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Original Research

Using natural language processing to explore characteristics and management of patients with axial spondyloarthritis and psoriatic arthritis treated under real-world conditions in Spain: SpAINET study

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Abstract

Background: Spondyloarthritis (SpA) is a group of related but phenotypically distinct inflammatory disorders that include axial SpA (axSpA) and psoriatic arthritis (PsA). Information on the characteristics and management of these patients in the real world remains scarce.

Objectives: To explore the characteristics and management [disease activity assessment and treatment with secukinumab (SEC) or other biologic disease-modifying antirheumatic drugs (bDMARDs)] of axSpA and PsA patients using natural language processing (NLP) in Electronic Health Records (EHRs).

Design: National, multicenter, observational, and retrospective study.

Methods: We analyzed free-text and structured clinical information from EHR at three hospitals. All adult patients with axSpA, PsA or non-classified SpA from 2018 to 2021 with minimum follow-up of three months were included when starting SEC or other bDMARDs. Clinical variables were extracted using *EHRead*® technology based on Systemized Nomenclature of Medicine-Clinical Terms (SNOMED CT) terminology.

Results: Out of 887,735 patients, 758 were included, of which 328 had axSpA [58.5% male; mean (SD) age of 50.7 (12.7) years], 365 PsA [54.8% female, 53.9 (12.4) years], and 65 non-classified SpA. Mean (SD) time since diagnosis was 36.8 (61.0) and 24.1 (35.2) months for axSpA and PsA, respectively. Only 116 axSpA patients (35.3%) had available Ankylosing Spondylitis Disease Activity Score (ASDAS) or Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) at bDMARD onset, of which 61 presented active disease. Disease Activity in PSoriatic Arthritis (DAPSA) or Disease Assessment Score - 28 joints (DAS-28) values at bDMARD onset were available for only 61 PsA (16.7%) patients, with 23 of them having active disease. The number of patients with available tender joint count or swollen joint count assessment was 68 (20.7%) and 59 (18%) for axSpA, and 115 (31.5%) and 119 (32.6%) for PsA, respectively. SEC was used in 63 (19.2%) axSpA patients and in 63 (17.3%) PsA patients.

Conclusion: Using NLP, the study showed that around one-third of axSpA and one-sixth of PsA patients have disease activity assessments with ASDAS/BASDAI or DAPSA/DAS-28, respectively, highlighting an area of improvement in these patients' management.

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Plain language summary

Investigating axial spondyloarthritis and psoriatic arthritis patients using natural language processing

We conducted a study in Spain to better understand patients with specific rheumatic conditions known as axial spondyloarthritis (axSpA) and psoriatic arthritis (PsA). To analyze their characteristics, we used a computer technology called EHRead, which uses Natural Language Processing (NLP) to analyze free text from electronic health records. Out of a large group of patients, we focused on 758 individuals who had axSpA or PsA. Most of the axSpA patients were men, and they were around 51 years old on average. For the PsA patients, most were women, and their average age was about 54 years. We analyzed outcomes and treatments of these patients. Our findings showed that we can describe and assess a cohort of patients from real world using NLP. Besides, only about one-third of axSpA patients and one-sixth of PsA patients had their respective outcomes completely assessed, which indicates that there is potential room for improvement in the management of axSpA and PsA. The most promising feature in our study is the use of NLP, an artificial intelligence technology that helps us understand information in medical records written in free text. This can help us explore the characteristics of patients and their management in the real world, bringing an opportunity to enhance the care of patients with axSpA and PsA.

Keywords: axial spondylarthritis, bDMARDs, natural language processing, psoriatic arthritis, secukinumab, spondyloarthritis

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Introduction

Spondyloarthritis (SpA) is a diverse group of inflammatory rheumatic disorders that share certain genetic predisposing factors and clinical features. SpA are characterized by axial and/or peripheral arthritis, and are often associated with enthesitis, dactylitis and extra-musculoskeletal manifestations, such as uveitis or psoriasis. Axial SpA (axSpA) and psoriatic arthritis (PsA) are the most frequent SpA subtypes, with prevalence rates estimated at 0.3% and 0.6% in Spain, respectively.[1,2]

Current guidelines[3,4] for managing patients with SpA recommend treating patients according to a predefined treatment target. In this regard, the validated tool Ankylosing Spondylitis Disease Activity Score (ASDAS) ≥ 2.1 indicating high disease activity or, alternatively, the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI ≥ 4 indicating high disease activity have been proposed to assess the level of disease activity in axSpA during the patient follow-up. Similar scores for PsA have been also previously described as the Disease Activity in PSoriatic Arthritis (DAPSA) or the Disease Activity Score (DAS). In rheumatology, composite indices are commonly used and are useful as a complement to the clinical history and specific tests. However, most of the studies evaluating the use of disease activity assessments either have prospective designs or offer descriptive analyses of those scores, focusing on specific populations with available data. Moreover, the choice to use the assessments by the medical professional is based on their experience and on the adaptation to the objective sought,[5] so little is known about their daily use.

Based on disease activity indices as a treatment target, guidelines recommend first-line nonsteroidal anti-inflammatory drugs (NSAIDs) for axSpA treatment, and tumor necrosis factor inhibitors (TNFi) or IL-17 inhibitor (IL-17i) as first biologic disease-modifying antirheumatic drug (bDMARD) in those cases with persistent disease activity or insufficient response.[3,4] Recommendations for PsA treatment include NSAIDs, local glucocorticoid injections, and conventional synthetic DMARDs (csDMARD) in patients with arthritis and poor prognostic factors. Therapy with bDMARDs, such

as TNFi, IL-17i or IL-12/23 inhibitors, is reserved for PsA patients who have failed to previous treatment options, according to the European Alliance of Associations for Rheumatology (EULAR) recommendations.[6] On the other hand, the Group for Research and Assessment of Psoriasis and Psoriatic Arthritis recommends that the choice of bDMARDs should be based on considering the treatment that covers the higher number of domains, with IL-17i being recommended as the bDMARDs of choice for each of the core PsA domains.[7] Secukinumab (SEC) is a first-class human monoclonal antibody targeting IL-17A and has demonstrated efficacy and safety in different double-blind, placebo-controlled phase III randomized clinical trials (RCT) in both PsA[8–12] and axSpA[13–21] populations. So far, over 750,000 patients in the real world have been treated with SEC. However, despite results from RCTs have been confirmed in some studies conducted in the clinical practice setting,[22–25] the real-world data and evidence of SEC is still scarce.

RCTs provide meaningful information on drug safety and efficacy. They report activity disease indexes prospectively recorded according to study protocols, but do not reflect real-life patients due to their narrow inclusion criteria. Moreover, their brief follow-up periods make their findings difficult to apply to routine clinical practice. Complementarily, studies using real-world data from Electronic Health Records (EHRs) provide key information on patients' characteristics, drug performance and patient follow-up under real-world conditions.[26,27] This unique source of information allows to explore the gap of what is occurring in the real setting, when information is not prospectively collected. However, most of the information on EHRs is written by physicians in free textboxes and is therefore recorded in an unstructured format, hampering its use for research purposes.

Innovations in natural language processing (NLP) and machine learning (ML) hold great potential for processing format-free text data,[28,29] including that of EHRs. These tools might enable the identification of large cohorts of patients meeting research needs in a non-labor-intense manner, which is especially difficult in relatively uncommon conditions, such as axSpA and PsA.[30,31] Existing literature demonstrate the utility of NLP in identifying axSpA patients, and similar technologies have been used to assess outcomes in rheumatic conditions like rheumatoid arthritis.[30–33] However, there is a conspicuous absence of research employing NLP methods in axSpA or PsA and information on the characteristics and management of SpA patients in the real world remains scarce.

In this context, we aimed to characterize patients with axSpA and PsA in the clinical practice, describing their demographic and clinical characteristics as well as their clinical and pharmacological management (including the assessment of disease activity and treatment with SEC or other bDMARDs) through information contained on EHRs extracted using NLP and ML methods.

Methods

Study design

This was a multicenter, retrospective, and observational study based on secondary use of data (free-text and structured clinical information) included in the EHRs. The study was conducted at all available services and departments (including inpatient hospital, outpatient hospital, and emergency service) of three public hospitals in Spain: Hospital Universitario Infanta Sofía (Madrid), Hospital Regional Universitario Carlos Haya (Málaga), and Hospital Clínico Universitario (Valencia). Data from 1st January 2018 to 1st January 2021 was retrieved based on data availability at each center (in all three hospitals data from 2018 and 2019, in two hospitals from 2020, and in one hospital from 2021). The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[34]

Adult patients with available EHRs at the participating hospitals diagnosed with SpA who were receiving or had received bDMARDs and had been followed-up for at least three months were included in the study and stratified in axSpA, PsA or non-classified SpA. Patients who had participated in a RCT during the study period were excluded. Patients included in the axSpA or PsA groups were divided into two groups, those receiving SEC (axSpA-SEC and PsA-SEC) and those receiving other bDMARDs (axSpA-other bDMARD and PsA-other bDMARD). Patients in the treatment subgroups were further classified as experienced (those who had received bDMARDs prior to the one which allowed them to be included in the study) or naïve (those who had not been treated with biologics before). Patients in the non-classified SpA were no longer analyzed.

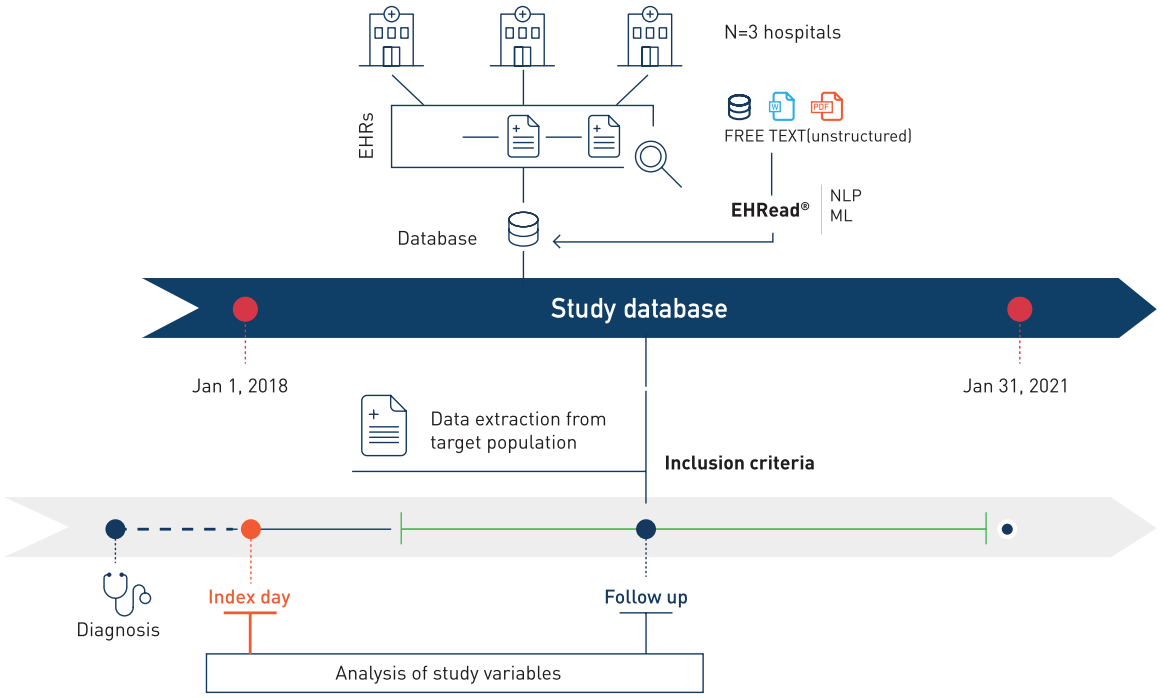

Figure 1. Study design and *EHRead*® workflow.

The date on which patients met all selection criteria was considered the index date. The drug of reference (bDMARDs) for each patient was used to determine the index date. In case of SEC-treated patients, the index date was the date of SEC initiation, even if they had previously received any other bDMARD. The index date for patients treated exclusively with other bDMARDs corresponded to the first time the drug was mentioned in patients' EHRs during the study period (Figure 1). Study variables were collected from the index date until loss of patient follow-up or data collection during the study period. When available, information from the pre-index period was used to describe specific patients' characteristics, such as comorbidities.

Study variables and outcomes

Gender, age, date of diagnosis, symptoms, time since diagnosis, time from first arthropathy symptom to diagnosis, comorbidities, number of affected joints, and visual analogue scale (VAS) scores were collected for all patients at study inclusion. The availability of disease activity indexes [BASDAI or ASDAS for axSpA patients and DAPSA or Disease Assessment Score in 28 joints (DAS-28) for PsA population] was also retrieved. For the description of treatment patterns, prior drugs (from disease diagnosis to the index date) and concomitant drugs (from index to last follow-up or data collection) were assessed among the following: NSAIDs, glucocorticoids, csDMARDs, bDMARDs, and analgesics.

Data source

The source of information was structured and unstructured free-text data, included by medical practitioners in the EHRs of patients.

Data were captured using *EHRead*® technology developed by Medsavana S.L. (Madrid, Spain), which uses NLP and ML techniques to extract, interpret, and translate into usable variables all the information (including numerical values and notes) contained in EHRs.[35–40]

For this purpose, data available at the different participating sites were anonymized and processed using SAVANA's *EHRead*® technology. This NLP technology allows for the extraction and subsequent standardization of clinical concepts to a common terminology. Briefly, *EHRead*® uses a collaborative approach for extracting and processing each study variable. First, each variable was designed by an interdisciplinary team

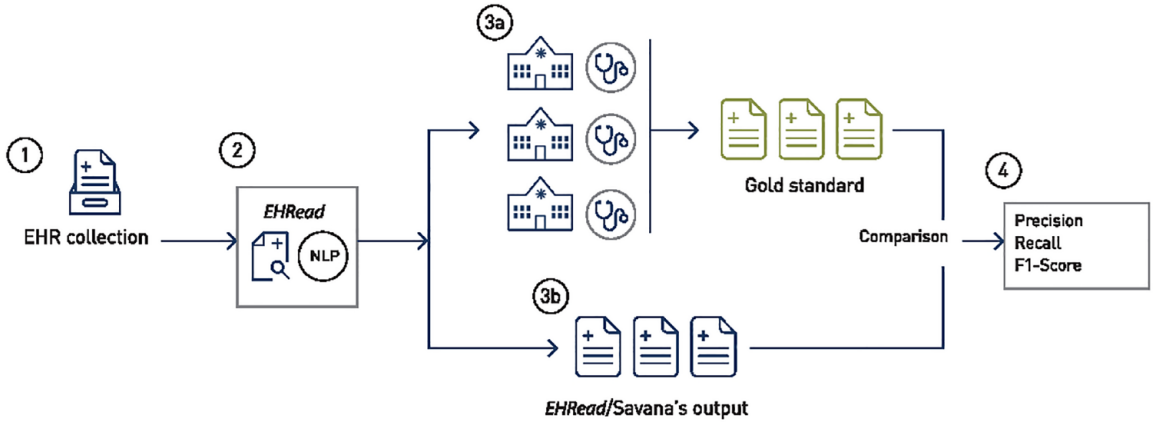

Figure 2. Evaluation process.

comprising medical research experts, clinical data scientists, and NLP experts. Second, the extraction method for the variables was formulated during a specialized NLP development stage. Within this framework, unstructured text was transformed into actionable variables. In this regard, the terminology used by *EHRead*® is based on SNOMED CT (Systemized Nomenclature of Medicine-Clinical Terms), a multilingual medical terminology system that includes codes, concepts, synonyms, subordinate concepts (children), acronyms, and definitions used in clinical documentation.[41] Conceptual definitions of all study variables were pre-specified and mapped to clinical entities present in SNOMED CT using the SNOMED CT browser. Finally, these variables were then integrated into a database *via* a series of NLP and ML modules that were able to attribute context to the clinical terms, both from an intention (the term is either stated in an affirmative way or negated, or is part of a conjecture or opinion) and from a temporal perspective (current or historical). These modules addressed named entity recognition, section identification, temporal analysis, entity disambiguation, along with attribute and negation/speculation.[42] During the process, we ensured that information was not accessible and traceability to individual patients was impossible.

The accuracy of this system has already been verified in different studies by comparing *EHRead*®'s output with a reference or 'study-specific gold standard', which consists of a set of EHRs annotated manually by expert physicians.[38,43–45]

External evaluation of data retrieval

In order to evaluate system's accuracy when identifying EHRs containing mentions of study-related variables, an analysis comparing SAVANA *EHRead*® output with physicians' annotations was carried out. Medical experts together with NLP experts selected the sample of 14 variables for assessment that was representative for the study (SpA, PsA, AxSpA, AS, DAPSA, ASDAS, BASDAI, dactylitis, C reactive protein, enthesitis, etanercept, infliximab, SEC, and adalimumab).

For this process, a set of randomly selected EHRs collected *via EHRead*® were manually annotated by two different physicians from each participating site. When annotations were finalized, a third physician reviewed them and resolved differences, generating a gold standard corpus. Using the gold standard as a reference, the performance of SAVANA *EHRead*® was assessed based on standard metrics, namely precision (P), recall (R) and F-measure (Figure 2) as follows: P = TP/TP + FP; R = TP/TP + FN; and F-measure = 2*P*R/P + R, where TP = true positive (a correctly identified register), FP = false positive (erroneously identified register) and FN = false negative (a register that should have been identified but was not). An average of the metrics for each hospital was calculated for the final analysis.

Data analysis

A descriptive statistical analysis was performed for all study variables. For categorical variables, frequency and percentages are shown, whereas continuous variables are described using the mean

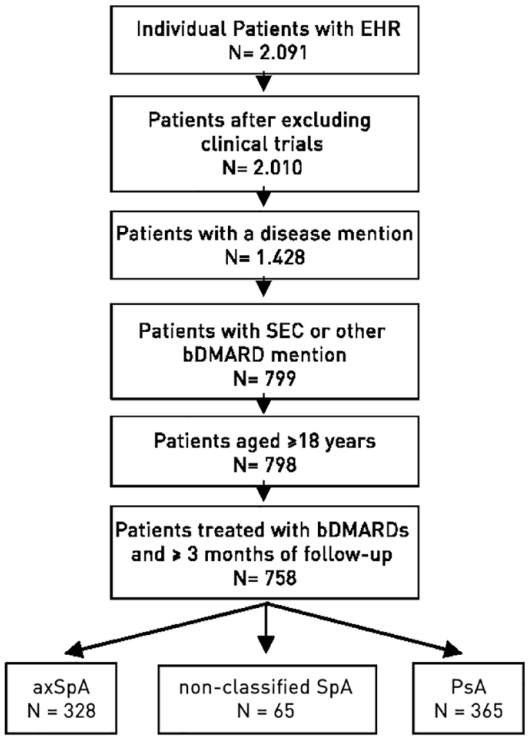

Figure 3. Patient flow.
This figure shows the flow of patients included at each step of the patients' selection process, based on the filters applied at each step.
axSpA, axial Spondyloarthritis.

and the standard deviation (SD) or the median and interquartile range (Q1, Q3). The number of patients with available data for each variable is also provided and percentages are based on the number of non-missing observations.

Results

Patient population

Out of 887,735 patients, a total of 758 patients met selection criteria and were finally included in the study (Figure 3). Among them, 328 (43.3%) were diagnosed with axSpA, 365 (48.2%) with PsA, and 65 (8.6%) with a non-classified SpA subtype.

Baseline demographic and clinical characteristics

Main sociodemographic and clinical characteristics of patients with axSpA and PsA are included in Table 1. Briefly, patients with axSpA were mostly male (58.5%), with a mean (SD) age of 50.7 (12.7) years. Median (Q1, Q3) time since diagnosis to index date was 25.6 (7.2, 45.1) months, with a mean (SD) of 36.8 (61.0) months. Enthesitis was the most common peripheral symptom (24.1%) and 72 (22%) patients presented uveitis. The most prevalent comorbidity in the axSpA population was lung disease (16.5%).

For patients with PsA, the mean (SD) age was 53.9 (12.4) and 54.8% were female. Median (Q1, Q3) time since diagnosis to index date was 17.6 (4.5, 32.7) months, with a mean (SD) of 24.1 (35.2) months. Dactylitis was present in 18.9% of PsA patients, and 75.9% of them suffering from psoriasis. Liver disease (23.0%), lung disease (17.5%), and depression (14%) were the most frequent comorbid conditions in patients with PsA.

Availability of disease activity measurements in EHRs

Baseline ASDAS or BASDAI were detected in 116 patients (35.3%), whereas a valid score with an associated value was detected in the EHRs of 79 (24.1%) axSpA patients. Based on available disease activity indexes, 61 (77.2%) axSpA patients had active disease at index date [Figure 4(a)]. The number of axSpA patients with available Tender Joint Count (TJC) or Swollen Joint Count (SJC) assessment was 68 (20.7%) and 59 (18%), respectively. Mean (SD) pain assessment according to VAS was 5.03 (2.8).

Baseline DAPSA or DAS28 was detected in 61 patients (16.7%), and a specific value for the score was found in the EHRs of only 36 (9.8%) PsA patients, among which 23 (63.8%) had active disease at index date [Figure 4(b)]. The number of PsA patients with available TJC or SJC assessment was 115 (31.5%) and 119 (32.6%), respectively. Mean (SD) pain assessment according to VAS was 4.3 (3.1) in these patients.

Treatment

Of the 328 axSpA patients who were included in the study, 63 (19.2%) patients started SEC treatment during the study period. Among axSpA-SEC, 19 (30.2%) patients were bDMARDs naïve, whereas 44 (69.8%) patients were experienced. Among axSpA treated with other bDMARDs, 216 (81.5%) patients were naïve and 49 (18.5%) patients were experienced. Regarding

Table 1. Demographic and clinical characteristics at index.

Variable	axSpA			PsA		
	axSpA-SEC (63)	axSpA Other bDMARD (265)	Total axSpA (328)	PsA-SEC (63)	PsA Other bDMARD (265)	Total PsA (365)
Gender, male *n* (%)	32 (54.2)	151 (59.4)	183 (58.5)	25 (40.3)	135 (46.2)	160 (45.2)
Age, mean (SD)	50.7 (13.3)	50.6 (12.6)	50.7 (12.7)	47.7 (13.6)	55.2 (11.8)	53.9 (12.4)
Time (months) since diagnosis to index						
N available (%)	59 (93.7)	232 (87.5)	291 (88.7)	53 (84.1)	278 (92.1)	331 (90.7)
Median (Q1, Q3)	25.6 (5.8, 47.7)	25.7 (7.3, 43.7)	25.6 (7.2, 45.1)	18.1 (5.0, 29.0)	17.5 (4.4, 33.8)	17.6 (4.5, 32.7)
Time (months) since first arthropathy symptom to diagnosis						
N available (%)	9 (14.3)	36 (13.6)	45 (13.7)	19 (30.2)	94 (31.1)	113 (31.0)
Median (Q1, Q3)	1.8 (0.4, 3.2)	12.1 (5.8, 27.5)	9.6 (3, 27.1)	6.9 (3.2, 21.6)	7.0 (2.9, 19.3)	6.9 (2.9, 19.5)
Symptoms						
Dactylitis, *n* (%)	5 (7.9)	20 (7.5)	25 (7.6)	11 (17.5)	58 (19.2)	69 (18.9)
Enthesitis, *n* (%)	21 (33.3)	58 (21.9)	79 (24.1)	10 (15.9)	45 (14.9)	55 (15.1)
Psoriasis, *n* (%)	9 (14.3)	43 (16.2)	52 (15.9)	54 (85.7)	223 (73.8)	277 (75.9)
Uveitis, *n* (%)	10 (15.9)	62 (23.4)	72 (22.0)	2 (3.2)	20 (6.6)	22 (6.0)
Comorbidities (>10%)						
Lung disease, *n* (%)	10 (15.9)	44 (16.6)	54 (16.5)	7 (11.1)	57 (18.9)	64 (17.5)
Anxiety, *n* (%)	8 (12.7)	30 (11.3)	38 (11.6)	15 (23.8)	31 (10.3)	46 (12.6)
Liver disease, *n* (%)	8 (12.7)	29 (10.9)	37 (11.3)	21 (33.3)	63 (20.9)	84 (23.0)
Depression, *n* (%)	6 (9.5)	21 (7.9)	27 (8.2)	12 (19.0)	39 (12.9)	51 (14.0)
Hypertension, *n* (%)	3 (4.8)	26 (9.8)	29 (8.8)	8 (12.7)	37 (12.3)	45 (12.3)
Fractures, *n* (%)	4 (6.3)	24 (9.1)	26 (7.9)	8 (12.7)	31 (10.3)	39 (10.7)
Disease activity						
Reported affected joints (non-missing) *n* (%)	14 (22.2)	61 (23)	75 (22.9)	23 (36.5)	112 (37.1)	135 (37)
No. affected joints (⩾1) *n* (%)	7 (50.0)	9 (14.7)	16 (21.3)	17 (27)	59 (19.5)	76 (20.8)

(Continued)

Table 1. (Continued)

Variable	axSpA			PsA		
	axSpA-SEC (63)	axSpA Other bDMARD (265)	Total axSpA (328)	PsA-SEC (63)	PsA Other bDMARD (265)	Total PsA (365)
TJC *n* (%)	14 (22.2)	54 (20.4)	68 (20.7)	21 (33.3)	94 (31.1)	115 (31.5)
⩾1, *n* (%)	7 (50.0)	9 (16.7)	16 (23.5)	16 (76.2)	59 (62.8)	75 (65.2)
Mean (SD)	1.39 (1.96)	0.57 (1.81)	0.74 (1.86)	4.92 (6.05)	3.27 (4.04)	3.57 (4.49)
SJC *n* (%)	11 (17.5)	48 (18.1)	59 (18)	19 (30.2)	100 (33.1)	119 (32.6)
⩾1, *n* (%)	5 (45.4)	5 (10.4)	10 (16.9)	13 (68.4)	52 (52)	65 (54.6)
Mean (SD)	1.23 (1.97)	0.44 (1.84)	0.58 (1.88)	3.16 (4.57)	1.65 (2.39)	1.89 (2.88)
Pain (VAS)						
N available (%)	13 (20.6)	33 (12.5)	46 (14.0)	11 (17.5)	33 (10.9)	44 (12.1)
Mean (SD)	4.7 (2.6)	5.2 (3)	5.0 (2.9)	4.8 (3.6)	4.1 (2.95)	4.3 (3.1)

axSpA, axial SpA; bDMARD, biologic disease-modifying antirheumatic drug; PsA, psoriatic arthritis; SD, standard deviation; SEC, Secukinumab; SJC, Swollen joint count; SpA, Spondyloarthritis; TJC, Tender joint count; VAS, visual analogue scale.

prior treatments, 97.7% of experienced axSpA-SEC patients had been treated with TNFi. The use of previous csDMARDs, NSAIDs, and analgesics in naïve and experienced patients is played in Table 2. SEC was used concomitantly with NSAIDs in 15 (23.8%) axSpA patients. Injectable glucocorticoids were the second most common used concomitant drug in the axSpA population (Table 2).

Among the 365 PsA patients included, 63 (17.3%) patients were treated with SEC, 18 (28.6%) patients of whom were naïve and 45 (71.4%) patients were experienced. In PsA patients treated with other bDMARDs, 220 (72.8%) patients were naïve and 82 (27.2%) patients were experienced. Regarding prior treatments, 84.4% of experienced PsA-SEC users had been treated with TNFi before (Table 3). SEC was used concomitantly with NSAIDs in 15 (23.8%) PsA patients. Similar rates of concomitant csDMARDs and analgesics use are observed (Table 3).

Evaluation of system accuracy

The search terms used to identify EHRs containing mentions of axSpA, PsA, and their disease-related variables are listed in Table 4, as well as precision, recall, and F-measure values obtained for each of them.

EHRead® identified axSpA and PsA with a precision of 0.7 and 0.8, a recall of 0.7 and 0.7, and a F-score of 0.8 and 0.7, respectively.

Discussion

Using NLP and ML techniques, we were able to explore clinical and demographic characteristics of a large series of patients with axSpA and PsA receiving bDMARD in Spain. In summary, 328 patients had a diagnosis of axSpA and 365 of PsA. The average time from diagnosis was 3 and 2 years in axSpA and PsA patients, respectively. Enthesitis was the most common peripheral symptom in patients with axSpA and three-quarters of PsA patients had psoriasis. Most axSpA and PsA patients presented active disease at inclusion and were treated with TNFi.

Baseline ASDAS/BASDAI or DAPSA/DAS-28 values were available for a low proportion of patients (24.1% of axSpA and 9.8% of PsA patients). Current recommendations for the management of patients with axSpA and PsA include regular collection of validated disease activity outcomes.[6,46,47] In this regard, enhanced

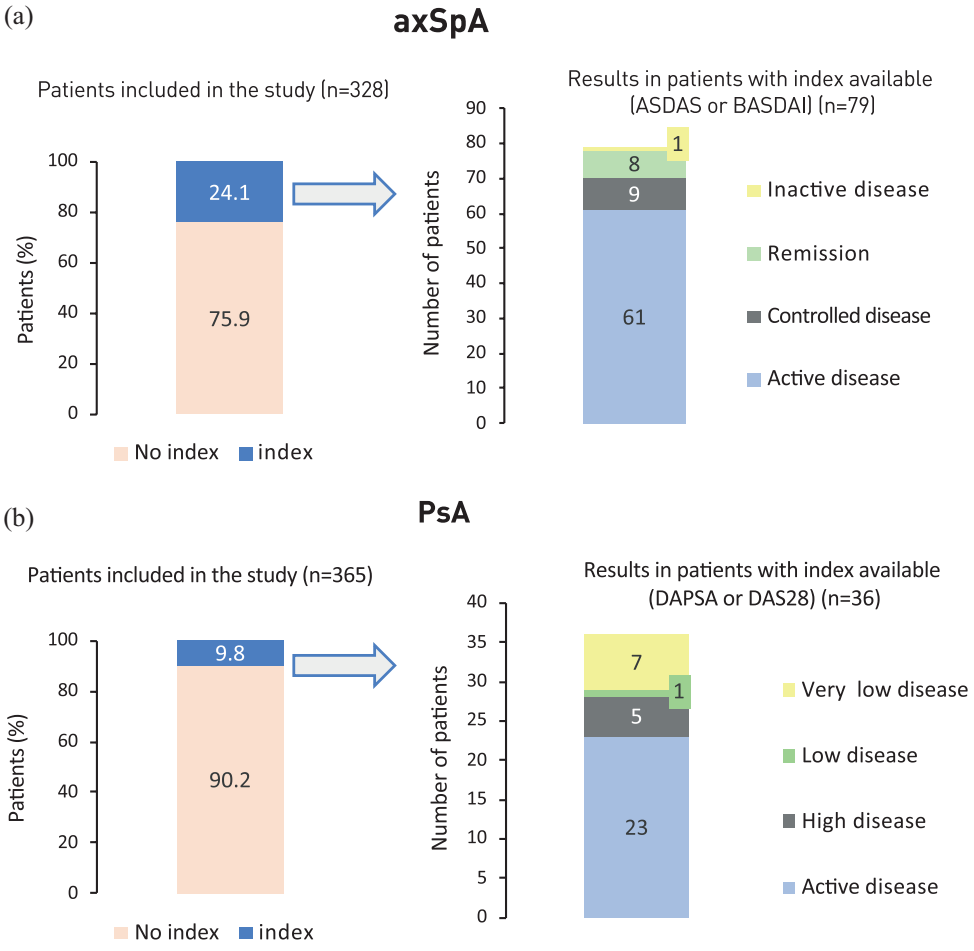

Figure 4. Disease activity status at baseline for (a) axSpA and (b) PsA patients.
axSpA, axial Spondyloarthritis; PsA, psoriatic arthritis.

monitoring through consistent and frequent disease activity assessments, as stated in the ASAS-EULAR recommendations for the management of axSpA,[3] could have multiple positive implications for patient outcomes, ranging from better disease management to tailored therapeutic strategies, together with a more objective and longitudinal monitoring of the disease. Then, both clinical factors and patient-reported outcomes must be considered to fully understand disease burden and make well-informed treatment decisions. However, while advances in patients management have been made, disagreements remain among clinicians regarding which instruments should be used and, as a consequence, they are not widely implemented in routine clinical practice, particularly in PsA.[48] Our real-life results show the low availability of disease activity indexes in the medical records of axSpA patients not included in clinical trials. These results are in line with those reported in prior studies from other European countries in daily-care rheumatology settings. In a recent study conducted in France with 320 axSpA patients, 41% and 38% of patients had a BASDAI and an ASDAS reported, respectively, and at least one index was available in 56% of the EHRs.[49] In regard to the availability of disease activity indexes in the context of PsA, it has been observed that, in Spain, joint involvement was not quantified in around 60% of the medical records; in 87% of them, there was no composite joint index available and 84% did not have a measure of function.[50,51] In agreement with these findings, the present study showed that around 80% and 70% of axSpA and PsA patients, respectively, did not have TJC or SJC assessments registered on their EHRs. These results highlight the fact that the latest recommendations encouraging regularly monitoring of disease activity in SpA patients are not always followed, or if followed, they are not consistently reported in the EHRs.

Table 2. Prior and concomitant treatments in patients with axSpA.

Treatment	axSpA-SEC			axSpA-other bDMARD		
	Naïve (19)	Experienced (44)	Total (63)	Naïve (216)	Experienced (49)	Total (265)
Follow-up time (months), mean (SD)	23.0 (16.1)	21.8 (17.5)	22.2 (16.9)	18.8 (10.5)	18.1 (12.4)	18.7 (10.8)
Prior treatments						
NSAID, *n* (%)	10 (52.6)	25 (56.8)	35 (55.6)	114 (52.8)	29 (59.2)	143 (54)
Glucocorticoid injections, *n* (%)	0 (0)	2 (4.5)	2 (3.2)	5 (2.3)	4 (8.2)	9 (3.4)
csDMARDs, *n* (%)	7 (36.8)	30 (68.2)	37 (58.7)	107 (49.5)	35 (71.4)	142 (53.6)
bDMARD						
TNFi, *n* (%)	–	43 (97.7)	43 (68.3)	–	48 (98)	48 (18.1)
AntiI-L-17A, *n* (%)	–	1 (2.3)	1 (1.6)	–	1 (2)	1 (0.4)
Other MoA, *n* (%)	–	0 (0)	0 (0)	–	1 (2)	1 (0.4)
Analgesics, *n* (%)	4 (21.1)	17 (38.6)	21 (33.3)	41 (19)	16 (32.7)	57 (21.5)
Concomitant treatments						
NSAID, *n* (%)	5 (26.3)	10 (22.7)	15 (23.8)	24 (11.1)	5 (10.2)	29 (10.9)
Glucocorticoid injections, *n* (%)	3 (15.8)	5 (11.4)	8 (12.7)	4 (1.9)	1 (2)	5 (1.9)
csDMARDs, *n* (%)	1 (5.3)	5 (11.4)	6 (9.5)	10 (4.6)	2 (4.1)	12 (4.5)
Analgesics, *n* (%)	2 (10.5)	4 (9.1)	6 (9.5)	15 (6.9)	4 (8.2)	19 (7.2)

axSpA, axial SpA; bDMARDs: biologic disease-modifying antirheumatic drugs; csDMARDs: conventional synthetic disease-modifying antirheumatic drugs; MoA: mechanism of action; TNFi: tumor necrosis factor inhibitors; NSAID: non-steroidal anti-inflammatory drug; SD, standard deviation; SEC, Secukinumab.

Variations in documentation practices among hospitals, non-standardized reporting, or limited time for assessment and calculation of the indices in some settings could explain our results. In an attempt to overcome this gap, a set of strategies aimed at improving the initial evaluation and follow-up of patients with SpA in Spain (CREA project) were elaborated using the Delphi method and have been recently published.[47,52] Rheumatologists agreed that the desirable time for visits was considerably shorter than the currently dedicated time, and there was a lack of healthcare professionals, including specialized nurses, involved in the follow-up of these patients.[47] However, in addition to the implementation of measures that allow better quality assistance, healthcare professional's education should focus not only on the importance of adhering to guidelines, but on emphasizing that good practices include proper documentation in EHRs.

As it has been demonstrated, cutting-edge technologies, such as NLP and ML, enable the accurate detection of specific disease features, captured as unstructured information in patients' EHRs.[36,41–43] This holds great potential to improve the understanding of peripheral, extra-musculoskeletal manifestations, and comorbidities in patients with axSpA and PsA treated in real clinical practice. NLP also allows for the discovery of relevant insights concerning drug effectiveness,[44] which has been limited in this study due to the low availability of disease activity indexes. Improving adherence to clinical practice guidelines, encouraging the correct reporting of information in EHRs and standardizing protocols in data collection is needed, and it would not only improve the quality of care and patient outcomes but also the substrate for conducting real-life studies of higher quality allowing more and better evidence generation. Importantly, the efficacy of NLP and ML for data extraction and analysis is

Table 3. Prior and concomitant treatments in patients with PsA.

Treatment	PsA-SEC			PsA-other bDMARD		
	Naïve (18)	Experienced (45)	Total (63)	Naïve (220)	Experienced (82)	Total (302)
Follow-up time (months), mean (SD)	17.87 (11.37)	14.39 (14.47)	15.38 (13.66)	15.6 (9.5)	12.3 (11.0)	14.7 (10)
Prior treatments						
NSAID, *n* (%)	12 (66.7)	25 (55.6)	37 (58.7)	93 (42.3)	43 (52.4)	136 (45)
Glucocorticoid injections, *n* (%)	1 (5.6)	1 (2.2)	2 (3.2)	4 (1.8)	2 (2.4)	6 (2)
csDMARDs, *n* (%)	16 (88.9)	34 (75.6)	50 (79.4)	179 (81.4)	77 (93.9)	256 (84.8)
bDMARD						
TNFi, *n* (%)	–	38 (84.4)	38 (60.3)	–	69 (84.1)	69 (22.8)
Anti-IL-17A, *n* (%)	–	9 (20)	10 (15.9)	–	4 (4.9)	4 (1.3)
Other MoA, *n* (%)	–	23 (51.1)	23 (36.5)	–	25 (30.5)	25 (8.3)
Analgesics, *n* (%)	6 (33.3)	13 (28.9)	19 (30.2)	37 (16.8)	22 (26.8)	59 (19.5)
Concomitant treatments						
NSAID, *n* (%)	7 (38.9)	8 (17.8)	15 (23.8)	18 (8.2)	12 (14.6)	30 (9.9)
Glucocorticoid injections, *n* (%)	1 (5.6)	3 (6.7)	4 (6.3)	2 (0.9)	2 (2.4)	4 (1.3)
csDMARDs, *n* (%)	3 (16.7)	9 (20)	12 (19)	15 (6.8)	7 (8.5)	22 (7.3)
Analgesics, *n* (%)	4 (22.2)	8 (17.8)	12 (19)	12 (5.5)	9 (11)	21 (7)

bDMARDs, biologic disease-modifying antirheumatic drugs; csDMARDs, conventional synthetic disease-modifying antirheumatic drugs; MoA, mechanism of action; NSAID, non-steroidal anti-inflammatory drugs; PsA, psoriatic arthritis; SD, standard deviation; SEC, Secukinumab; TNFi, tumor necrosis factor inhibitors.

constrained by the quality and completeness of the original data. Incorporating strategies for rigorous data capture in clinical practice through standardized documentation can significantly amplify the quality of data collated, enabling more robust analyses and enhancing the clinical relevance and reliability of our findings.

The study has several limitations that must be discussed. The main limitation is the source of data, as study findings depend on the availability and accuracy of the information written by physicians in EHRs during routine clinical practice. Due to its retrospective design, there was neither guarantee that all study variables were present for each individual patient, nor that all variables included were available in all records. Even if multiple records are available for a patient, there is no assurance that the targeted variables will be present in those files. This limitation may introduce a recall bias or a report bias, which may be additionally influenced by clinical circumstances, sociocultural contexts, or other unidentified factors. Second, the identification of patients could have been compromised by the accuracy of the *EHRead*® technology to detect these cases. Thus, the models deployed for data interpretation and reading are not yet fully optimized, potentially resulting in incorrect categorization of some variables. However, these limitations are inherent to real-world data studies and are offset by the large volume of data and patient populations examined and by the quality system of the technology, which has internal and external validation. Moreover, the evaluation of the system accuracy showed that within all available EHRs, axSpA and PsA cases were accurately identified. Third, even if the number of patients included here was higher than in most previous observational studies assessing the effectiveness of SEC,[23,25,26,51] disease activity indexes were not available in most patients; therefore, information on SEC outcomes was scarce. Lastly, only three hospitals were involved in the study, so the generalizability

Table 4. Performance of *EHRead*® identifying records that contain key variables.

Variable	Precision	Recall	F1-score
Etanercept	1.000	0.886	0.939
ASDAS	0.895	0.971	0.932
Dactylitis	0.815	0.983	0.891
Secukinumab	0.968	0.811	0.882
Adalimumab	0.978	0.750	0.849
BASDAI	0.758	0.962	0.847
C reactive protein	0.816	0.879	0.846
Psoriatic arthritis	0.798	0.735	0.765
Axial spondyloarthritis	0.700	0.700	0.700
Ankylosing spondylitis	1.000	0.519	0.683
Infliximab	1.000	0.500	0.667
DAPSA	0.500	1.000	0.667
Enthesitis	0.484	0.863	0.620
Spondyloarthritis	0.617	0.433	0.509

ASDAS, ankylosing spondylitis disease activity score; BASDAI, bath ankylosing spondylitis disease activity Index; DAPSA, disease activity in psoriatic arthritis.

of results is limited, and additional studies will be needed to extrapolate the findings to the general population of SpA in Spain. Moreover, although hospitals from different regions in Spain participated in the study, data were not available for the entire study period in all centers.

Studies using NLP and ML might be useful to assess treatment effectiveness in the clinical practice. The use of standardized terminologies such as SNOMED CT, a multilingual medical terminology system, may help to further enhance the generalizability of these technologies by mitigating language-specific bias and enabling uniform coding across diverse linguistic backgrounds. Future studies aiming to evaluate this will need to include a higher number of patients and be performed in a larger number of sites, including centers from different countries around Europe. Furthermore, the potential of this technology to improve the diagnosis, treatment and follow-up of SpA patients is also worth considering for these additional studies. ML models have been shown to facilitate an early diagnosis of axSpA and PsA,[53,54] and to aid in PsA evaluation and management by analyzing medical images, predicting complications and improving treatment discovery.[55]

Conclusion

To our knowledge, SpaINET is the first study aiming to use NLP and ML to analyze disease outcomes in both axSpA and PsA patients in real life. Our study showed that most axSpA and PsA patients do not have comprehensive disease activity assessments available at bDMARD initiation in their EHRs. This underscores a significant gap in the documentation of crucial parameters like ASDAS, BASDAI, DAPSA, and DAS28, as well as joint counts. The data obtained in the study do not allow us to draw definite conclusions about disease control in patients with axSpA and PsA, but highlight the need for more consistent data recording of disease activity indices in routine care in Spain. Moreover, based on our findings and the current guidelines, clinicians are encouraged to adopt these standardized measures in real-world practice to improve the understanding of rheumatic diseases and patient outcomes.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and Good Clinical Practice guidelines and was approved by the Ethics Committees of La Paz University hospital in Madrid, Spain [this Committee decided to issue a favorable opinion on 27 May 2021 (minutes no. 10-2021)]. As data were retrospectively captured from patients' EHRs in an anonymized and dissociated irreversibly manner, patient consent was not required for this study.

Consent for publication

Not applicable.

Author contributions

Diego Benavent: Investigation; Methodology; Writing – review & editing.

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DB participated as speaker's bureau for Janssen, UCB, Abbvie, Galapagos, Lilly, BMS, and MSD, and received grant/research support from Novartis. DB, JM-C, ECR, and MT are employees at SAVANA Research. SM-F has received honoraria from Novartis for participating in the present study. IDlM declares no conflict of interest. AF participated as speaker's bureau for Novartis and is local principal investigator in clinical trials promoted by Novartis. CrS and CaS were employees at Novartis Farmacéutica SA at the time of the study.

Availability of data and materials

Dataset generated and/or analyzed during the study is the property of Novartis. Anonymized datasets and related documents such as statistical analysis plan, protocol, and amendments can be shared upon reasonable request through a data sharing agreement.

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Supplemental material

Supplemental material for this article is available online.

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