Healthcare databases in Europe for studying medicine use and safety during pregnancy

Rachel A. Charlton1*, Amanda J. Neville2, Sue Jordan3, Anna Pierini4, Christine Damase-Michel5, Kari Klungsøyr6,7, Anne-Marie Nybo Andersen8, Anne Vinkel Hansen9, Rosa Gini10, Jens H. J. Bos11, Aurora Pucci12, Caroline Hurault-Delarue5, Caroline J. Brooks13, Lolkje T. W. de Jong-van den Berg11 and Corinne S. de Vries1

1Department of Pharmacy and Pharmacology, University of Bath, Bath, UK
2IMER (Emilia-Romagna Registry of Birth Defects), Azienda Ospedaliero-Universitaria di Ferrara, Ferrara, Italy
3Department of Nursing, College of Human and Health Sciences, Swansea University, Swansea, Wales, UK
4Institute of Clinical Physiology, National Research Council (IFC-CNR), Pisa, Italy
5Pharmacologie, Médicale, Faculté de Médecine, Université de Toulouse III, INSERM UMR1027, Toulouse, France
6Medical Birth Registry of Norway, The Norwegian Institute of Public Health, Oslo, Norway
7Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway
8Section of Social Medicine, Department of Public Health, University of Copenhagen, Copenhagen, Denmark
9Hospital Lillebaelt, Kolding, Denmark
10Agenzia Regionale di Sanità della Toscana, Florence, Italy
11Pharmacoepidemiology and Pharmacoeconomics Unit, Department of Pharmacy, University of Groningen, Groningen, The Netherlands
12Drug Policy Service, Emilia-Romagna Region Health Authority, Bologna, Italy
13Institute of Life Science, College of Medicine, Swansea University, Swansea, Wales, UK

ABSTRACT

Purpose The aim of this study was to describe a number of electronic healthcare databases in Europe in terms of the population covered, the source of the data captured and the availability of data on key variables required for evaluating medicine use and medicine safety during pregnancy.

Methods A sample of electronic healthcare databases that captured pregnancies and prescription data was selected on the basis of contacts within the EUROCAT network. For each participating database, a database inventory was completed.

Results Eight databases were included, and the total population covered was 25 million. All databases recorded live births, seven captured stillbirths and five had full data available on spontaneous pregnancy losses and induced terminations. In six databases, data were usually available to determine the date of the woman’s last menstrual period, whereas in the remainder, algorithms were needed to establish a best estimate for at least some pregnancies. In seven databases, it was possible to use data recorded in the databases to identify pregnancies where the offspring had a congenital anomaly. Information on confounding variables was more commonly available in databases capturing data recorded by primary-care practitioners. All databases captured maternal co-prescribing and a measure of socioeconomic status.

Conclusion This study suggests that within Europe, electronic healthcare databases may be valuable sources of data for evaluating medicine use and safety during pregnancy. The suitability of a particular database, however, will depend on the research question, the type of medicine to be evaluated, the prevalence of its use and any adverse outcomes of interest. © 2014 The Authors. Pharmacoepidemiology and Drug Safety published by John Wiley & Sons, Ltd.

KEY WORDS—electronic medical records; automated data; pregnancy; teratogens; pharmacoepidemiology

INTRODUCTION

Medication use during pregnancy is common,1–5 and for some classes of medicine, such as selective serotonin reuptake inhibitors, there has been an increase in prescribing over time.6 The safety of a medicine when used during pregnancy is often unknown at the time of market approval. This is largely due to the limited ability of animal studies to predict human teratogenesis and the fact that pregnant women are typically excluded from pre-marketing randomised controlled clinical
The safety of medicine use during pregnancy can therefore only be evaluated post-marketing.

Over the last 50 years, a number of surveillance methods have been introduced including spontaneous reporting, case-control surveillance systems and pregnancy exposure registries. These methods have some limitations, however, particularly in relation to voluntary reporting and small sample sizes. It is these limitations that have contributed to the expansion of the use of electronic healthcare databases, containing anonymised patient data, for evaluating the safety of medicine use during pregnancy.

When evaluating the safety of medicine use during pregnancy, the reliability of exposure and outcome assessment are important considerations. Electronic healthcare databases can often provide detailed data on potential prescription drug exposure, although they lack information on non-compliance, over-the-counter medicine use (medicines purchased without a prescription) and the precise timing of exposure.

In terms of outcome data, although information on pregnancy losses may be captured, the level of detail regarding congenital anomalies in the offspring can be limited, and this can hamper drug safety in pregnancy research using healthcare databases alone. In Europe, the European network of population-based registries for the epidemiological surveillance of congenital anomalies (EUROCAT) comprises 43 registries of congenital anomaly registrations in 23 different countries. These registries capture detailed and extensive outcome information regarding the specific types of congenital anomaly although there may be underreporting in some registries, and information on medicine exposure in utero can be limited. A study evaluating first-trimester exposure to the anticonvulsant lamotrigine and the risk of oral clefts in the offspring was the first study to use EUROCAT congenital anomaly data, including the medication exposure data routinely recorded by the registries, to carry out a risk assessment. This work is now being developed further within EUROMediCAT, a Seventh Framework Programme study funded by the European Commission that aims to make more systematic use of electronic healthcare databases in combination with EUROCAT congenital anomaly data and build a European system for the evaluation of medicine use in pregnancy in relation to the risk of congenital anomalies. This paper describes eight electronic healthcare databases in Europe contributing to EUROMediCAT.

**METHODS**

A sample of electronic healthcare databases that captured pregnancies and prescription data was selected for this study on the basis of contacts within the EUROCAT network. For each participating database, an inventory was completed to provide information on the population covered, the source of the data captured and the availability of data on key variables required for evaluating medicine use during pregnancy as well as pregnancy outcomes. This inventory was completed on the basis of the data available within these databases between 2004 and 2012. Ethical and data access approvals were obtained from the relevant governance infrastructures.

**RESULTS**

Seven databases were selected to participate in the study: two in the UK, two in Italy, and one each in Denmark, the Netherlands and Norway. Mid-way through the study, an eighth centre from France also offered to collaborate. With the exception of the IADB.nl database in the Netherlands and the Clinical Practice Research Datalink (CPRD) in the UK, all databases involved the linkage of multiple individual databases to enable the capture of pregnancies, prescription data and additional information on potential confounding variables. For the remainder of this paper, linked databases will be referred to as a single database. A summary of the eight databases can be found in Table 1.

**Population covered**

The total population covered by the eight databases was 25 million. The Danish and Norwegian databases covered the entire population in each country whereas those in the Netherlands, France and Italy covered a particular region (Northern Netherlands, Haute Garonne, Emilia-Romagna and Tuscany), and the databases in the UK captured a sample of the population (the CPRD capturing ~8% of the UK population and the Secure Anonymised Information Linkage (SAIL) database capturing approximately 40% of the population of Wales). The potential for loss to follow-up varied between databases with patients in Denmark, Norway and Italy only leaving as a result of death or emigrating from the country/region, whereas in other databases, exit from the database could result, for example, from the patient changing general practitioner (GP) or the GP practice withdrawing from the database.

**Exposure data**

The databases in the UK captured exposure data based on the issue of a prescription whereas all other databases captured pharmacy dispensing data and therefore only
<table>
<thead>
<tr>
<th>Country/region</th>
<th>Netherlands</th>
<th>Denmark</th>
<th>Norway</th>
<th>Italy—Emilia-Romagna</th>
<th>Italy—Tuscany</th>
<th>UK</th>
<th>Wales</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involves database record linkage</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes*</td>
<td>Yes†</td>
</tr>
<tr>
<td>Population base</td>
<td>IADB.nl database</td>
<td>Danish National Birth Registry</td>
<td>of Norway Medical Birth Registry</td>
<td>4 200 000</td>
<td>Certificate of Delivery (CeDAP)</td>
<td>Hospital Discharges Registry</td>
<td>5 000 000</td>
<td>Clinical Practice Research Datalink (CPRD)**</td>
</tr>
<tr>
<td>Database for live and stillbirth pregnancy identification</td>
<td>N/A</td>
<td>Danish National Patient Registry</td>
<td>of Norway Medical Birth Registry</td>
<td>N/A</td>
<td>Discharges for Induced Terminations and Spontaneous Abortions. Hospital Discharges Registry</td>
<td>Clinical Practice Research Datalink</td>
<td>Patient Episode Database for Wales (PEDW)</td>
<td>1 200 000</td>
</tr>
<tr>
<td>Database for pregnancy loss identification</td>
<td>IADB.nl database</td>
<td>Danish Prescription Registry</td>
<td>Norwegian Prescription Database (ERPD)</td>
<td>Emilia-Romagna Prescription Database (TPD)</td>
<td>Tuscany Prescription Database</td>
<td>Clinical Practice Research Datalink</td>
<td>The General Practice (GP) Dataset</td>
<td>French Health Insurance System Database (CPAM)</td>
</tr>
<tr>
<td>Source for medicine use data</td>
<td>Pharmacy dispensing</td>
<td>Pharmacy dispensing</td>
<td>Pharmacy dispensing</td>
<td>Pharmacy dispensing**</td>
<td>Pharmacy dispensing and Healthcare Facilities Dispensing (except hospitals)**</td>
<td>GP practice prescribing**</td>
<td>GP practice prescribing**</td>
<td>Pharmacy dispensing</td>
</tr>
<tr>
<td>Start of first data collection §§</td>
<td>1995</td>
<td>1996***</td>
<td>2004†††</td>
<td>2003</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Capture outpatient prescribing</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Capture inpatient prescribing</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Some</td>
<td>Some</td>
<td>No</td>
</tr>
<tr>
<td>Medical coding system</td>
<td>N/A</td>
<td>ICD-10</td>
<td>ICD-10</td>
<td>ICD-9/10</td>
<td>ICD-9</td>
<td>Read</td>
<td>Read</td>
<td>N/A</td>
</tr>
<tr>
<td>Opportunity to request additional data</td>
<td>No</td>
<td>Yes**, ***</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes**</td>
<td>Yes***</td>
<td>Yes****</td>
</tr>
</tbody>
</table>

N/A, not available; ICD, International Classification of Diseases.
*Secure Anonymised Information Linkage (SAIL) database.
†EFEMERIS database.
‡The size of the population captured by the CPRD has grown steadily over time and was approximately 5.0 million in May 2012.
§The Danish National Prescription Registry has been collecting prescriptions since 1995, and the Birth and Patient registries of Norway go further back.
**Previously the General Practice Research Database (GPRD).
††Including only products reimbursed by the Italian National Health Service and excluding those dispensed to outpatients in a hospital pharmacy.
‡‡Including non-GP prescribers working within the GP practice.
†††For many databases, the data have become richer over time, and additional data sources have become available.
****The Danish National Prescription Registry has been collecting prescription data since 1995, and the Birth and Patient registries of Norway go further back.
††††The Norwegian Prescription Database started collecting prescription data in 2004, but the Norwegian Medical Birth Registry has been collecting pregnancy outcome data since 1967.
†††‡Opportunity to review against charts and to request further information via questionnaires.
****Opportunity to request linkage to other datasets.
†††††Opportunity to request further information only for medical abortions.
those prescriptions actually dispensed (Table 1). The majority of databases did not capture prescriptions issued to inpatients during a hospital stay; in the UK databases, however, some were captured if the GP entered them following receipt of a hospital letter. In Denmark, Norway and the Netherlands, all other prescriptions were captured, including private prescriptions, although a small number of rare or expensive medicines (e.g. cancer treatments) may not have been captured if they were dispensed at the hospital to outpatients. In the French database, all prescriptions for reimbursed drugs were captured, regardless of whether they had been prescribed by a GP or a specialist or had been issued privately. In the Italian databases, prescriptions reimbursed by the National Health Service were captured; however, the majority of private prescriptions and prescriptions issued by a specialist to outpatients that were dispensed at a hospital pharmacy were not captured; the extent of hospital dispensing to outpatients varied by product and drug class. In the UK databases, the majority of prescriptions captured were those issued by a GP or non-GP prescriber within primary care. Private prescriptions and prescriptions initiated by a specialist in a hospital outpatient department were largely not captured, but any repeat prescriptions that were subsequently issued by the GP were captured.

Determining the precise timing of exposure is crucial when evaluating medicine use and safety during pregnancy. To do this, accurate information on the first day of the last menstrual period (LMP) is required. Some databases such as those in Denmark, France and Norway have this information or can calculate it on the basis of gestational age at delivery for the majority of pregnancies. In other databases, such as the CPRD, information on the LMP is only sometimes recorded, and algorithms need to be created to determine a best estimate (Table 2).

**Pregnancies captured**

Table 2 summarises pregnancy-related information for each of the databases. The number of pregnancies captured per year varied from ~2000 in the Netherlands to ~88,000 in Denmark. This variation reflects the difference in the size of the source populations covered and the types of pregnancy outcomes captured. All databases captured live and stillbirth deliveries with the exception of the IADB.nl database where stillbirth data were not available. Induced terminations of pregnancy and spontaneous pregnancy losses were captured in all databases, except those in the Netherlands and Emilia-Romagna (Tables 1 and 2). In the Norwegian Medical Birth Registry, however, induced terminations after 12 weeks’ gestation were only registered when the foetus had a congenital anomaly and spontaneous abortions were underreported, particularly those occurring before 16 weeks’ gestation. Although the databases in Wales and Tuscany captured data on pregnancy losses, in Wales, the data are considered too sensitive to release for research, and in Tuscany, most could not be linked to prescription data. None of the databases captured very early pregnancy losses that occur before the pregnancy is clinically recognised.

**Outcome data**

The most frequently studied adverse pregnancy outcome following in utero medication exposure is the risk of major congenital anomalies. It was possible to identify congenital anomalies in pregnancies that ended in a live or stillbirth in all databases, with the exception of the IADB.nl database.1 In Denmark and Norway, congenital anomaly data could be obtained from the national birth registers, and in Italy, they were captured through the ‘Certificate of Delivery Assistance’. In the CPRD, congenital anomalies could be identified from the infants’ GP records; in Wales, they could be identified from linking to the congenital anomalies database; and in France, they could be identified from the Mother and Child Protection Centre database and the Antenatal Diagnostic Centre database for induced abortions. Identification of pregnancies that were terminated following a pre-natal diagnosis of a congenital anomaly was largely restricted to databases that captured induced terminations of pregnancy. The completeness and reliability of recording of congenital anomalies, along with the level of detail, may vary between databases and by specific type of anomaly. Within some databases, there is the opportunity to request additional non-coded data, full paper medical records or to send questionnaires that can help verify or refute diagnoses recorded in the coded data (Table 1). In addition to information on congenital anomalies, some databases were able to provide data on other adverse pregnancy outcomes such as prematurity, low or high birth weight and intrauterine growth retardation (Table 2).

**Data on potential confounding variables**

Table 3 summarises the availability of data on potential confounding variables. Information on smoking status and alcohol intake was more commonly available in databases that captured data recorded in primary care, particularly those in the Netherlands and Emilia-Romagna (Tables 1 and 2). In the Norwegian Medical Birth Registry, however, induced terminations after 12 weeks’ gestation were only registered when the foetus had a congenital anomaly and spontaneous abortions were underreported, particularly those occurring before 16 weeks’ gestation. Although the databases in Wales and Tuscany captured data on pregnancy losses, in Wales, the data are considered too sensitive to release for research, and in Tuscany, most could not be linked to prescription data. None of the databases captured very early pregnancy losses that occur before the pregnancy is clinically recognised.

---

1 Congenital anomalies are not recorded in the database itself; however, congenital anomalies can be identified via the North Netherlands EUROCAT registry.
Table 2. Pregnancy information captured by the different databases

| Country/region | Database(s) that capture pregnancy data | Annual number of pregnancies* | Total number of pregnancies in the database in 2012 | Captures stillbirths | Captures induced terminations of pregnancy | Captures spontaneous abortions | Percentage of pregnancies resulting in a loss | Can identify multiple births (e.g. twins) | Date of last menstrual period available | Data on birth weight | Data on gestational age including prematurity | Able to identify congenital anomalies | Data on intrauterine growth retardation | Data on developmental delay in childhood |
|---------------|---------------------------------------|-------------------------------|-----------------------------------------------|---------------------|----------------------------------------|------------------------------------|------------------------------------------|----------------------------------|-------------------------------------|-------------------------------|----------------------------------|---------------------------------------------|-----------------------------------|-----------------------------------|------------------------------|
| Netherlands   | IADB.nl database                      | ~2000                         | 27000                                         | No                  | No                                     | No                                 | NA                                       | Yes                              | Estimated                          | No               | No                              | No                             | No                             | No                                      |
| Denmark       | Danish National Birth Registry and Danish National Patient Registry | ~88 000                       | 1 300 000†                                  | Yes                 | Yes                                    | Yes†                              | Yes                                      | Yes                              | Calculated from gestational age     | Most births                      | Yes                             | Yes                           | Yes                                      | Yes                               |
| Norway        | Medical Birth Registry of Norway      | ~60 000                       | 532 000                                      | Yes                 | Yes                                    | Yes**                             | Yes                                      | Yes                              | Calculated from gestational age     | Yes                             | Yes                             | Yes                           | Yes                                      | Yes                               |
| Italy—Emilia-Romagna | Emilia-Romagna CeDAP                   | ~40 000                       | 350 000                                      | Yes                 | No                                     | Yes                               | Yes                                      | Yes                              | Calculated from gestational age     | Yes                             | Yes                             | Yes                           | Yes                                      | Yes                               |
| Italy—Tuscany | Tuscany CeDAP and the Discharges for Induced Terminations and Spontaneous Abortions Database | ~32 000                       | 300 000                                      | Yes                 | Yes                                    | Yes                               | Yes                                      | Yes                              | Yes                                | Some                           | Yes                             | Yes                           | Yes                                      | Yes                               |
| UK            | Clinical Practice Research Datalink   | ~80 000                       | 1 000 000                                    | Yes                 | Yes                                    | Yes                               | Yes                                      | Yes                              | Yes                                | Some                           | Yes                             | Yes                           | Yes                                      | Yes                               |
| Wales         | National Community Child Health Database and the Patient Episode Database for Wales | ~45 000                       | 500 000                                      | Yes                 | Yes                                    | Yes                               | Yes                                      | Yes                              | Yes                                | Some                           | Yes                             | Yes                           | Yes                                      | Yes                               |
| France        | EFEMERIS                               | ~1 0000                       | 79 000                                       | Yes                 | Yes                                    | Yes                               | Yes                                      | Yes                              | Yes                                | Some                           | Yes                             | Yes                           | Yes                                      | Yes                               |

*Including pregnancy losses where captured.
†Only women hospitalised in the University Hospital of Toulouse (PMSI database).
‡Those occurring from 12 weeks’ gestation with a congenital anomaly.
§Those occurring from 12 weeks’ gestation although some underreporting especially for those occurring at less than 16 weeks.
¶Pregnancy losses are captured but access is restricted, and these data are not currently available for research.
**Pregnancy losses are captured by the database, but the majority cannot be linked to prescription data.
††Compulsory notification of those occurring from 12 weeks’ gestation although some underreporting especially for those occurring at less than 16 weeks.
‡‡‡Congenital anomalies are not recorded in the database itself; however, congenital anomalies can be identified via the North Netherlands EUROCAT registry.
§§§At 9 and 24 months.

NA, not available.

**R. A. CHARLTON ET AL.**

although smoking status was available for the majority of pregnancies ending in a live delivery in the Italian, Danish and Norwegian databases. Data on pre-pregnancy body mass index (BMI) were available for the majority of patients in the CPRD and Tuscany databases. In Denmark, smoking status and BMI data were not recorded in the Patient Registry and were therefore only available for deliveries. Limited data on smoking and alcohol use were available in France. Data on socioeconomic status were captured in all databases. All databases had the potential to capture data on additional medicines being prescribed or dispensed to

| Table 3. Covariate data recorded in each of the databases |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Country/region                  | noodles         | Denmark         | Norway          | Italy—Emilia-Romagna | Italy—Tuscany   | UK              | Wales           | France          |
| Databases                       | IADB.nl         | Danish National Birth Registry, Patient Registry and Prescription Registry | Medical Birth Registry of Norway and Prescription Database | Emilia-Romagna (CeDAP + ERPD) | Tuscany (CeDAP + TPD) | General Practice Research Database | Secure Anonymised Information Linkage (SAIL) Databank | EFEMERIS         |
| Smoking status                  | No              | Yes*            | Yes†            | Yes              | Yes            | Yes              | Yes             | Some            | Some            | Some            | Some            |
| Alcohol consumption             | No              | Yes‡             | No              | Yes              | No             | No              | Yes            | Some            | Some            | Some            | Some            |
| Pre-pregnancy body mass index   | No              | Yes*            | No              | No^              | Yes            | Yes             | Some           | No              | No              | No              | No              |
| A measure of socioeconomic status| Yes**           | Yes††           | Yes‡‡           | Yes††           | Yes‡‡          | Yes***          | Yes***         | Yes‡‡‡          | Yes‡‡‡          | Yes‡‡‡          | Yes‡‡‡          |
| Maternal co-prescribing         | Yes             | Yes             | Yes             | Yes              | Yes            | Yes             | Yes            | Yes             | Yes             | Yes             | Yes             |
| Standard-dose folic acid (0.4 mg) | No              | No              | Most            | Some             | Some           | Some—when prescribed Yes | Yes             | Some—when prescribed†† Most§§§ |
| High-dose folic acid (5 mg)     | Yes             | Yes             | Yes             | Yes              | Yes            | Yes             | Yes            | Yes             | Yes             | Yes             | Most§§§         |
| Indication for prescribing      | No              | Some            | Yes****         | No               | No             | Majority         | Some           | No              | No              | No              | No              |
| Maternal co-morbidity           | No              | Yes             | Yes             | No               | No             | Yes             | Yes            | Yes             | Some          | Some          | Some‡‡‡         |
| Family history of congenital anomalies | No              | Some            | Yes             | Yes             | Yes            | No              | No             | For medical terminations |
| Maternal occupation             | No              | No              | No              | Yes             | No             | No              | No             | No              | Yes‡‡‡         | Yes‡‡‡         | Yes‡‡‡         |
| Maternal age at pregnancy start | Yes             | Yes             | Yes             | Yes              | Yes            | Yes             | Yes            | Yes             | Yes             | Yes             | Yes           |

*Available for pregnancies that result in a delivery but not for those that end in a pregnancy loss.
Available for deliveries and spontaneous abortions but not induced terminations.
*Only for births, but data often missing (children certificates (PMI database)).
*Not for the majority of the study period but available from 2012 in CeDAP.
**Based on address/postcode.
††Based on maternal education level.
‡‡Available for all mothers registered in the MBRN and when the outcome is a termination of pregnancy owing to a congenital malformation through linkage with the Education Database of Norway.
§§Available at a patient and practice level based on the Index of Multiple Deprivation (IMD) score, based on address and postcode.
***Based on Townsend scores and ranks and Welsh Index of Multiple Deprivation.
****Based on maternal occupation—only available for live births.
†††All prescriptions are free in Wales so women may prefer to get a prescription rather than buy it over the counter without a prescription.
§§§Both high-dose and low-dose folic acid are available over the counter without a prescription, but both can be reimbursed, so women prefer to have them prescribed.
*****Only for reimbursed prescriptions.
††††For medical abortions and births (hypertension, diabetes, pre-eclampsia and open response).
‡‡‡‡Only for live births.
women other than the medicine specifically being evaluated as part of a study (maternal co-prescribing). None of the databases, however, captured data on medicines bought over the counter, which often includes standard-dose 0.4 mg folic acid. As a result, information on folic acid exposure, which reduces the risk of some congenital anomalies when taken during the periconceptional period,\textsuperscript{24,25} was often restricted to women who received the higher 5 mg dose, which in most countries is only available on prescription (Table 3).

Availability of data on the indication for prescribing varied between databases. In the Norwegian prescription database, this information was available for all medicines that were reimbursed, although the level of detail on the indication has improved since 2009. In Denmark, some information on indication for prescribing could be inferred from hospital diagnoses prior to prescription. In the CPRD and SAIL, the patients’ full medical records were available, and the indication for prescribing could be inferred from diagnoses recorded on or around the same date as a prescription for a particular product. No data on the indication for prescribing were available within the French, Italian or Dutch databases.

For the UK and Danish databases, diagnoses of maternal comorbidities could be obtained from the same data sources as those used for the indication of prescribing. In Norway, however, information on chronic diseases that the woman had before pregnancy was recorded in the Medical Birth Registry. In France, only data on hypertension during pregnancy, gestational diabetes and pre-eclampsia were available. No data on maternal comorbidities were available within the Italian or Dutch databases, although for some chronic conditions, it may be possible to use prescription records as proxies. Recording of a family history of congenital anomalies was rare, and none of the databases captured information on maternal diet.

**DISCUSSION**

Eight electronic healthcare databases that capture useful information regarding medicine use during pregnancy and a range of pregnancy outcomes have been described. To our knowledge, this paper is the first to provide a comprehensive overview of the populations covered by these databases, the types of data captured and the information available regarding variables required for the study of medicine use and safety during pregnancy.

**Sample size considerations**

One of the strengths of electronic healthcare databases is the large number of pregnancies they capture. Congenital anomalies are rare and arise from different embryonic tissues and at different gestational stages. As a consequence, the mechanism and timing of interference with embryogenesis will differ, and individual anomalies need to be considered separately, rather than amalgamated under a single all-embracing congenital anomaly category.\textsuperscript{26} In addition, the exposures of interest may be relatively uncommon in pregnancy, and most medicines need to be evaluated individually, as often a ‘class effect’ cannot be assumed.\textsuperscript{7} A classic example is the difference in teratogenicity of glutethimide, which is not a major teratogen, and its derivative thalidomide. Both of these products are glutarimides, and both are hypnotics, yet their effects on the foetus are dramatically different.\textsuperscript{27} The fact that congenital anomalies as well as exposures need to be considered at a granular rather than an aggregate level has considerable implications for the required sample size for evaluations of medicine safety in pregnancy.

The large number of pregnancies captured within the electronic healthcare databases described in this study and the fact that the data are routinely collected make them a valuable tool for evaluating medicine use during pregnancy. For medicines that are new to the market or used to treat less prevalent conditions, however, even these large databases may be less capable than pregnancy exposure registries of capturing an adequate sample of exposed pregnancies during a particular period.\textsuperscript{28,29}

**Exposure data**

The type of exposure data captured differed between databases, with the majority capturing prescription dispensing data whereas the UK databases captured all prescriptions issued. In France and Italy, only prescriptions reimbursed by the health service were captured.\textsuperscript{4,23,30} One of the strengths of electronic healthcare databases is that prescription information is recorded prospectively and independently, by the prescriber or dispensing pharmacist, avoiding any maternal recall bias.\textsuperscript{31} In addition, the level of detail available in terms of the specific product, the quantity and daily dose prescribed tends to be high, and these variables can often be used to calculate the duration and, hence, timing of potential exposure. Unlike exposure data obtained via a maternal interview, databases do not provide information on non-compliance and whether the patient took the medicine as directed. The likelihood of exposure misclassification may be less of a concern for databases capturing dispensed prescriptions than those capturing all prescriptions issued, but, in addition, knowledge of the extent and
type of prescriptions not captured in the database and the impact of these is important.

In database research, exposure misclassification can also occur as the result of inaccurate information on the LMP date. Only six of the eight databases contained this information, or the gestational age at delivery, for the majority of pregnancies. The potential for exposure misclassification resulting from inaccuracies in the LMP date will be greater for products prescribed for short-term use (e.g. antibiotics) than for those used long-term to treat chronic conditions.

Outcome data

In all databases, with the exception of the IADB.nl database in the Netherlands, it was possible to identify congenital anomalies. Unlike pregnancy exposure registries and case–control surveillance systems, which often have the benefit of review by a consultant paediatrician or teratologist and very detailed information on the specific congenital anomaly, electronic healthcare databases often lack detail on anomalies, and researchers may have to rely on the entry of a single medical code. In general, databases that include links to medical birth registries and congenital anomaly registers such as EUROCAT are likely to contain the most detailed information on anomalies, and it is an objective of the EUROMediCAT project to pilot the linkage between healthcare databases and EUROCAT congenital anomaly registries, where they co-exist.

An advantage of some of the databases reviewed was their potential for capturing induced terminations in addition to pregnancies ending in a delivery. This is particularly beneficial given that many of the more serious congenital anomalies may be diagnosed prenatally and may subsequently be terminated. If such anomalies are caused by a medicine, but not captured, the analyses would fail to identify an increased risk. Some databases in this review allowed the identification of clinically recognised spontaneous as well as induced pregnancy loss, premature birth, low or high birth weight and intrauterine growth retardation.

Potential risk factors and confounders

Surveillance systems that collect data from maternal interviews and questionnaires have the benefit of being able to request information on additional risk factors and potential confounders, whereas in databases, the availability of this information can be limited. In this review, UK primary-care databases contained the most information on the commonly considered potential confounding factors such as smoking status and alcohol consumption.

CONCLUSION

Post-marketing surveillance systems are essential for evaluating the use and safety of medicines during pregnancy. This study suggests that, within Europe, electronic healthcare databases may be valuable sources of data that can provide information on medicine utilisation patterns, user characteristics and medicine safety during pregnancy. They may complement existing EUROCAT or case–control surveillance systems, especially where no pregnancy registry is in place. Given the potential of databases in the field of medication use in pregnancy, one aspect of the EUROMediCAT study will involve using the databases described in this paper to establish the extent and nature of use of antiepileptic drugs, antidiabetic medicines, asthma medicines and selective serotonin reuptake inhibitors during pregnancy in the different regions. It will explore the relationship between users of the four drug groups previously mentioned and other health behaviours and exposures in order to identify possible confounders and effect modifiers in drug teratogenicity studies. The findings of the medicine utilisation studies will then be used to inform other aspects of EUROMediCAT, which are focussing on linking selected electronic healthcare databases to EUROCAT congenital anomaly registries to study the safety of these medicines when used during pregnancy.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

KEY POINTS

- Post-marketing surveillance systems are essential for evaluating the use and safety of medicines during pregnancy.
- Within Europe, electronic healthcare databases may provide valuable data on medicine utilisation patterns, user characteristics and medicine safety during pregnancy.
- Electronic healthcare databases in Europe have the potential to complement existing EUROCAT or case–control surveillance systems for evaluating medicine use and safety during pregnancy.

ETHICS STATEMENT

Ethical and data access approvals were obtained from the relevant governance infrastructures where needed.
ACKNOWLEDGEMENTS
The authors would like to acknowledge all the data providers who made anonymised data available for research. The work presented in this paper describes anonymised data held in the SAIL system, which is part of the national e-health records research infrastructure for Wales, and the authors also thank David Tucker, Martin Heaven, Daniel Thayer, Karen Tingay and Leila Pinder for their contribution to the work carried out with SAIL data. This paper also describes data from the Full Feature General Practice Research Database obtained under licence from the UK Medicines and Healthcare Products Regulatory Agency. However, the interpretation and conclusions contained in this report are those of the authors alone. The Tuscany Registry of Birth Defects is funded by the ‘Direzione Generale Diritti di cittadinanza e Coesione sociale—Regione Toscana.’ The Emilia-Romagna Registry of Birth Defects is funded by the Emilia-Romagna Region Health authority grant number Delibera 56412/ 2010. The EFEMERIS Database is funded by Agence Nationale de Securité du Médicament, Caisse Nationale d’Assurance Maladie des travailleurs salariés, Programme Hospitalier de Recherche Clinique (PHRC).

Financial support for this study was provided by the European Union under the 7th Framework Programme (grant agreement HEALTH-F5-2011-260598).

REFERENCES