

The European Union (EU) Medical Device Regulation (MDR) 2017/745, effective since 2021, has introduced more stringent requirements for high-risk medical devices, emphasizing the need for proactive post-market surveillance (PMS) through real-world data sources such as Field Safety Notices (FSNs). FSNs that report device problems, communicated by manufacturers and published on national competent authorities' websites, could play a fundamental role in deriving trends to allow signalling possible devices or categories of devices at higher risk of problems once on the market. However, EU-specific challenges — such as jurisdictional complexity, fragmented data, use of different languages and nomenclatures among Member States, and delays and uncertainties in the availability of the European Database on Medical Devices (EUDAMED) — hinder efficient retrieval and utilization of the information embedded in the FSNs for enhanced PMS analysis.

Within the EU-funded CORE-MD project, our aim was to address these barriers by designing and developing a novel IT tool to automatically retrieve, structure, re-classify using the European Medical Device Nomenclature (EMDN) system based on a hierarchical classification of medical categories structured up to 7 levels with increasing detail, and display in an aggregated way the publicly accessible FSNs. To do so, country-specific web scraping techniques were developed to collect FSNs from both EU and non-EU countries, with only 16 of 27 EU countries consistently updating FSNs. By leveraging Natural Language Processing (NLP) techniques, unstructured text from FSNs was transformed into structured data. As a first step, if the manufacturer and device name were not provided as structured fields, such information needed to be recognized within the retrieved text using Named Entity Recognition techniques. Since linkage to the EMDN codes was rarely included in FSNs, except for about one-third of the Italian ones, Entity Resolution was required to assign the appropriate EMDN codes across all FSNs, including those from countries lacking a device dataset with EMDN classifications. By applying such framework, 65,036 FSNs published up to 31/12/2023 were retrieved from 16 EU countries, of which 40,212 (61.83%) were successfully assigned the proper EMDN. The framework's performance was tested, using the Italian FSNs for which the EMDN was publicly provided, with accuracies ranging from 87.34% to 98.71% for EMDN level 1 and from 64.15% to 85.71% even for level 4. Similarly, 71,180 FSNs published up to 31/12/2023 from non-EU countries (Australia, Brazil, Canada, the UK and the USA) were retrieved, of which 36,597 (51.41%) were assigned the appropriated EMDN codes. The database of all retrieved FSNs is now updated monthly by automatically checking for newly published FSNs, thus ensuring a consistent and reliable dataset for ongoing analysis.

To enhance data quality, a structured methodological framework combining NLP, vision transformers, and community detection algorithms in graphs was developed to identify duplicated FSNs across countries. Vision transformers, a deep learning architecture designed for image recognition and analysis, were used to process and extract image-based features from raw PDF and scanned files, while text-based features were also derived for each document. These features were combined to compute an adjacency matrix that captured both image and text similarities between documents. This matrix was used to represent each

document, and consequently each FSN, as a node within a graph, where community detection algorithms were applied to identify clusters corresponding to potential groups of duplicated FSNs. By balancing image and text data similarity, this approach effectively addressed challenges related to language and format variations in the underlying PDF files.

An interactive and user-friendly desktop application, the CORE-MD PMS Tool, was developed using Flutter, a cross-platform framework for building responsive interfaces, as the front-end and MongoDB, a NoSQL database designed for flexible and scalable data management, as the back-end, to facilitate the retrieval and exploration of the generated centralized database. Users can customize queries based on different criteria (e.g., country, manufacturer, device, EMDN levels, time interval, etc.), and assess tailored results in real-time. The usability of the developed application was preliminary tested in six potential users by quantitative assessment using the System Usability Scale, reaching a score equal to 82.92, with further evaluations by Notified Bodies underway.

To enhance risk assessment, we proposed redefined pharmacovigilance indices, like the Proportional Reporting Ratio and Reporting Odds Ratio, applied to a subset of the centralized FSN dataset focusing on orthopaedic prostheses. This helped to identify device subcategories and manufacturers with higher risk profiles within the same EMDN level. Comparative analyses with other real-world data sources, such as registries and scientific literature, demonstrated that each source is complementary to each other as it can identify unique safety concerns. For instance, 55% of total knee implants were jointly identified by both FSNs and registry data, while each source also detected unique safety signals. Furthermore, 70% of a randomly selected group of hip and knee prostheses had at least one safety signal across different sources, each providing distinct insights. In a different application scenario focused on implantable pacemakers, both literature and FSNs identified overlapping issues as well as source-specific problems.

By leveraging NLP, we demonstrated the potential of IT tools applied to the medical device regulatory field, by developing the scalable and efficient CORE-MD PMS Tool, capable of providing a unified platform with practical utility for real-world insights. The tool has been designed to support key stakeholders, including manufacturers and Expert Panels, by enabling trend visualization and efficient data retrieval. By integrating such derived information with different real-world data sources, such as registries and literature, the CORE-MD PMS Tool can enhance risk assessment, improve early safety signal detection, and support informed regulatory decision-making. This multi-source and data-driven approach creates a solid foundation for proactive PMS, as well as future advancements toward evidence-based practices and informed decision-making in the field of regulatory science.