively for medication-oriented research questions is likely to reflect the relative ease with which medication data can be extracted. Equally their lack of use for investigations of symptom profiles or illicit substance use reflects the lack of structured data on these constructs in most records systems. A transition is likely to be needed whereby the data resources themselves are shaped, at least to some extent, by research priorities; however, this is only likely to be effective if the research priorities, in turn, are shaped by the needs of clinical services and those who use them.

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Compliance with ethical standards

Ethical standards This article does not contain clinical studies or patient data.

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. Raghupathi W, Raghupathi V (2014) Big data analytics in healthcare: promise and potential. Health Inf Sci Syst 2:3. doi:10.1186/2047-2501-2-3

2. Coorevits P, Sundgren M, Klein GO, Bahr A, Claerhout B, Daniel C, Dugas M, Dupont D, Schmidt A, Singleton P, De Moor G, Kalra D (2013) Electronic health records: new opportunities for clinical research. J Intern Med 274(6):547–560. doi:10.1111/joim.12119

3. Allebeck P (2009) The use of population based registers in psychiatric research. Acta Psychiatr Scand 120(5):386–391. doi:10.1111/j.1600-0447.2009.01474.x

4. Spiranovic C, Matthews A, Scanlan J, Kirkby KC (2016) Increasing knowledge of mental illness through secondary research of electronic health records: opportunities and challenges. Adv Ment Health 14(1):14–25

5. Perera G, Soremekun M, Breen G, Stewart R (2009) The psychiatric case register: noble past, challenging present, but exciting future. Br J Psychiatry 195(3):191–193

6. Munk-Jørgensen P, Ockels N, Golberg D, Ruggeri M, Thornicroft G (2014) Fifty years’ development and future perspectives of psychiatric register research. Acta Psychiatr Scand 130(2):87–98

7. Alaghebandan R, MacDonald D (2013) Use of administrative health databases and case definitions in surveillance of depressive disorders: a review. OA Epidemiol 1:3

8. Monteith S, Glenn T, Geddes J, Bauer M (2015) Big data are coming to psychiatry: a general introduction. Int J Bipolar Disord 3:21. doi:10.1186/s40345-015-0038-9

9. Weber GM, Mandl KD, Kohane IS (2014) Finding the missing link for big biomedical data. JAMA 311(24):2479–2480. doi:10.1001/jama.2014.4228

10. Jensen PB, Jensen LJ, Brunak S (2012) Mining electronic health records: towards better research applications and clinical care. Nat Rev Genet 13(6):395–405

11. Myklebust A, Bjerkesset O, Dewey M, Prince M, Overland S, Stewart R (2007) Anxiety, depression and cause-specific mortality. Psychosom Med 69:323–331

12. Myklebust A, Overland S, Dahl AA, Krookstad S, Bjerkesset O, Glozier N, Aaro LE, Prince M (2006) A population-based cohort study of the effect of common mental disorders on disability pension awards. Am J Psychiatry 163(8):1412–1418

13. Häyrinen K, Saranto K, Nykänen P (2008) Definition, structure, content, use and impacts of electronic health records: a review of the research literature. Int J Med Inform 77(5):291–304

14. Rosenbloom ST, Denny JC, Xu H, Lorenzi N, Stead WW, Johnson KB (2011) Data from clinical notes: a perspective on the tension between structure and flexible documentation. J Am Med Inform Assoc 18(2):181–186

15. Eason K, Waterson P (2014) Fitness for purpose when there are many different purposes: who are electronic patient records for? Health Inf J 20(3):189–198. doi:10.1177/1460458213501006

16. Morrison Z, Fernando B, Kalra D, Cresswell K, Sheikh A (2014) National evaluation of the benefits and risks of greater structuring and coding of the electronic health record: exploratory qualitative investigation. J Am Med Inform Assoc 21(3):492–500. doi:10.1136/amiajnl-2013-001666

17. Whooley M (2010) Diagnostic ambivalence: psychiatric workarounds and the diagnostic and statistical manual of mental disorders. Soc Health Illn 32(3):452–469. doi:10.1111/j.1467-9566.2010.01230.x

18. Anderson HD, Pace WD, Brandt E, Nielsen RD, Allen RR, Libby AM, West DR, Valuck RJ (2015) Monitoring suicidal patients in primary care using electronic health records. J Am Board Family Med 28(1):65–71. doi:10.3122/jabfm.2015.01.140181

19. Hripcsak G, Albers DJ (2013) Next-generation phenotyping of electronic health records. J Am Med Inform Assoc 20(1):117–121. doi:10.1136/amiajnl-2012-001145

20. Perera G, Broadbent M, Callard F, Chang C-K, Downes J, Dutta R, Fernandes A, Hayes RD, Henderson M, Jackson R, Jewell A, Kadra G, Little R, Pritchard M, Shetty H, Tulloch A, Stewart R (2016) Cohort profile of the South London and Maudsley NHS Foundation Trust Biomedical Research Centre (SLaM BRC) case register: current status and recent enhancement of an electronic mental health record-derived data resource. BMJ Open. doi:10.1136/bmjopen-2015-008721

21. St-Maurice J, Kuo MH, Gooch P (2013) A proof of concept for assessing emergency room use with primary care data and natural language processing. Methods Inf Med 52(1):33–42. doi:10.3414/ME12-01-0012

22. Wei W-Q, Teixeira PL, Mo H, Cronin RM, Warner JL, Denny JC (2015) Combining billing codes, clinical notes, and medications from electronic health records provides superior phenotyping performance. J Am Med Inform Assoc. doi:10.1136/bmjopen-2015-008721

23. Barbaresi WJ, Colligan RC, Weaver AL, Katrusic SK (2008) The incidence of clinically diagnosed versus research-identified...
autism in Olmsted County, Minnesota, 1976–1997: results from a retrospective, population-based study. J Autism Dev Disord 39(3):464–470. doi:10.1007/s10803-008-0645-8

24. Knopman DS, Petersen RC, Rocca WA, Larson EB, Ganguli M (2011) Passive case-finding for Alzheimer’s disease and dementia in two U.S. communities. Alzheimer’s Dement 7(1):53–60. doi:10.1016/j.jalz.2010.11.001

25. Patel R, Jayatilleke N, Broadbent M, Chang C-K, Foskett N, Gorrell G, Hayes RD, Jackson R, Johnston C, Shetty H (2015) Positive symptoms in schizophrenia: a study in a large clinical sample of patients using a novel automated method. BMJ Open 5(9):e007619

26. Perlis R, Ioannou D, Castro V, Murphy S, Gainer V, Winneker J, Adams M, Davis R, Schmidt M, Ahmed A, Gull J, Crawford P, Lynch P, Liu J, Coleman K (2011) C-B1-01: psychotherapeutic prescription patterns across health plans in the mental health research network. Clin Med Res 9(3–4):183. doi:10.3121/cmr.2011.10.20.01-b1-01

27. Knopman DS, Petersen RC, Rocca WA, Larson EB, Ganguli M (2011) Passive case-finding for Alzheimer’s disease and dementia in two U.S. communities. Alzheimer’s Dement 7(1):53–60. doi:10.1016/j.jalz.2010.11.001

28. INBIOED Consortium, Kouskoumevakii I, Mayer MA, Brunak S, Shublaq N (2013) The interface between systems biology and medical informatics. Promoting and Monitoring Biomedical Informatics in Europe. INBIOEDVision, European Commission

29. Richesson RL, Hammond WE, Nahm M, Wixted D, Simon GE, Robinson JG, Bauck AE, Cifelli D, Smerck MM, Dickerson J, Laws RL, Madigan RA, Rusinovitch SA, Kluchar C, Califf RM (2013) Electronic health records based phenotyping in next-generation clinical trials: a perspective from the NIH Health Care Systems Collaboratory. J Am Med Inform Assoc JAMIA 20(e2):e355–e364. doi:10.1136/amiajnl-2013-001946

30. Poulin C, Shiner B, Thompson P, Vepstas L, Young-Xu Y, Goertzel B, Watts B, Flashman L, McAllister T (2014) Predicting the risk of suicide by analyzing the text of clinical notes. PLoS One 9(1):e85733. doi:10.1371/journal.pone.0085733

31. Huang SH, LePendu P, Iyer SV, Tai-Seale M, Carrell D, Shah NH (2014) Toward personalizing treatment for depression: predicting diagnosis and severity. J Am Med Inform Assoc JAMIA 21(6):1069–1075. doi:10.1136/amiajnl-2014-002733

32. Tulloch AD, Frayn E, Craig TK, Nicholson TR (2012) Khat use among Somali mental health service users in South London. Soc Psychiatry Psychiatr Epidemiol 47(10):1649–1656

33. Su YP, Chang CK, Hayes RD, Harrison S, Lee W, Broadbent M, Cenni A, Beck A, Adams M, Davis R, Schmidt M, Ahmed A, Gull J, Crawford P, Lynch P, Liu J, Coleman K (2011) C-B1-01: psychotherapeutic prescription patterns across health plans in the mental health research network. Clin Med Res 9(3–4):183. doi:10.3121/cmr.2011.10.20.01-b1-01

34. Morkem R, Barber D, Williamson T, Patten SB (2015) A Canadian primary care sentinel surveillance network study evaluating antidepressant prescribing in Canada from 2006 to 2012. Can J Psychiatry 60(12):564–570

35. Wong ST, Manca D, Barber D, Morkem R, Khan S, Kotecha J, Williamson T, Birchwhistle R, Patten S (2014) The diagnosis of depression and its treatment in Canadian primary care practices: an epidemiological study. CMAJ Open 2(4):e337–E342. doi:10.9779/cmaj.2014.0052

36. Osborn DPJ, Hardoon S, Omar RZ, Holt RIG, King M, Larsen J, Marston L, Morris RW, Nazareth I, Walters K, Petersen I (2015) Cardiovascular risk prediction models for people with severe mental illness: results from the prediction and management of cardiovascular risk in people with severe mental illnesses (PRIMROSE) research program. JAMA Psychiatry 72(2):143–151. doi:10.1001/jamapsychiatry.2014.2133
51. Buckingham C, Adams A (2014) Integrating patients’ and clinical mental health expertise within a single online decision support system: myGRIST. Paper presented at the International Conference on Communication in Healthcare, Amsterdam.

52. Blumenthal D (2009) Stimulating the adoption of health information technology. N Engl J Med 360(15):1477–1479. doi: 10.1056/NEJMep0901592

53. Harpe SE (2009) Using secondary data sources for pharmacoepidemiology and outcomes research. Pharmacother J Hum Pharmacol Drug Ther 29(2):138–153

54. Huybrechts KF, Schneeweiss S, Gerhard T, Offson M, Avorn J, Levin R, Lucas JA, Crystal S (2012) Comparative Safety of antipsychotic medications in nursing home residents. J Am Geriatr Soc 60(3):420–429. doi:10.1111/j.1532-5415.2011.03853.x

55. Gianfrancesco FD, Sajatovic M, Rajagopalan K, Wang R-H (2008) Antipsychotic treatment adherence and associated mental health care use among individuals with bipolar disorder. Clin Ther 30(7):1358–1374. doi:10.1016/S1049-2918(08)80062-8

56. Smith DJ, Nicholl BI, Cullen B, Martin D, Ul-Haq Z, Evans J, Whiteford HA, Degenhardt L, Rehm J, Baxter AJ, Ferrari AJ, Sfetcu R, Katschnig H, Amaddeo F, REFINEMENT Study Group (2012) RESEARCH on FNancing systems’ Effect on the Quality of MENTal health care, eDESDR-LTC. http://www.edesdeproject.eu/images/news/newpdf9.pdf. Accessed 20 July 2016

57. Whiteford HA, Degenhardt L, Rehm J, Baxter AJ, Ferrari AJ, Erskine HE, Charlson FJ, Norman RE, Flaxman AD, Johns N, Burstein R, Murray CJ, Vos T (2013) Global burden of disease attributable to mental and substance use disorders: findings from the Global Burden of Disease Study 2010. Lancet 382(9904):1575–1586

58. Smith DJ, Nicholl BI, Cullen B, Martin D, Ul-Haq Z, Evans J, Gill JM, Roberts B, Gallacher J, Mackay D (2013) Prevalence and characteristics of probable major depression and bipolar disorder within UK biobank: cross-sectional study of 172,751 participants. PLoS One 8(11):e75362

59. Cross-Disorder Group of the Psychiatric Genomics C (2013) REFINEMENT Study Group (2012) RESEARCH on FNancing systems’ Effect on the Quality of MENTal health care, eDESDR-LTC. http://www.edesdeproject.eu/images/news/newpdf9.pdf. Accessed 20 July 2016 (supplementary-information)
69. Morgan VA, Croft ML, Valuri GM, Zubrick SR, Bower C, McNeil TF, Jablensky AV (2012) Intellectual disability and other neuropsychiatric outcomes in high-risk children of mothers with schizophrenia, bipolar disorder and unipolar major depression. Br J Psychiatry 200(4): 282–289
70. Morgan VA, Valuri GM, Croft ML, Griffith JA, Shah S, Young DJ, Jablensky AV (2011) Cohort profile: pathways of risk from conception to disease: the Western Australian schizophrenia high-risk e-Cohort. Int J Epidemiol 40(6):1477–1485. doi:10.1093/ije/dyq167
71. Andrews G, Anstey K, Brodaty H, Issakidis C, Luscombe G (1999) Recall of depressive episode 25 years previously. Psychol Med 29(04):787–791
72. Prime Minister’s Office (2015) Prime Minister’s challenge on dementia 2020. GOV.UK. https://www.gov.uk/government/publications/prime-ministers-challenge-on-dementia-2020/prime-ministers-challenge-on-dementia-2020. Accessed 14 Apr 16
73. NHS Digital (2015) Quality and outcomes framework publications. NHS digital (formerly health & social care information centre, HSCIC). http://www.hscic.gov.uk/qof. Accessed 20 July 2016
74. Rait G, Walters K, Griffin M, Buszewicz M, Petersen I, Nazareth I (2009) Recent trends in the incidence of recorded depression in primary care. Br J Psychiatry 195(6):520–524. doi:10.1192/bjp.bp.108.058636
75. Walters K, Rait G, Griffin M, Buszewicz M, Nazareth I (2012) Recent trends in the incidence of anxiety diagnoses and symptoms in primary care. PLoS One 7(8):e41670. doi:10.1371/journal.pone.0041670
76. John A, McGregor J, Fone D, Dunstan F, Cornish R, Lyons RA, Lloyd KR (2016) Case-finding for common mental disorders of anxiety and depression in primary care: an external validation of routinely collected data. BMC Med Inform Decis Mak 16(1):1–10. doi:10.1186/s12911-016-0274-7
77. Hammerman A, Dreher J, Klang SH, Munitz H, Cohen AD, Goldfracht M (2008) Antipsychotics and diabetes: an age-related association. Ann Pharmacother 42(9):1316–1322. doi:10.1345/aph.1L015
78. Lichtenberg P, Kaplan Z, Grinshpoon A, Feldman D, Nahon D (1999) The goals and limitations of Israel’s psychiat case register. Psychiatr Serv 50(8):1043–1048
79. Cheung NT, Fung KW, Wong KC, Cheung A, Cheung J, Ho W, Cheung C, Shung E, Fung V, Fung H (2001) Medical information—the state of the art in the Hospital Authority, Int J Med Inform 62(2–3):113–119. doi:10.1016/S1386-5056(01)00155-1
80. Park S, Kim J-W, Kim B-N, Bae J-H, Shin M-S, Yoo H-J, Cho H-J, Cheung C, Shung E, Fung V, Fung H (2001) Medical information—the state of the art in the Hospital Authority, Int J Med Inform 62(2–3):113–119. doi:10.1016/S1386-5056(01)00155-1
81. John A, McGregor J, Fone D, Dunstan F, Cornish R, Lyons RA, Lloyd KR (2016) Case-finding for common mental disorders of anxiety and depression in primary care: an external validation of routinely collected data. BMC Med Inform Decis Mak 16(1):1–10. doi:10.1186/s12911-016-0274-7
82. Donisi V, Jones J, Pertile R, Salazzari D, Grigolotti L, Tansella M, Amaddeo F (2011) The difficulty of predicting the costs of community-based mental health care. A comprehensive case register study. Epidemiol Psychiact Sci 20(03):245–256
83. Lay B, Nordt C, Rossler W (2007) Trends in psychiatric hospitalisation of people with schizophrenia: a register-based investigation over the last three decades. Schizophr Res 97(1–3):68–78
84. Margulis AV, Kang EM, Hammad TA (2014) Patterns of prescription of antidepressants and antipsychotics across and within pregnancies in a population-based UK cohort. Matern Child Health J 18(7):1742–1752
85. Fernandez-Pujals AM, Adams MJ, Thomson P, McKeehan AG, Blackwood DH, Smith BH, Dominiczak AF, Morris AD, Matthews K, Campbell A (2015) Epidemiology and heritability of major depressive disorder, stratified by age of onset, sex, and illness course in generation scotland: scottish family health study (GS: SFHS). PLoS One 10(11):e0142197
86. Wilkinson J, Bywaters E, Sinopski V, Choppin S, Macleod J, Dennis MS, Lloyd K (2015) Trends in psychiatric hospitalisation of people with psychosis: a register-based study using a large primary care database. Psychol Health Med 21(2):252–260
87. Ravens-Sieberer U (2014) How often do German children and adolescents show signs of common mental health problems? Results from different methodological approaches—a cross-sectional study. BMC Public Health 14(1):1–14. doi:10.1186/1471-2458-14-229
88. Sultana J, Italiano D, Spina E, Cricelli C, Lapi F, Gambassi G, Trifiro G (2014) Changes in the prescribing pattern of antidepressant drugs in elderly patients: an Italian, nationwide, population-based study. Eur J Clin Pharmacol 70(4):469–478
89. Bocquier A, Cortaredona S, Verdoux H, Sciortino V, Vauleau S, Verger P (2013) Social inequalities in new antidepressant treatment: a study at the individual and neighborhood levels. Ann Epidemiol 23(3):99–105. doi:10.1016/j.annepidem.2012.12.008
90. Frick U, Frick H, Languth B, Landgrebe M, Hübner-Liebermann B, Hajak G (2013) The revolving door phenomenon revisited: time to readmission in 17,415 patients with 37,697 hospitalisations at a German psychiatric hospital. PLoS One 8(10):e75612
91. Wilson J, Bywaters E, Sinopski V, Choppin S, Macleod J, Dennis MS, Lloyd K (2015) Recent trends in the incidence of anxiety and prescription of anxiolytics and hypnotics in children and young people: an e-cohort study. J Affect Disord 183:134–141
92. Lloyd K, McGregor J, John A, Craddock N, Walters JT, Linden D, Jones I, Bentall R, Lyons RA, Ford DV, Owen MJ (2015) A national population-based e-cohort of people with psychosis (PsyCymru) linking prospectively ascertainment phenomenologically rich and genetic data to routinely collected records: overview, recruitment and linkage. Schizophr Res 166(1–3):131–136
93. Munk-Jorgensen P, Ostergaard SD (2011) Register-based studies of mental disorders. Scand J Public Health 39(7 Suppl):170–174
94. Thorgerisson TE, Oskarsson H, Desnica N, Kostic JP, Stensfoss JG, Kolbeinsson H, Lindal E, Gaganashvili N, Frigge ML, Kong A, Stefansson K, Gulcher JR (2003) Anxiety with...
panic disorder linked to chromosome 9q in Iceland. Am J Hum Genet 72(5):1221–1230. doi:10.1086/375141
99. Maas J, Verheij RA, de Vries S, Spreeuwenberg P, Schellevis FG, Groenewegen PP (2009) Morbidity is related to a green living environment. J Epidemiol Community Health 63(12):967–973. doi:10.1136/jech.2008.079038
100. Haukka J, Suominen K, Partonen T, Lönnqvist J (2008) Determinants and outcomes of serious attempted suicide: a nationwide study in Finland, 1996–2003. Am J Epidemiol 167(10):1155–1163. doi:10.1093/aje/kwn017
101. Braam AW, van Ommeren OWHR, van Buuren ML, Laan W, Smeets HM, Engelhard IM (2016) Local geographical distribution of acute involuntary psychiatric admissions in subdistricts in and around Utrecht, the Netherlands. J Emerg Med 50(3):449–457. doi:10.1016/j.jemermed.2015.06.057
102. Evensen S, Wisløff T, Lystad JU, Bull H, Ueland T, Falkum E (2015) Prevalence, employment rate, and cost of schizophrenia in a high-income welfare society: a population-based study using comprehensive health and welfare registers. Schizophr Bull. doi:10.1093/schbul/sbu141
103. Hansen DG, Rosholm J-U, Gichangi A, Vach W (2007) Increased use of antidepressants at the end of life: population-based study among people aged 65 years and above. Age Ageing 36(4):449–454
104. Katona L, Čzobor P, Bitter I (2014) Real-world effectiveness of antipsychotic monotherapy vs. polypharmacy in schizophrenia: to switch or to combine? A nationwide study in Hungary. Schizophr Res 152(1):246–254. doi:10.1016/j.schres.2013.10.034
105. Dlouhý M, Barták M (2013) Mental health financing in six eastern European countries. E + M Ekonometrie a management 16(4):4–13
106. Ritchie CW, Molinuevo JL, Truyen L, Satlin A, Van der Geyten S, Lovestoe S (2016) Development of interventions for the secondary prevention of Alzheimer’s dementia: the European Prevention of Alzheimer’s Dementia (EPAD) project. Lancet Psychiatry 3(2);179–186. doi:10.1016/s2215-0366(15)00454-x
107. Murphy D, Spooren W (2012) EU-AIMS: a boost to autism research. Nat Rev Drug Discov 11(11):815–816
108. Zoéga H, Furu K, Hallbörsön M, Thomsen PH, Sourander A, Martikainen JE (2011) Use of ADHD drugs in the Nordic countries: a population-based comparison study. Acta Psychiatr Scand 123(5):360–367. doi:10.1111/j.1600-0447.2010.01607.x
109. Requena G, Huerta C, Gardarsdottir H, Logie J, González-González R, Abbing-Karahargopian V, Miret M, Schneider C, Souverein PC, Webb D, Ansono A, Boudiaf N, Martin E, Oliva B, Alvarez A, De Groth MCH, Bate A, Johansson S, Schlenger R, Reynolds R, Klungel OH, de Abajo FJ (2015) Hip/femur fractures associated with the use of benzodiazepines (anxiolytics, hypnotics and related drugs): a methodological approach to assess consistencies across databases from the PROTECT-EU project. Pharmacoepidemiol Drug Saf. doi:10.1002/pds.3816
110. Lesage A, Rochette L, Emond V, Pelletier E, St-Laurent D, Diulio FB, Kelsey S (2015) A surveillance system to monitor quality indicators (MHQIs) for inpatient psychiatry based on the interRAI mental health assessment. BMC Health Serv Res 13(1):1–12. doi:10.1186/1472-6963-13-15
111. Meng X, D’Arcy C, Templier R (2013) Trends in psychotropic use in Saskatchewan from 1983 to 2007. Can J Psychiatry 58(7):426–431
112. Tung JY, Do CB, Hinds DA, Kiefer AK, Macpherson JM, Choudry AB, Francke U, Naughton BT, Mountain JL, Wojcicki A (2011) Efficient replication of over 180 genetic associations with self-reported medical data. PLoS One 6(8):e23473
113. Smith MW, Stocks C, Santora PB (2015) Hospital readmission rates and emergency department visits for mental health and substance abuse conditions. Community Ment Health J 51(2):190–197. doi:10.1007/s10597-014-9784-x
114. McDavid A, Crane PK, Newton KM, Crosslin DR, McCormick W, Weston N, Ehrlich K, Hart E, Harrison R, Kukull WA, Rottscieit C, Peissig P, Stefanski E, McCarty CA, Zuvich RL, Ritchie MD, Haines JL, Denny JC, Schellenberg GD, de Andrade M, Kullo I, Li R, Mirel D, Crenshaw A, Bowen JD, Li G, Tsuang D, McCurry S, Teri L, Larson EB, Jarvik GP, Carlson CS (2013) Enhancing the Power of genetic association studies through the use of silver standard cases derived from electronic medical records. PLoS One 8(6):e63481. doi:10.1371/journal.pone.0063481
115. Olsson M, Kroenke K, Wang S, Blanco C (2014) Trends in office-based mental health care provided by psychiatrists and primary care physicians. J Clin Psychiatry 75(3):247–253
116. Estiri H, Chan Y-F, Baldwin L-M, Jung H, Cole A, Stephens KA (2015) Visualizing anomalies in electronic health record data: the variability explorer tool. AMIA Summits Transl Sci Proc 2015:56–60
117. Lin EH, Heckbert SR, Rutter CM, Katon WJ, Cecchanopawski P, Ludman EJ, Oliver M, Young BA, McCulloch DK, Von Korff M (2009) Depression and increased mortality in diabetes: unexpected causes of death. Ann Fam Med 7(5):414–421. doi:10.1370/afm.998
118. Clark RE, Weir S, Ouellette RA, Zhang J, Baxter JD (2009) Beyond health plans: behavioral health disorders and quality of diabetes and asthma care for medicare beneficiaries. Med Care 47(5):545–552. doi:10.1097/MLR.0b013e318190bd4b5
119. Raebel MA, Penfold R, McMahon AW, Reichman M, Shetterly S, Goodrich G, Andrade S, Correll CU, Gerhard T (2014) Adherence to guidelines for glucose assessment in starting second-generation antipsychotics. Pediatrics 134(5):e1308–e1314. doi:10.1542/peds.2014-0828
120. Lin EH, QJ, Kline-Simon AH, Mordecai DJ, Weisner C (2015) Prevalence of behavioral health disorders and associated chronic disease burden in a commercially insured health system: findings of a case–control study. Gen Hosp Psychiatry 37(2):101–108. doi:10.1016/j.genhospsyc.2014.12.005
121. Sohn S, Kocher J-PA, Chute CG, Savova GK (2011) Drug side effect extraction from clinical narratives of psychiatry and psychology patients. J Am Med Inform Assoc 18(Supplement 1):i144–i149. doi:10.1136/amiajnl-2011-000351
122. Watkins KE, Smith B, Akincigil A, Sorbero ME, Paddock S, Woodruffe A, Huang C, Crystal S, Pincus HA (2016) The quality of medication treatment for mental disorders in the department of veterans affairs and in private-sector plans. Psychiatr Serv 67(4):391–396
123. Medicaid Medical Directors Learning Network, Rutgers Center for Education and Research on Mental Health Therapeutics (2011) Antipsychotic medication use in medicaid children and adolescents, Rutgers University. http://rci.rutgers.edu/~cseap/ MMDLNAPKIDS.html. Accessed 20 July 2016
124. Ahmedani BK, Solberg LI, Copeland LA, Fang-Hollingsworth Y, Stewart C, Hu J, Nerenz DR, Williams LK, Cassidy-Bushrow AE, Waxmonskey J, Lu CY, Witzelfelder BE, Owen-Smith AA, Coleman KJ, Lynch FL, Ahmed AT, Beck A, Rossom RC, Simon GE (2015) Psychiatric comorbidity and 30-day
readmissions after hospitalization for heart failure, AMI, and pneumonia. Psychiatr Serv 66(2):134–140. doi:10.1176/appi.ps.201300518

Ghassemi M, Marshall J, Singh N, Stone DJ, Celi LA (2014) Leveraging a critical care database: selective serotonin reuptake inhibitor use prior to icu admission is associated with increased hospital mortality. Chest 145(4):745–752. doi:10.1378/chest.13-1722

Alexander GC, Gallacher SA, Mascola A, Moloney RM, Stafford RS (2011) Increasing off-label use of antipsychotic medications in the United States, 1995–2008. Pharmacoepidemiol Drug Saf 20(2):177–184. doi:10.1002/pds.2082

Melamed RD, Khiahbian H, Rabadian R (2014) Data-driven discovery of seasonally linked diseases from an electronic health records system. BMC Bioinform 15(6):1–10. doi:10.1186/1471-2105-15-s6-s3

Goyal D, Wang EJ, Shen J, Wong EC, Palaniappan LP (2012) Hypomagnesemia in the correctional setting. AIDS Care 20(1):124–129. doi:10.1080/09540012.2014.925632

Castro VM, Clements CC, Murphy SN, Gainer VS, Fava M, Berger A, Edelsberg J, Treglia M, Alvir JMJ, Oster G (2012) Change in healthcare utilization and costs following initiation of benzodiazepine therapy for long-term treatment of generalized anxiety disorder: a retrospective cohort study. BMC Psychiatry 12(1):1–10. doi:10.1186/1471-244X-12-177

Connolly Gibbons MB, Rothbard A, Farris KD, Wiltsey Stirman JS, Baillargeon JG, Paar DP, Wu H, Giordano TP, Murray O, Raj KS, Keane-Miller C, Golden NH (2012) Clinical characteristics in database research. Psychiatr Serv 63(10):957–960. doi:10.1176/appi.ps.201100518

Bauer MS, Lee A, Miller CJ, Bajor L, Li M, Penfold RB (2015) The relationship between cat bites and human depression using epidemiologic and clinical collections for genomic studies of complex traits. Hum Hered 79(3–4):137–146

Morgan K, Foroud TM, Kukull WA, Hannequin D, Powell JF, Buxbaum JD, Campion D, Crane PK, Baldwin C, Becker T, Owen MJ, Faber KM, Jonsson PV, Combarros O, O'Donovan S, Montgomery K, Warrington E, Hamilton-Nelson KL, Gu W, Razquin C, Pastor P, Nieto E, Hamilton-Azulay J, Maier W, Hampel H, Aging Research in Genomic E, Moebus S, Mcoccio P, Del Zoppo M, Maier W, Hampel H, Pilotto A, Bullido M, Panza F, Caffarra P, Nacmias B, Gilbert JR, Mayhau M, Lannfelt L, Hakonarson H, Pichter S, Carrascillo MM, Ingelsson M, Bates D, Alvarez V, Zocchi V, Valdarees C, Cosgrove S, Coto E, Hamilton-Nelson K, Gu W, Razquin C, Pastor P, Morgan K, Foroud TM, Kukull WA, Hannequin D, Powell JF, Nalls MA, Ritchie K, Lunetta KL, Kauwe JSK, Boerwinkle E, Riemenschneider M, Boada M, Hiltunen M, Martin ER, Schmidt R, Rujescu D, Wang L-S, Cartegena J-F, Mayeux R, Tsuzorio C, Hofman A, Nothen MM, Graff C, Psaty BM, Jones L, Haines JL, Holmans PA, Lathrop M, Pericak-Vance MA, Launer LJ, Farrer LA, van Duijn CM, Van Broeckhoven C, Moskvina V, Seshadri S, Williams J, Schellenberg GD, Amouyel P (2013) Meta-analysis of 74,046 individuals identifies 11 new susceptibility loci for Alzheimer’s disease. Nat Genet 45(12):1452–1458. doi:10.1038/ng.2802. http://www.nature.com/ng/journal/v45n09/abs/ng.2711.html. Accessed 20 July 2016 (supplementary-information)

Garriock HA, Kraft JB, Shyn SL, Peters EJ, Yokoyama JS, Jenkins GD, Reinalda MS, Slager SL, McGrath PJ, Hamilton SP (2010) A genomewide association study of citalopram response in major depressive disorder. Biol Psychiatry 67(2):133–138. doi:10.1016/j.biopsych.2009.08.029
