EpiHosp: A web-based visualization tool enabling the exploratory analysis of complications of implantable medical devices from a nationwide hospital database

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Abstract. Administrative data can be used for the surveillance of the outcomes of implantable medical devices (IMDs). The objective of this work is to build a web-based tool allowing for an exploratory analysis of time-dependent events that may occur after the implementation of an IMD. This tool should enable a pharmacoepidemiologist to explore on the fly the relationship between a given IMD and a potential outcome. This tool mine the French nationwide database of inpatient stays from 2008 to 2013. The data are preprocessed in order to optimize the queries. A web tool is developed in PHP, MySQL and Javascript. The user selects one or a group of IMD from a tree, and can filter the results using years and hospital names. Four result pages describe the selected inpatient stays: (1) temporal and demographic description, (2) a description of the geographical location of the hospital, (3) a description of the geographical place of residence of the patient and (4) a table showing the rehospitalization reasons by decreasing order of frequency. Then, the user can select one readmission reason and display dynamically the probability of readmission by mean of a Kaplan-Meier curve with confidence intervals. This tool enables to dynamically monitor the occurrence of time-dependent complications of IMD.

Keywords: Medical device, data reuse, patient safety, big data.

Introduction

Epidemiological studies on implantable medical devices (IMD) are classically based on specific registers, or on reuse of medical administrative databases. They enable to monitor the complications secondary to the implementation of IMD. Thus, for example in the case of total hip or knee replacements, studies about complications can involve hundreds of thousands of patients [1], or even millions of patients [2].

Recent projects have assessed the interest of big observational databases for monitoring adverse drug events (ADEs) following drug commercialization. Many methods were compared in OMOP project [3] for the detection of ADEs and a

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methodological framework seems now mature for monitoring drug complications through these big databases. The statistical power is then sufficient to identify rare events and perform inferential analyzes. A first category of methods enable the detection of drug and effect couples, a second category of methods generally enable the surveillance of the occurrence of a chosen effect. It seems reasonable to assume that those methods could be translated to the field of IMDs. Such an approach seems necessary as the pre-market evaluation of IMDs in terms of safety and efficacy are not as complete as for drugs.

Data visualization tools have an essential role in the exploitation that can be made of big databases. They play a role in the field of epidemiological surveillance by the identification of clusters in time and space [4], particularly for infectious disease [5]. They enable the formulation of hypotheses to be verified later according to a rigorous methodology to get out of a possible observer bias. These tools may give the possibility to visualize an aggregate result for one or more strata of interest. This is the case of the tool "project LIBRA" [6], which enables to build retrospective cohorts of patients receiving a specific drug, from a medical and administrative database. These cohorts are then followed for 12 months and a rate of occurrence of an event of interest is computed. A similar tool could be useful for monitoring IMDs. In addition, the events of interest being time-dependent, it seems useful to treat them as such in the context of exploratory analysis, by enabling the dynamic construction of Kaplan-Meier survival curves.

The objective of this work is to build an interactive web tool reusing the French nationwide exhaustive database of inpatient stays, in order to allow for an exploratory analysis of the inpatient stays during which the IMD is implemented, and the rate and reasons for readmission of patients over time. This tool should enable a pharmacoepidemiologist to explore on the fly the relationship between a given IMD and a potential outcome.

1. Methods

The "acute care" part of the French nationwide exhaustive database of inpatient stays is reused for the years 2008 to 2013 (n=150,355,319 stays). These data were obtained after approval of the national commission in charge of privacy protection (CNIL). Table 1 presents the data available for each inpatient stay: They notably include medical diagnoses, medical procedures, length of stay, discharge month and year, hospital location, patient residence location, age, gender, and the anonymous unique nationwide identifier of the patient. All those data have first been collected for the purpose of hospital payment by health insurances. This identifier is used to track any readmissions following the implementation of an IMD. Among the medical diagnoses, the "principal diagnosis" corresponds to the medical reason of the hospital admission, as known once the patient has been discharged.

All the inpatient stays of the patients having at least one inpatient stay including a code of IMD are extracted. This represents approximately 400,000 inpatient stays per year. There are on average about 4 IMDs per inpatient stay, as there is one different code for each part of the IMD. For example, in the case of total hip replacement, there is a code for the head, the insert, the shaft, etc.

Table 1. Types of data available for each inpatient stay

Variables	Terminology
Implantable medical devices	French LPP code
Diagnoses	ICD-10
Procedures	French CCAM code
Hospital	National identifier
Length of stay, year and month	-
Residence of the patient	ZIP code
Age and gender	-
Unique national anonym identifier of the patient	Unique code

A web tool is developed using PHP, MySQL, Apache and Javascript. Graphics displayed to the user are drawn using free Javascript libraries or programmed de novo, especially for dynamic construction of Kaplan-Meier curve. Queries are optimized using a preprocessing of data tables: The data are aggregated for each target graphic with respect to the filtration criterions that are made available to the user. Two counts are computed: A first one to know the total number of IMDs, a second one to know the total number of inpatient stays having at least one of the IMD selected by the user. The terminologies and their hierarchy are also included in the database.

2. Results

The result consists of a web-based application. After logging in, the user selects one IMD or a group of IMDs from the tree classification of IMD, which adds the corresponding codes to the field "Medical device identifier" shown in Figure 1. The user can then filter the query by specifying the year(s) and the hospital(s). Then, 4 validation buttons are available, and redirect the user to 4 report pages: "Demography", "Geography", "Origin of the patient", and "Rehospitalisation" (the corresponding result pages are presented below). The processing time of the most voluminous request including all years, hospitals and IMDs is only a few seconds (Intel Core i7-4600U 2.10GHz CPU): Data preprocessing enables to divide this duration by about 500 in average.

Figure 1. Screen proposed to the user to define the request.

We detail the result generated for each button:

- "Demography" button: Inpatient stays with IMD are described with a time histogram of the date of implementation of the IMD, a histogram of the length of stay, a histogram of the patients' age, a pie chart of the gender, a bar chart of the most common diagnoses of the inpatient stays, a bar chart of the most frequent procedures and a bar chart of the most frequent IMDs.
- "Geography" button: Inpatient stays are presented on an interactive map of France as shown on Figure 2. By moving the mouse over the regions, the user

can see on the right side of the screen the number of inpatient stays and the number of IMDs per hospital.

- "Origin of the patient" button: The geographical origin of the patients having an inpatient stay with IMD implementation is presented in a manner similar to that shown on Figure 2. If the user filters the query to a specific hospital (or region), the map enables to visualize the catchment area of this hospital (or region).
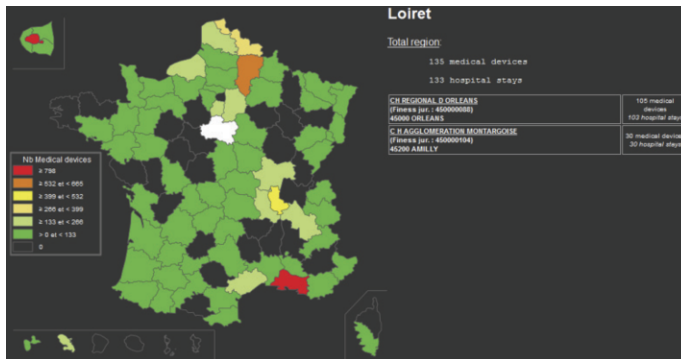

Figure 2. Geographical distribution of the patients.

- "Rehospitalisation" button: A table containing the readmission reasons is displayed. The user can then select one or several diagnoses of interest and start displaying the corresponding Kaplan-Meier curve. The example of output on Figure 3 shows the occurrence of mechanical complication secondary to total hip replacement. The "Survival probability" axis shows the probability for being free of any mechanical complication of the hip replacement.
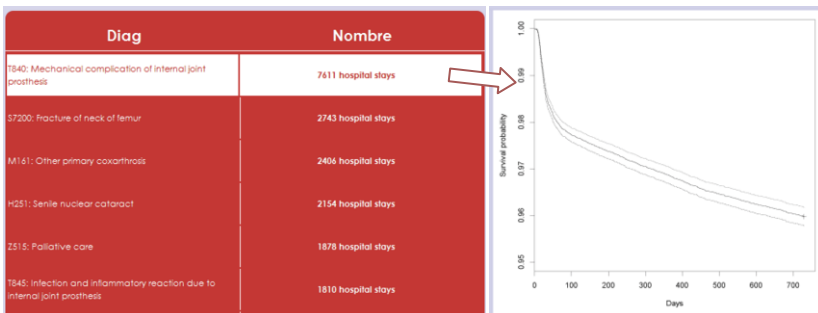

Figure 3. Readmission reasons, and Kaplan-Meier curve corresponding to one of them.

3. Discussion

An exploratory tool dedicated to the follow-up of IMDs has been built. It enables the user to visualize interactive temporal, demographic and geographical descriptions of inpatient stays with IMD implementation. It also enables to monitor the occurrence of time-dependent readmission events by the dynamic generation of Kaplan-Meier curves. This work further confirms the interest of reusing medical administrative databases for

monitoring therapeutic complications that may occur secondarily to the implementation of IMDs.

Several limitations related to the reuse of administrative French nationwide database have to be discussed. First, this database does not have any unique IMD identifier, unlike dedicated registers [7]. Moreover, information about the inpatient stays with IMD is available only in public or non-profit hospitals. Fortunately, this database also contains medical and administrative information from private profit hospitals, which enables to trace appropriately the readmission of the patients even in such hospital settings. Finally, a thorough job of data quality management has to be performed before using the database.

The usability of this tool is being evaluated. This tool for monitoring inpatient stays with IMDs could be generalized to other types of data, and could for instance enable to monitor the complications of procedures or the complications of chronic diseases. Adding statistical analyzes based on data-mining methods are envisaged by connecting this tool to the R statistical software [8].

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