Feasibility of Using Common Data Model for Orthopedic Research: Analysis of Risk Factors for Periprosthetic Joint Infection after Total Joint Arthroplasty

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Abstract

Background: Common data model (CDM) is a standardized data structure defined to efficiently use different sources in hospitals. A study using the CDM is scarce for orthopedic outcome researches due to the complexity of variables. We aimed to test the feasibility of applying CDM in the orthopedic field and analyzed risk factors for periprosthetic joint infection (PJI) after total joint arthroplasty (TJA) using CDM.

Methods: We undertook a retrospective cohort study of all primary and revision hip and knee TJAs at our institution from January 2003 to October 2017. We identified potential risk factors for PJI after TJAs in the literatures, which included preoperative demographic/social factors, previous medical history, intraoperative factors, laboratory results and others. The data sourced from EMR was extracted, transformed, and loaded into CDM.

Results: Variables such as demographic/social factors, medical history and laboratory results could be converted into CDM, but the other known risk factors could not. In total, 12,320 primary hip and knee TJAs and 120 revision arthroplasties were identified. Among them, 34 revisions were done because of PJI. Risk factors of PJI were hypertension and urinary tract infection after total hip arthroplasty, and age (70-79 years), male sex, anemia, steroid use, and urinary tract infection after total knee arthroplasty.

Conclusions: This study demonstrates that orthopedic outcome researches using CDM is feasible although data converting to CDM was possible for limited factors. Further data transforming technologies need to be developed to analyze more factors relevant to orthopedic area, such as intraoperative factors and imaging findings.

Background

Research using medical information has been actively carried out through the development of the information technology (IT). Commonly, electronic medical records (EMR) or administrative claims databases have been widely used for observational studies of clinical data. However, inconsistent data formats make large-scale clinical research collaboration between hospitals difficult and take a lot of time and effort. Thus, the need for standardization of EMR data is considered important in the medical field. The development of standard clinical information models is an attempt to tackle the storage and exchange of clinical data. Some researchers have shown that analyzing EMR data using standard-based methods is economical and improves efficiency [21, 25]. Common Data Model (CDM) allows for the systematic analysis of disparate observational databases. The concept is to transform different data into a standardized common data format by coding schemes and terminologies.

Total joint arthroplasty (TJA) is a commonly performed orthopedic procedure that can improve quality of life in patients with advanced arthritis. Over the past two decades, the number of TJAs has increased exponentially [7]. However, periprosthetic joint infection (PJI), which is the most serious complication of TJA, can result in severely limited joint function and increased mortality. Many studies have attempted to identify risk factors for PJI, which include rheumatoid arthritis, diabetes, renal disease, depression,
hypercholesterolemia, anemia, urinary tract infection, hypertension, age, male, obesity, smoking, steroid use, blood transfusion, prolonged operative time, wound problem, and malnutrition [1, 2, 4, 6, 8–10, 15–17, 20, 24, 26–28, 30, 34]. However, only a few of them have considered multiple risk factors [2, 4, 6, 8, 27, 34]. Furthermore, results obtained from different studies examining the same risk factor have reported conflicting results [29].

Although several studies have been performed for orthopedic outcome researches using EMR or administrative claims databases, studies using CDM is scarce due to the complexity of variables in the orthopedic field. Therefore, we wanted to test the feasibility of applying CDM in the orthopedic research, especially for evaluation of risk factors of PJI. As such, the purposes of this study were, 1) to apply standard CDM methods and algorithms to an observational orthopedic research, and to identify problems in converting EMR parameters into CDM, and 2) to evaluate risk factors of PJI when analyzed by CDM.

Methods

Patients

We obtained approval from Institutional Review Board (IRB) for this retrospective review of medical records. We included patients who underwent primary TJAs (hip and knee) from January 2003 to October 2017 at our institution, which is a referral, training hospital located in an urban area in South Korea. We first identified cases of revision after TJA by using the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) diagnosis codes in EMR. The reasons for revision were periprosthetic joint infection (PJI), loosening, prosthesis failure, periprosthetic fracture, osteolysis, and dislocation. Then we identified cases of PJI from the revision cases and focused on the risk factors of PJI (Fig. 1). The patients with prior primary or revision surgery at outside hospitals were excluded. Staged revision procedures for infection were counted only once.

Risk factors for PJI

We searched for all possible risk factors for PJI in the literatures[2, 3, 13, 29, 34] and collected the following clinical data: preoperative demographic/social factors (age and sex), previous medical history (comorbidities and drug history), intraoperative factors (operative time, oxygenation, preparation, skin closure, and blood transfusion), laboratory results (albumin, cholesterol, blood cell counts, inflammatory markers, etc.) and others (admission days, observation duration, and venous thromboembolism prophylaxis). Among these data, we identified items that could be converted to CDM to test the feasibility. All clinical data abstracted were at the time of primary TJA.

Conversion of EMR parameters to CDM

The algorithm that EMR data converted to CDM is as follows; mapping EMR to standard concepts, extraction-transformation-loading (ETL) of patient data into CDM, and evaluation of the CDM-based results [11](Fig. 2). The coding system used for diagnosis in the EMR is an ICD-10 code, whereas the
standard concept of CDM for diagnosis is based on the Systematized Nomenclature of Medicine Clinical Terms (SNOMED-CT) [31]. Although most codes was mapped to CDM through the SNOMED-CT, the standard concepts of CDM for drug exposure was based on the RxNorm from the US National Library of Medicine for medications [19]. However, all of codes in EMR were not corresponded to mapping in the CDM version available at the time of this research. Therefore, we conducted to find the corresponding CDM code with the mapped code, which was then re-grouped to obtain the desired value from the code in the CDM. To ensure minimal grouping errors and minimal information loss, four authors reviewed the concept mappings and achieved agreement by consensus.

To perform mapped patient data into CDM, extraction, transformation, and loading (ETL) process is required. We performed the ETL process on five tables. Five core tables are involved in our data loading: person [demographic characteristics], condition occurrence [medical history], measurement [laboratory results], procedure occurrence [procedures], and drug exposure [drug use] (Fig. 3).

To load patient data into CDM, we developed the ETL scripts as a form of Standard Query Language (SQL) according to study design, and performed them as actual ETL process (Fig. 4).

**Statistical analysis**

For categorical variables, chi-squared and fisher’s exact test were performed using PJI as a dependent variable and each parameter as an independent variable. For blood results two variables (low vs. high) were generated based on the reference ranges used by our hospital laboratory and analyzed as categorical variables. Continuous variables were analyzed by using t-tests and categorical variables by chi-square tests. We performed logistic regression analysis to identify risk factors associated with PJI. Odd ratios (OR) and 95% confidence intervals (CI) were calculated using R package for Windows with the level of significance set at P < 0.05. We also calculated adjusted OR using the propensity score matching for age and sex to reduce selection bias. We used MatchIt package to conduct propensity score matching with a ratio of one to five.

**Results**

**Patient characteristics**

A total of 12,320 primary TJAs (4,758 total hip arthroplasties (THAs) and 7,562 knee total knee arthroplasties (TKA)) were identified from January 2003 and October 2017. The most common cause was osteoarthritis (THA, 1040; TKA, 7305). Others cause included inflammatory arthritis, avascular necrosis, congenital dysplasia, fracture, ankylosis, dislocation, instability. There were 120 revision surgeries (1%, 120/12,320) including 71 after THA (1.5%) and 49 TKA (0.7%). The most common causes for revision after THA were loosening (21 cases, 27.3%), followed by PJI (16 cases, 20.8%), periprosthetic fracture (16 cases, 20.8%), prosthesis failure (11 cases, 14.3%), dislocation (10 cases, 13%), and osteolysis (3 cases, 3.9%). For TKA, loosening (28 cases, 52.8%) was also the most common cause for
revision, followed by PJI (18 cases, 34%), osteolysis (3 cases, 5.7%), prosthesis failure (3 cases, 5.7%), and periprosthetic fracture (1 case, 1.9%) (Table 1).

| Causes of primary and revision total hip and knee arthroplasty |
|---------------------------------------------------------------|
| **Primary arthroplasty (n = 12320)**                          | **Revision arthroplasty (n = 120)**                     |
| Hip (n = 4758)                                                 | Hip (n = 71)                                           |
| Knee (n = 7562)                                                | Knee (n = 49)                                          |
| **Diagnoses**                                                 | **Diagnoses**                                         |
| **Number**                                                    | **Number**                                            |
| AVN                                                          | AVN                                                    |
| 1648 (36.5%)                                                  | 62 (0.8%)                                             |
| OA                                                           | Prosthetic failure                                    |
| 7305 (92.8%)                                                  | 11 (14.3%)                                            |
| Fracture                                                      | Periprosthetic fracture                               |
| 1063 (23.5%)                                                  | 16 (20.8%)                                            |
| RA                                                           | Osteolysis                                            |
| 366 (4.7%)                                                    | 3 (5.7%)                                              |
| OA                                                           | RA                                                    |
| 1040 (23%)                                                    | 366 (4.7%)                                            |
| Inflammatory arthritis                                       | AVN                                                   |
| 186 (4.1%)                                                    | 62 (0.8%)                                             |
| Traumatic OA                                                 | Prosthetic failure                                    |
| 76 (1%)                                                       | 11 (14.3%)                                            |
| OA                                                           | Periprosthetic fracture                               |
| 177 (3.9%)                                                    | 16 (20.8%)                                            |
| Inflammatory arthritis                                       | Osteolysis                                            |
| 35 (0.5%)                                                     | 3 (5.7%)                                              |
| RA                                                           | Dislocation                                           |
| 148 (3.3%)                                                    | 10 (13%)                                              |
| Congenital dysplasia                                         | Periprosthetic fracture                               |
| 10 (0.1%)                                                     | 1 (1.9%)                                               |
| Dislocation                                                  |                                                      |
| 100 (2.2%)                                                    |                                                       |
| Ankylosis                                                    |                                                      |
| 80 (1.8%)                                                     |                                                       |
| Traumatic OA                                                 | Fracture                                              |
| 41 (1%)                                                       | 3 (0.03%)                                              |
| Traumatic AVN                                                |                                                        |
| 28 (0.6%)                                                     |                                                        |
| Instability                                                  |                                                        |
| 4 (0.1%)                                                      |                                                        |
| Gout                                                         |                                                        |
| 1 (0.02%)                                                     |                                                        |

AVN, avascular necrosis; OA, osteoarthritis; RA, Rheumatoid arthritis; PJI, periprosthetic joint infection
Conversion of EMR parameters to CDM

EMR variables such as demographic/social factors (age, sex), previous medical history (comorbidities, drug history), laboratory results (albumin, cholesterol, blood cell counts, inflammatory markers, etc.) and admission days were converted into CDM. However, intraoperative factors (operative time, oxygenation, preparation, skin closure, and blood transfusion) and others (observation duration, and venous thromboembolism prophylaxis) could not be converted to CDM (Table 2).

| Category                        | Parameter                  | Conversion to CDM (Yes/No) | Obstacles to conversion                                      |
|---------------------------------|----------------------------|----------------------------|--------------------------------------------------------------|
| Demographic factors             | Age                        | Yes                        |                                                              |
|                                 | Sex                        | Yes                        |                                                              |
| Previous medical history        | Comorbidities              | Yes                        |                                                              |
|                                 | Drug history               | Yes                        |                                                              |
| Laboratory results              |                            | Yes                        |                                                              |
| Intraoperative factors          | Operative time             | No                         | No corresponding CDM code                                   |
|                                 | Oxygenation                | No                         | No corresponding CDM code                                   |
|                                 | Preparation                | No                         | No mapping of terminology code in EMR                       |
|                                 | Skin closure               | No                         | No EMR data                                                 |
|                                 | Blood transfusion          | No                         | No corresponding CDM code                                   |
| Others                          | Admission days             | Yes                        |                                                              |
|                                 | Observation duration       | No                         | No corresponding CDM code                                   |
|                                 | Venous thromboembolism     | No                         | No mapping of terminology code in EMR                       |

CDM, common data model; EMR, electronic medical records

Risk factors of PJI
Among the variables that could be converted to CDM, hypertension (OR, 4.6; 95% CI, 1.7–12.7; Adjusted OR, 9; 95% CI, 2.7–30.6) and urinary tract infection (OR, 14.6; 95% CI, 3.2–66.3; Adjusted OR, N/A) were found to be associated with PJI after THA.

For TKA, age bracket of 70 to 79 years (OR, 5.4; 95% CI, 1.9–15.2), male (OR, 5.7; 95% CI, 2.1–15.2), anemia (OR, 12.2; 95% CI, 2.8–54.1), steroid use (OR, 4.4; 95% CI, 1.3–15.1), and urinary tract infection (OR, 13.7; 95% CI, 3.1–60.7) were found to be associated with PJI. We identified that anemia, steroid use and UTI were equally significant factors after adjustment (Table 3, 4, Additional file 1). However, there was no evidence of any significant associations of PJI with laboratory results (Additional file 2).
Table 3
Demographic factors as risk factors of PJI

| Category | Risk factor | Hip | Knee |
|----------|-------------|-----|------|
|          |             | Revision | Non-revision | P-value | Odds Ratio (95%CI) | Revision | Non-revision | P-value | Odds Ratio (95%CI) |
| Demo-     | Mean Age (years) | 62.8 | 59.8 | 71.4 | 66.7 |
|graphic    |              |      |      |      |      |
| factors   | Age          | 2    | 18   | 0.384 | 1.6 (0.4 ~ 7.1) | 1        | 1        | 0.532 | 1.4 (0.2 ~ 10.3) |
|          | 10–19        | 2    | 160  | 1     | 0.287 (4.2 ~ 0.8) | 13       | 4        | 0.000 | 5.4 (1.9 ~ 15.2) |
|          | 20–29        | 4    | 411  | 1     | 0.287 (4.2 ~ 0.8) | 3        | 25       | 0.002 | 0.2 (0.1 ~ 0.6)  |
|          | 30–39        | 3    | 585  | 1     | 0.287 (4.2 ~ 0.8) | 1        | 310      | 1      | 0.6 (0.1 ~ 3.8)  |
|          | 40–49        | 2    | 762  | 1     | 0.752 (0.6 ~ 5.9) | 2439     | 3945     | 1      | 0.5 (0.1 ~ 3.8)  |
|          | 50–59        | 3    | 775  | 1     | 0.732 (0.6 ~ 5.9) | 780      | 9        | 1      | 0.5 (0.1 ~ 3.8)  |
|          | 60–69        | 10   | 1011 | 1     | 0.732 (0.6 ~ 5.9) | 780      | 9        | 1      | 0.5 (0.1 ~ 3.8)  |
|          | 70–79        | 8    | 805  | 1     | 0.732 (0.6 ~ 5.9) | 780      | 9        | 1      | 0.5 (0.1 ~ 3.8)  |
|          | 80–89        | 15   | 156  | 1     | 0.6 (0.1 ~ 2.5)  | 54       | 156      | 1      | 0.6 (0.1 ~ 2.5)  |
|          | 90–99        | 4    | 4    | 2.5   | 1.2 (0.3 ~ 4.3)  | 123      | 123      | 1      | 1.2 (0.3 ~ 4.3)  |
|          | 100–109      | 0    | 0    | 0.0    | 1.2 (0.3 ~ 4.3)  | 123      | 123      | 1      | 1.2 (0.3 ~ 4.3)  |
|          | 110–119      | 0    | 0    | 0.0    | 1.2 (0.3 ~ 4.3)  | 123      | 123      | 1      | 1.2 (0.3 ~ 4.3)  |
|          | >120         | 0    | 0    | 0.0    | 1.2 (0.3 ~ 4.3)  | 123      | 123      | 1      | 1.2 (0.3 ~ 4.3)  |
| Male sex | 9            | 2022 | 0.188 | 2.0 (0.7 ~ 56) | 6        | 608      | 0.002 | 5.7 (2.1 ~ 15.2) |

Boldface indicates statistical significance.
Table 4
Previous medical history as risk factors of PJI

| Category                      | Risk factor | Adjusted hip group | Adjusted knee group |
|-------------------------------|-------------|--------------------|---------------------|
|                               |             | Revisio (n = 16)   | Non-revisio (n = 80) | P-value | Odds Ratio (95%CI) | Revisio (n = 18) | Non-revisio (n = 90) | P-value | Odds Ratio (95%CI) |
| Previous medical history      | HTN         | 8                  | 8                   | 0.0006 | 9 (2.7 ~ 30.6)   | 9                | 30                   | 0.1789 | 2 (0.7 ~ 5.6)   |
|                               | Anemia      | 1                  | 0                   | 2       | 0.0264 NA        | 2                | 0                   | 0.0039 | NA               |
|                               | Steroid use | 0                  |                    | 3       | 0.0039 NA        | 3                | 0                   | 0.0264 | NA               |
|                               | UTI         | 2                  | 0                   | 0.0263 | NA               | 2                | 0                   | 0.0264 | NA               |

HTN, hypertension; UTI, urinary tract infection

Boldface indicates statistical significance.

Detailed information on the Table 4 is given in Additional file 1.

Discussion

Rationale, Summary, Significance

We aimed to test the feasibility of applying common data model (CDM) in the orthopedic field and analyzed risk factors for periprosthetic joint infection (PJI) after total joint arthroplasty. Variables such as demographic/social factors, medical history, laboratory results and admission days could be converted into CDM, but the others such as intraoperative factors, observation duration, and venous thromboembolism prophylaxis could not be converted to CDM. When analyzed by using CDM, we found that hypertension and urinary tract infection were risk factors of PJI after THA, and age bracket of 70 to 79 years, male, anemia, steroid use and urinary tract infection were risk factors of PJI after TKA. This study demonstrates orthopedic researches using CDM is feasible although data converting to CDM was possible for limited factors.

Conversion of EMR parameters to CDM

The CDM is designed to include all observational data derived from the EMR to support the generation of reliable evidence [11, 25]. It is important to obtain what we want from the study by properly designing the algorithm with the parameters currently available in the CDM. Creating mappings the variable EMR data
into the target CDM concepts is also crucial to improve patient data standardization [14, 22]. Thus, in previous studies, cohort studies have been mainly focused on the pharmacoepidemiological research as treatment of diseases and epidemiological analysis of deaths from certain diseases [11, 12, 19, 23, 32, 33]. In our case, we focused on parameters related to risk factors for PJI after TJA and constructed the algorithm directly using SQL, not through programs already created within the CDM, to achieve the desired results in our study. Of course, the code mapping process was not easy. Four authors reviewed the code mapping, but because of incomplete concepts matching and difference between the coding systems, a little information loss was inevitable. In addition, the data in EMR are typically expressed in non-standard terms, and the textual variable values are often in free-style using different local expressions, we could not standardize these terms and the textual values into standard concepts in this study.

The main advantages of research using CDM is that such studies can be conducted on a larger scale, against lower costs, and within shorter time frames than traditional studies [5]. Also, it protects the privacy and security of patients in research because not the information of a certain patient but the information of a certain result is used in CDM tool [25]. In our study, to maintain patient confidentiality privacy and security, the original patient identifications were removed when the patient data were converted to the CDM. The CDM is also an important part of multi-organization collaborative research [19, 22]. Because each hospital has a different structure in patient information, it is necessary to cooperate with multiple hospitals to provide information for standardization of patient information through CDM tool. However, differences in data structures and coding system are still major barriers to standardize data in CDM tool [31].

**Risk factors of PJI**

In this study, hypertension was identified as a significant risk factor of PJI after THA, which is concurrent with some studies [1, 2, 6, 30]. The studies demonstrated that hypertension is associated with delayed wound healing following TJA.

Urinary tract infection (UTI) was a significant risk factor of PJI after both THA and TKA in this study. Usually, UTI is more common in women than in men and the reported prevalence of UTI in women undergoing primary TJA ranges from 5.1–36% [4, 6, 9, 26]. Therefore, symptomatic UTI should be treated before proceeding TJA.

We found an association between age and risk of revision, which is consistent with previous findings [5, 7, 17–21]. Although older patient age would seem to coincide with poorer nutritional status and thus elevated infection risk, some studies reported an increased risk of revision for relatively younger patients [7, 17, 18, 22].

This study found that a male sex was a significant risk factor of PJI after TKA, which coincides with some studies [3, 6, 15, 27, 29]. A study suggested that men can get a greater degree of surgical trauma and tissue necrosis than in women [27]. Also, men have a more active life-style than women after TJA.
Therefore, differences in exercise volume can cause overuse differences after TJA, which may result in revision surgery.

In this study, preoperative anemia was also associated with risk factors of PJI after TKA. Anemia is usually associated with a patient’s poor nutritional status. Previous literatures have shown that primary TJA patients who have preoperative anemia are more likely to receive blood transfusions, which are associated with an increased risk of postoperative infection [2, 4, 8–10]. Therefore, patients should be preoperatively evaluated for causes of anemia, such as iron deficiency, and considered for recombinant human erythropoietin treatment in order to decrease the risk of PJI [8, 10].

We also found steroid use as a risk factor of PJI after TKA, which is consistent with previous literatures [2, 6, 18, 28]. The association between steroid use and PJI is likely to be mediated at least in part by impaired wound healing due to the anti-inflammatory and immuno-suppressive effects of steroids [20]. In addition, steroid use can cause problems of calcium and vitamin D metabolism, zinc deficiency, and most importantly an accelerated bone mineral loss [16].

**Limitations of study**

There are several limitations to our study that must be noted. First, although the study objective was to utilize a CDM to identify risk factors of PJI after TJA, we couldn’t analyze all of them that have been reported in the literature. We couldn’t use non-matching EMR code in CDM. In our further study, we will continue improving the scalability of the converting variable data to CDM. Further data transforming technologies need to be developed to analyze more factors relevant to orthopedic area, such as intraoperative factors and imaging findings. Second, the subjects were from a single institution and our methodology has not been tested with other uses. The research of CDM designed for one use might lack credibility in terms of methodology. Therefore, the generalizability still needs to be confirmed. We will conduct subsequent research to use multi-center data for large-scale analysis and further validate our methods.

**Conclusions**

This study presents an approach to achieve semantic standardization among different clinical data sources by using CDM in the orthopedic field. Although data converting to CDM was possible for limited factors, we could propose reusable data transforming method. Therefore, it may differ for other uses and associated data element sets, but we consider that the methodology reported here can be applied to other researches in the orthopedic field.

**Abbreviations**

EMR: Electronic medical records; CDM: Common data model; TJA: Total joint arthroplasty; THA: Total hip arthroplasty; TKA: Total knee arthroplasty; PJI: Periprosthetic joint infection; ETL: Extraction-
Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Seoul National University Bundang Hospital. We have obtained the written informed consent for participation in the study from all participants.

Consent for publication

Not applicable.

Availability of data and materials

All relevant data are included in this manuscript. Additional data may be requested by contacting the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

YJC, HSG participated in the design of the study. YJC, JHS measured the data. YJC, SJJ, HSG were responsible for the statistical analysis of the study. All authors contributed to the writing of the manuscript.

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Additional Files

The additional files for this article can be found as follows:

Additional file 1. Previous medical history and others related risk factors for revision due to PJI after primary TJAs.

Additional file 2. Laboratory results related risk factors for revision due to PJI after primary TJAs.

Figures
**Figure 1**

The patient selection flow chart.

**EMR data** ➔ **CDM** ➔ **CDM based analysis results**

- Standard concept mapping
  - (SNOMED-CT, RxNorm)

**Figure 2**

The algorithm that electronic medical records (EMR) data converted to common data model (CDM).
Figure 3

Extraction, Transformation, and Loading (ETL) process.

```
SELECT PROCEDURE_OCCURRENCE_ID, PERSON_ID,
    PROCEDURE_CONCEPT_ID, PROCEDURE_DATE,
    PROCEDURE_DATETIME, PROCEDURE_SOURCE_VALUE,
    MH(NEW) AS MH_1, MH(SAJ) AS MH_2, MH(Liver) AS Liver, MH(Aneinia) AS Aneinia,
    MH(Hypercho) AS Hypercho, MH(Depression) AS Depression, MH(Coagulation) AS Coagulation,
    MH(Heart) AS Heart, MH(Previous) AS Previous, MH(On) AS On,
    MH(Renal) AS Renal, MH(Pulmonary) AS Pulmonary, MH(FIB_PROC_DATE) FIB_PROC_DATE
FROM (SELECT A.*,  
    LSN_1.DEV FROM (PARTITION BY A.PERSON_ID, BM, ORDER BY A.PROCEDURE_DATE ASC) LSN_1
    CASE WHEN DEV = 'PRIMARY' AND LSN_1.DEV = 'PRIMARY' THEN 'REVISED_Y' ELSE 'REVISED_Y' END REVISED_Y
    CASE WHEN DEV = 'RA' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS RA
    CASE WHEN DEV = 'Liver' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Liver
    CASE WHEN DEV = 'Aneinia' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Aneinia
    CASE WHEN DEV = 'Hypercho' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Hypercho
    CASE WHEN DEV = 'Depression' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Depression
    CASE WHEN DEV = 'Coagulation' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Coagulation
    CASE WHEN DEV = 'Heart' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Heart
    CASE WHEN DEV = 'Previous' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Previous
    CASE WHEN DEV = 'On' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS On
    CASE WHEN DEV = 'Renal' AND CONDITION_START_DATE = FIB_PROC_DATE THEN CONDITION_START_DATE END AS Renal
    CASE WHEN DEV = 'Pulmonary' AND CONDITION_START_DATE = FIB_PROC_DATE THEN 'Pulmonary'
FROM (SELECT A.*,  
    'REVISED_Y' REVISED_Y FROM PROCEDURE_OCCURRENCE_REV a
    UNION ALL
    SELECT A.*, 'REVISION' REVISED_Y FROM PROCEDURE_OCCURRENCE_REV a
FROM (SELECT A.*,  
    RHV.RHV FROM (PARTITION BY PERSON_ID, RHV.RHV ORDER BY CONDITION_DATE ASC) RHV
    FROM CONDITION_OCCURRENCE_OBSERV a B ON A.PERSON_ID=B.PERSON_ID AND B.REV=1
LEFT OUTER JOIN (select a.*,  
    nhv.nhv FROM (PARTITION BY nhv.nhv, nhv.nhv ORDER BY CONDITION_DATE ASC) nhv
    FROM nhv.nhv nhv
    FROM nhv.nhv NHV
    WHERE nhv.REV='REVISED_Y'
GROUP BY nhv.nhv
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