Drugs
https://doi.org/10.1007/s40265-024-02028-1

SYSTEMATIC REVIEW

Drug Survival of IL-17 and IL-23 Inhibitors for Psoriasis: A Systematic Review and Meta-Analysis

Sarah E. Thomas[1] · Liana Barenbrug[1] · Gerjon Hannink[2] · Marieke M. B. Seyger[1] · Elke M. G. J. de Jong[1,3] · Juul M. P. A. van den Reek[1]

Accepted: 25 March 2024

Abstract

Background and Objective The most recently approved biologics for moderate-to-severe psoriasis are the interleukin (IL)-17 and IL-23 inhibitors. Drug survival is a frequently used outcome to assess drug performance in practice. An overview of the available drug survival studies regarding IL-17 and IL-23 inhibitors is lacking. Therefore, our objective was to assess the drug survival of IL-17 and IL-23 inhibitors for psoriasis.

Methods A search of PubMed, Embase, Cochrane Library and Web of Science was conducted (last search 27 December, 2023). Inclusion criteria were (1) cohort study; (2) patients aged ≥ 18 years with plaque psoriasis; and (3) evaluation of drug survival of at least one of the IL-17 and IL-23 inhibitors. Exclusion criteria were: primary focus on patients with psoriatic arthritis, fewer than ten study subjects and another language than English. The Preferred Reporting Items for Systematic Reviews and Meta-analyses reporting guideline was followed. Survival probabilities at monthly intervals were extracted from Kaplan–Meier curves using a semi-automated tool. Data were pooled using a non-parametric random-effects model to retrieve distribution-free summary survival curves. Summary drug survival curves were constructed per biologic for different discontinuation reasons: overall, ineffectiveness and adverse events, and split for the effect modifier biologic naivety. Results were analysed separately for registry/electronic health record data and for pharmacy/claims data.

Results A total of 69 studies aggregating drug survival outcomes of 48,704 patients on secukinumab, ixekizumab, brodalumab, guselkumab, risankizumab, and tildrakizumab were included. Summary drug survival estimates of registry/electronic health record studies for overall, ineffectiveness and adverse event related drug survival were high (all point estimates ≥ 0.8 at year 1) for included biologics, with highest estimates for guselkumab and risankizumab. All estimates for drug survival were higher in biologic naive than in experienced patients. Estimates of pharmacy/claims databases were substantially lower than estimates from the primary analyses based on registry/electronic health record data.

Conclusions This meta-analysis showed that the investigated IL-17 and IL-23 inhibitors had high drug survival rates, with highest rates for guselkumab and risankizumab drug survival. We showed that effect modifiers such as biologic naivety, and the source of data used (registry/electronic health record data vs pharmacy/claims databases) is relevant when interpreting drug survival studies.

1 Introduction

In patients with psoriasis, interleukin (IL)-17 and IL-23 play a major role in the pathogenesis of the disease [1]. The most recently developed biologics for psoriasis target the IL-17 and IL-23 pathway. Four IL-17 inhibitors (secukinumab, brodalumab, ixekizumab, bimekizumab) and three IL-23 inhibitors (guselkumab, tildrakizumab, risankizumab) are currently approved by the European Medicines Agency and US Food and Drug Administration. These drugs showed very good results in randomised clinical trials [2–4].

Liana Barenbrug and Gerjon Hannink have shared second authorship.

✉ Sarah E. Thomas
sarah.thomas@radboudumc.nl

[1] Department of Dermatology, Radboud University Medical Centre (Radboudumc), Mailbox 9101, 6500 HB Nijmegen, The Netherlands

[2] Department of Medical Imaging, Radboud University Medical Centre (Radboudumc), Nijmegen, The Netherlands

[3] Radboud University, Nijmegen, The Netherlands

Published online: 17 April 2024

Key Points

Many drug survival studies on interleukin-17 and interleukin-23 inhibitors have emerged. This meta-analysis provides an extensive and inclusive overview of all currently available drug survival data on these biologics.

Interleukin-17 and interleukin-23 inhibitors demonstrated high drug survival rates in psoriasis treatment, with highest rates for guselkumab and risankizumab.

Data from registry/electronic health records provided more information and had less risk of bias than pharmacy/claims databases in the context of drug survival.

However, this does not necessarily reflect their effectiveness in daily practice. Clinical trials are known for their strict inclusion and exclusion criteria, creating a homogeneous study population. This can impair the generalisability of trial results to the real-world population, which is often more heterogeneous [5]. In addition, differences in adherence to medication can lead to variations between outcomes of clinical trials and the real world [6]. To evaluate treatment in a real-world setting, drug survival, also known as "drug retention" or "drug persistence", is a commonly used measure. Drug survival is defined as the time that patients remain on the prescribed drug and is visualised using Kaplan–Meier curves. The outcomes of drug survival analyses can give insights in the number of patients discontinuing their treatment, but also in the reasons for discontinuation in daily practice. Main reasons for discontinuation are ineffectiveness and side effects. In addition, various patient-related variables can affect drug survival such as sex, body mass index, the presence of psoriatic arthritis or prior experience with other biologics [7].

Previously published systematic reviews on drug survival in patients with psoriasis focused on tumor necrosis factor-α inhibitors and the IL-12/23 inhibitor ustekinumab, except for Mourad et al. [8–10], who included secukinumab, ixekizumab and guselkumab. Since that time, two more IL-17 inihibitors and two more IL-23 inhibitors have become available, resulting in many new publications on drug survival of IL-17 inhibitors and IL-23 inhibitors. A review and meta-analysis on the drug survival of the newer biologics (IL-17 and IL-23 inhibitors) are not yet available. The advanced methodology used in this meta-analysis summarised the total course of drug survival curves. This provides more robust and precise summary drug survival estimates that enhance the reliability of findings. For patient-tailored treatment, a comprehensive overview of the newer biologics is essential in making evidence-based choices among the newer biologics available for psoriasis.

2 Methods

A systematic review and meta-analysis of real-world evidence on drug survival of IL-17 and IL-23 inhibitors for the treatment of psoriasis was conducted. The literature search and reporting were done according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) reporting guideline checklists [11–13]. The study protocol was registered in PROSPERO (CRD42021297356).

2.1 Literature Search

A literature search of PubMed, EMBASE, Cochrane Library and Web of Science was developed with the help of an institutional librarian and conducted by two authors (ST and LB, last search 27 December, 2023) to identify eligible studies. The search terms included several alternatives for drug survival analysis, such as 'Kaplan–Meier estimate', 'drug adherence', 'drug failure', 'drug retention', 'drug persistence' and 'drug discontinuation', combined with synonyms for psoriasis and the available biologics. The full search strategy can be viewed in Table 1 of the Electronic Supplementary Material (ESM).

2.2 Study Selection

Two authors (ST/LB) independently screened and selected relevant studies by using the Rayyan web tool [14]. Inclusion criteria were (1) the design was a cohort study, (2) the study subjects were patients aged ≥ 18 years with plaque psoriasis and (3) drug survival of at least one of the following biologics was described: secukinumab (SEC), ixekizumab (IXE), brodalumab (BRO), risankizumab (RIS), guselkumab (GUS) or tildrakizumab (TIL). Exclusion criteria were (1) studies with a primary focus on patients with psoriatic arthritis (e.g. selected from a rheumatological cohort), (2) studies with fewer than ten study subjects and (3) studies in another language than English.

When a full-text version was not available, or in case of other crucial missing data, authors of the specific study were contacted. All studies were carefully screened for overlapping patient populations and authors were contacted in case of doubt. In case of no response, only the cohort with the longest follow-up was analysed. Complex decisions

regarding whether to include specific outcomes of separate studies were deliberated within the study team (ST, MS EJ, JR).

2.3 Data Extraction

The following data were extracted by ST and LB and implemented in a pre-designed data-extraction spreadsheet: study design, author, year of publication, location, time frame, study design, setting, information source (electronic health records [EHR]/registry data; or pharmacy/claims data), patient population size, follow-up period, patient characteristics (age, sex, body mass index, age at onset of psoriasis, disease duration, baseline Psoriasis Area Severity Index score, presence of concomitant psoriatic arthritis) percentage biologic-naive patients, type of biologic treatment (IL-17 or IL-23 inhibitor), dosage, treatment regime, treatment duration. Drug survival was depicted as overall drug survival, ineffectiveness-related drug survival, adverse event-related drug survival, and drug survival for biologic-naive or experienced patients.

2.4 Methodological Quality Assessment

The quality of the included studies was assessed with the Quality in Prognostic Studies (QUIPS) tool and the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool [15, 16]. The QUIPS tool was partly adjusted in discussion with the study group to fit the study methodology of drug survival analyses (see Appendix 1 of the ESM). Two authors (ST/LB) independently evaluated each domain for all articles, resulting in an overall risk of bias (RoB) score per domain. In case of disagreement, a third author (JR) was consulted. The quality of evidence was also summarised using the Quality Rating Scheme for Studies and Other Evidence, a modification from the Oxford Centre for Evidence-Based Medicine.

2.5 Statistical Analysis

As we considered summary drug survival curves most informative to compile drug survival studies, we used a non-parametric random-effects model to retrieve a distribution-free summary drug survival curve described in detail by Combescure et al. [17] This method obtains a distribution-free summary drug survival curve by expanding the product limit estimator of drug survival for aggregated drug survival data. The extension of DerSimonian and Laird methodology for multiple outcomes was applied to account for between-study heterogeneity [17]. The I^2 statistic was used to measure the between-study variability of the arcsine transformed conditional survival estimates [18]. In contrast to a meta-analysis of drug survival at a single point in time, the homogeneity assumption is that the conditional drug survival probabilities are equal in the studies for any time *t*.

The main advantage of this approach over meta-analyses of drug survival probabilities at a single timepoint lies in the ability to use full drug survival curves. The estimated pooled drug survival at time *t* includes all studies, also studies ended before *t*, because the conditional drug survival probabilities before *t* are estimated with these same studies.

Summary drug survival curves with 95% confidence intervals (CIs) [based on Greenwood's formula] were estimated from the drug survival rates and the numbers-at-risk extracted from studies included in the meta-analysis. Drug survival probabilities at each timepoint were extracted using a semi-automated tool (Webplotdigitizer Version 4.5; https://automeris.io/WebPlotDigitizer/) at monthly intervals. The numbers of at-risk participants during different time intervals were calculated using the method previously described by Williamson et al. [19] and Tierney et al. [20] Heterogeneity was measured using I^2 values and Cochran's Q statistic. Statistical analyses were performed using R (R Foundation for Statistical Computing, Vienna, Austria) with package 'MetaSurv'.

Summary drug survival (pooled) curves of all separate biologics were constructed for different discontinuation reasons (events): overall drug survival, ineffectiveness-related drug survival and adverse event-related drug survival. As biologic naivety has shown to be an important variable influencing drug survival, drug survival data on biologic-naïve and biologic-experienced patients were also extracted if available [21]. In case no Kaplan–Meier curve was available, and drug survival rates were only described at specific timepoints in the text or tables, these rates were extrapolated to earlier timepoints and incorporated in sensitivity analyses but not in the primary analyses. Additionally, separate sensitivity analyses were performed excluding studies, which were classified as a high risk of bias in the QUIPS tool and as a serious risk of bias in the ROBINS-I tool.

Studies based on data from registry/EHR databases and studies using pharmacy/claims data were analysed as separate groups as the underlying information leading to drug survival was different and might influence drug survival. In registry/EHR studies, drug survival is not derived from data on insurance claims, but from the medical records (e.g. patient registry data/medical record investigations). The actual use by the patient, reason for discontinuation (including being lost to follow-up), temporary dose changes and definitive discontinuation dates are recorded in registry/EHR databases, whereas they are mostly not recorded in pharmacy/claims databases. Albeit being less precise on these

issues, pharmacy/claims databases lead to information in large groups of patients. Therefore, summary drug survival curves were constructed separately for (I) registry/EHR data and (II) pharmacy/claims data.

An overview of which study was included in each outcome can be found in Table 10 of the ESM. Additionally, in all figure legends, the references of the included studies for that specific outcome were stated.

2.6 Direct Comparison Summary Drug Survival Estimates

Summary drug survival estimates from the meta-analyses were directly compared at 1, 2 and 3 years between the different biologics for the overall drug survival and ineffectiveness-related drug survival using the methodology described by Klein et al. [22], and presented as differences in drug survival estimates with 95% CIs.

3 Results

3.1 Study Characteristics

The literature search resulted in 2299 records, after screening for duplicates 1615 unique records remained. Of these, 127 full-text articles were assessed for eligibility, resulting in 69 articles included in this review (Fig. 1, Appendices 2 and 3 of the ESM).

3.2 Quality Assessment

An overview of the quality assessment per domain using the QUIPS and ROBINS-I tool is provided in Tables 3 and 4 of the ESM. All studies that were assessed as high risk of bias in the QUIPS tool [23–74] and as serious risk of bias in the ROBINS-I tool [28, 31, 36, 45, 47, 52, 54–57, 60, 63, 66, 67, 69, 73, 75, 76] were excluded in separate sensitivity analyses. Results of the separate sensitivity analyses were in line with results of the main analyses and shown in Tables 7 and 8 of the ESM. Excluding studies marked as serious risk of bias using the ROBINS-I tool, summary survival estimates of registry/EHR studies were very similar. Pharmacy/claims database studies all had to be excluded because of their serious risk of bias assessment according to the ROBINS-I tool. When using the QUIPS tool to assess the risk of bias, many studies had to be excluded and summary survival estimates slightly changed in both directions. However, in general, results were still in line with the main analyses.

Using the Quality Rating Scheme for Studies and Other Evidence, most studies were rated with a 3: 'case-control studies; retrospective cohort study' (Table 5 of the ESM).

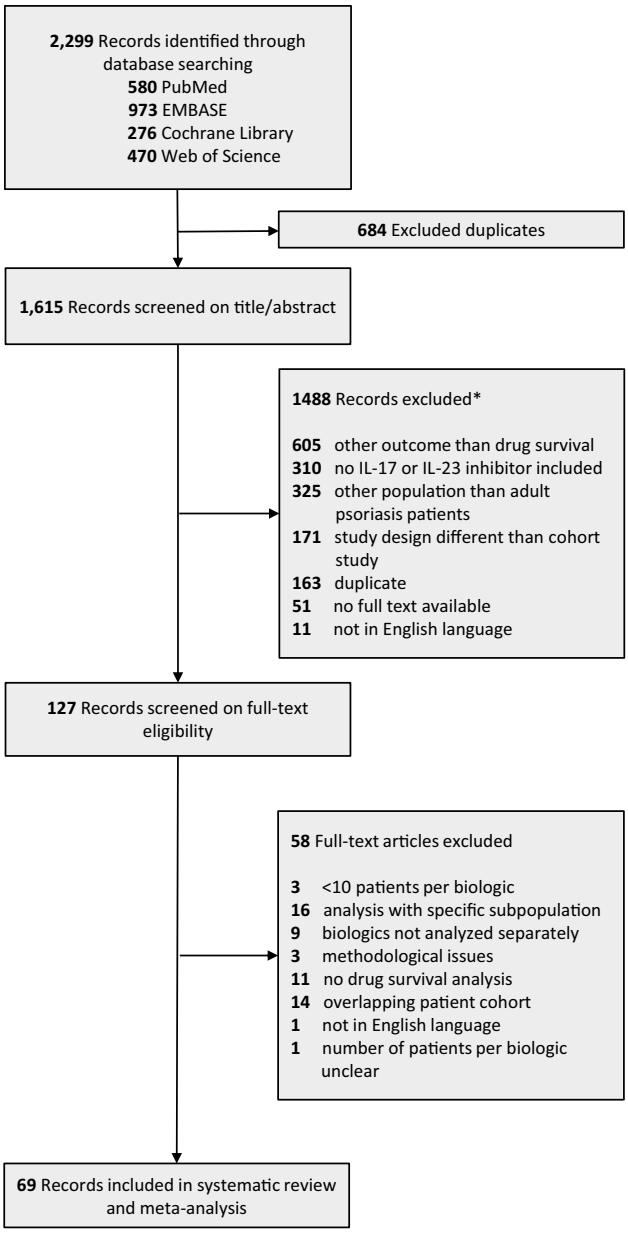

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. *Some studies were classified with more than one exclusion reason. *IL* interleukin

3.3 Systematic Review and Meta-Analysis

Forty-seven articles reported on SEC (23,960 patients), 31 on IXE (12,446 patients), 13 on BRO (2353 patients), 24 on GUS (8174 patients), 7 on RIS (1427 patients) and 4 on TIL (304 patients). In total, 48,704 patients were included in this literature review. The characteristics from the included studies are given in Table 2 of the ESM.

As stated, studies based on drug survival from registry/EHR data and studies using pharmacy/claims data were

analysed separately. (I) For registry/EHR data, several drug survival outcomes were analysed based on the available studies per agent. Our literature search yielded studies on overall drug survival for SEC, IXE, BRO, GUS, RIS and TIL, for drug survival split for biologic naivety for SEC, IXE, BRO, GUS and RIS, for ineffectiveness-related drug survival for SEC, IXE, BRO and GUS, and for adverse event-related drug survival for SEC, IXE and GUS. Regarding the separate biologics, SEC had the most available registry/EHR studies (34), followed by IXE (21), GUS (20), BRO (10), RIS (6) and TIL (4).

(II) In pharmacy/claims databases, discontinuation reasons were missing hence only overall drug survival studies were identified. A meta-analysis of pharmacy/claims database studies could be performed for SEC, IXE, BRO and GUS as these drugs had multiple studies available. Results split for biologic naivety of patients on SEC, IXE and GUS could also be included to construct summary drug survival curves.

3.3.1 Registry/Electronic Health Record Data

The registry/EHR data extracted were provided by medical records (42 studies; 11,365 patients) and patient registries (13 studies; 10,154 patients) from 29 different countries, mainly located in Europe. In Table 1, summary (drug) survival estimates (SSE) with 95% CIs per biologic regarding overall drug survival, ineffectiveness-related drug survival, adverse event-related drug survival and drug survival split for biologic naivety at 1, 2, 3 and 5 years of treatment are provided. Summary survival estimates for overall, ineffectiveness-related and adverse event-related drug survival were high for all included biologics (for instance, SSE all ≥ 0.8 at year 1) (see Table 1, Figs. 2 and 3). All estimates for biologic-naive patients were higher than the estimates of the same biologic for the experienced patients. For example, for IXE naive versus experienced at year 1, SSE were 0.83 (95% CI 0.77–0.89) and 0.72 (95% CI 0.65–0.80), respectively. Risankizumab showed the highest SSE for overall drug survival at years 1, 2 and 3 (all SSE > 0.86). Overall drug survival contained data on all biologics, whereas in the differentiated analyses (such as ineffectiveness, adverse events and biologic naivety) not all biologics were represented, especially RIS and TIL. These differentiated analyses showed that GUS consistently had the highest SSE on almost all drug survival outcomes; for example, the GUS SSE was 0.87 (95% CI 0.84–0.91) for 5-year ineffectiveness-related drug survival (Table 1). The only exception was SEC drug survival, which was highest in biologic-naive patients at year 1 with an SSE of 0.86 (95% CI 0.82–0.89). Summary drug survival estimates of the IL-17 inhibitors SEC, IXE and BRO were similar to each other for the 1-year and 2-year overall drug survival and ineffectiveness-related drug survival. One-year and 2-year adverse event-related drug survival of IL-17-inhibitors (SEC, IXE) was similar to that of GUS (SSE GUS 1 and 2 year 0.95 (95% CI 0.91–0.98) and 0.90 (95% CI 0.84–0.96)). The summary drug survival curves of the meta-analysis for adverse event-related drug survival and for drug survival split for biologic naivety are displayed in Figs. 1, 2 and 3 of the ESM. Heterogeneity between studies was low ($I^2 < 29\%$), see Table 1. Results of the sensitivity analyses, in which also studies where no Kaplan–Meier curves were provided [38, 47, 55, 77] were included, were very similar to the primary analyses, see Table 6 of the ESM.

3.3.2 Pharmacy/Claims Data

Table 1 also shows drug survival data (SSE from the meta-analysis or separate Kaplan–Meier drug survival estimates) for SEC, IXE, BRO and GUS from pharmacy/claims databases. Fourteen pharmacy/claims database studies (27,521 patients) could be included from nine different countries, most of which were conducted in North America). In Figures 4, 5 and 6 of the ESM, a visualisation of summary drug survival curves is provided (SEC, IXE, BRO, GUS, RIS). Summary survival estimates of pharmacy/claims data for 1-year and 2-year overall drug survival were low compared to SSE from registry/EHR data (e.g. 1-year and 2-year overall SSE for SEC pharmacy/claims data of 0.67 (95% CI 0.61–0.75) and 0.49 (95% CI 0.41–0.59) versus 0.81 (95% CI 0.77–0.85) and 0.66 (95% CI 0.61–0.72) in registry/EHR data, respectively). Heterogeneity between studies varied greatly (range I^2, 0–87%), see Table 1. The drug survival percentages of the sensitivity analysis using extrapolation of point estimates [31, 57] for pharmacy/claims databases are also reported in Table 6 of the ESM.

3.4 Direct Comparison Summary Drug Survival Estimates

Risankizumab had statistically significantly higher SSE for the overall drug survival at years 1, 2 and 3, compared with SEC and IXE, and higher rates at year 2 and 3 compared with BRO [estimated differences and 95% CIs SEC-RIS at years 1, 2 and 3; −0.11 (95% CI −0.17, −0.04), −0.22 (95% CI −0.32, −0.12), and −0.33 (95% CI −0.49, −0.17), respectively, IXE-RIS at years 1, 2, and 3; −0.12 (95% CI −0.21, −0.03), −0.21 (95% CI −0.33, −0.08), and −0.24 (95% CI −0.39, −0.10), respectively, BRO-RIS at years 2 and 3; −0.17 (95% CI −0.34, −0.00), and −0.23 (95% CI −0.44, −0.02), respectively]. Guselkumab also had statistically significantly higher SES for the overall drug survival at years 2 and 3, compared with SEC and IXE [estimated difference and 95% CI SEC-GUS at years 2 and 3; −0.15 (95% CI −0.25, −0.04) and −0.24 (95% CI

Table 1 Summary drug survival estimates (95% confidence intervals) per drug survival outcome

	Secukinumab	Ixekizumab	Brodalumab	Guselkumab	Risankizumab	Tildrakizumab
Registry/EHR data						
Overall drug survival						
Studies included	26 [24–26, 33, 34, 39–41, 44, 46, 48, 50, 51, 53, 62, 64, 68, 70, 72, 74, 80–85]	15 [23, 32, 33, 39, 40, 42–44, 46, 49, 62, 70, 81, 84, 85]	8 [39, 40, 58, 62, 84–87]	14 [29, 30, 33, 35, 37, 43, 44, 50, 59, 70, 84, 85, 88, 89]	5 [27, 50, 84, 85, 90]	4 [27, 50, 84, 91]
Patients included	6903	3101	1801	2641	1140	304
Heterogeneity, I^2 (%)	28.5	15.1	16.8	0.0	0.0	0.0
Year 1	0.81 (0.77–0.85)	0.79 (0.73–0.86)	0.81 (0.72–0.90)	0.87 (0.83–0.92)	0.91 (0.88–0.95)	0.80 (0.71–0.91)
Year 2	0.66 (0.61–0.72)	0.67 (0.60–0.75)	0.71 (0.60–0.83)	0.81 (0.75–0.86)	0.88 (0.83–0.93)	0.47 (0.24–0.94)
Year 3	0.53 (0.46–0.62)	0.61 (0.54–0.70)	0.62 (0.51–0.77)	0.77 (0.72–0.83)	0.86 (0.80–0.92)	NA
Year 5	0.38 (0.28–0.50)	0.55 (0.47–0.65)	NA	0.75 (0.69–0.81)	NA	NA
Ineffectiveness-related drug survival						
Studies included	6 [24, 34, 65, 71, 77, 83]	3 [23, 71, 77]	1 [71]	3 [71, 77, 89]	1 [71]	0
Patients included	4070	1660	116	1323	118	0
Heterogeneity, I^2 (%)	0.0	0.0	NA	0.0	NA	NA
Year 1	0.87 (0.83–0.92)	0.91 (0.86–0.96)	0.93[a]	0.93 (0.92–0.95)	0.96[a]	NA
Year 2	0.74 (0.70–0.79)	0.83 (0.75–0.93)	0.88[a]	0.90 (0.87–0.93)	NA	NA
Year 3	0.64 (0.58–0.70)	0.82 (0.73–0.90)	NA	0.89 (0.86–0.92)	NA	NA
Year 5	0.60 (0.53–0.69)	0.72 (0.64–0.81)	NA	0.87 (0.84–0.91)	NA	NA
Adverse event-related drug survival						
Studies included	3 [24, 77, 83]	2 [23, 77]	0	2 [77, 89]	0	0
Patients included	2995	1009	0	925	0	0
Heterogeneity, I^2 (%)	0.0	0.0	NA	0.0	NA	NA
Year 1	0.93 (0.90–0.96)	0.94 (0.90–0.98)	NA	0.95 (0.91–0.98)	NA	NA
Year 2	0.89 (0.85–0.93)	0.88 (0.85–0.91)	NA	0.90 (0.84–0.96)	NA	NA
Drug survival split for biological naivety						
Studies included biologic-naïve patients	16 [26, 39, 40, 44, 46, 51, 55, 60, 68, 70, 72, 75, 81, 83, 85, 92]	9 [39, 40, 44–46, 81, 85, 92, 93]	3 [40, 85, 92]	7 [29, 37, 44, 47, 85, 88, 92]	1 [85]	0
Patients included	1669	614	215	410	13	0
Heterogeneity, I^2 (%)	0.0	0.0	0.0	0.0	NA	NA
Year 1	0.86 (0.82–0.89)	0.83 (0.77–0.89)	0.84 (0.73–0.97)	0.83 (0.76–0.91)	1.00[a]	NA
Year 2	0.72 (0.67–0.77)	0.68 (0.60–0.76)	0.67 (0.50–0.92)	0.74 (0.66–0.83)	NA	NA
Year 3	0.58 (0.51–0.66)	0.57 (0.48–0.68)	NA	0.69 (0.59–0.80)	NA	
Studies included Biologic-experienced patients	16 [26, 39, 40, 44, 46, 51, 55, 60, 68, 70, 72, 75, 81, 83, 85, 92]	9 [39, 40, 44–46, 81, 85, 92, 93]	4 [39, 40, 85, 92]	7 [29, 37, 44, 85, 88, 92, 93]	1 [85]	0
Patients included	2727	1183	289	547	48	0

Table 1 (continued)

	Secukinumab	Ixekizumab	Brodalumab	Guselkumab	Risankizumab	Tildrakizumab
Heterogeneity, I^2 (%)	7.5	0.0	0.0	0.0	NA	NA
Year 1	0.77 (0.72–0.83)	0.72 (0.65–0.80)	0.72 (0.66–0.80)	0.81 (0.74–0.89)	0.95[a]	NA
Year 2	0.60 (0.53–0.67)	0.55 (0.47–0.65)	0.62 (0.52–0.73)	0.72 (0.62–0.83)	NA	NA
Year 3	0.48 (0.39–0.58)	0.47 (0.38–0.60)	0.51 (0.41–0.63)	0.62 (0.52–0.74)	NA	NA
	Secukinumab	Ixekizumab	Brodalumab	Guselkumab	Risankizumab	Tildrakizumab
Pharmacy/claims databases						
Overall drug survival						
Studies included	10 [28, 52, 54, 56, 61, 63, 66, 67, 69, 73]	7 [28, 52, 54, 56, 61, 69, 73]	2 [69, 94]	4 [28, 54, 67, 69]	1 [69]	0
Patients included	10687	5171	476	4832	327	0
Heterogeneity, I^2 (%)	72.7	62.9	0.0	86.9	NA	NA
Year 1	0.67 (0.61–0.75)	0.69 (0.58–0.82)	0.65 (0.57–0.74)	0.80 (0.63–1.00)	0.90[a]	NA
Year 2	0.49 (0.41–0.59)	0.54 (0.43–0.68)	0.53 (0.42–0.69)	0.66 (0.47–0.92)	NA	NA
Year 3	0.41 (0.33–0.51)	0.45 (0.33–0.61)	0.47 (0.36–0.62)	0.57 (0.35–0.92)	NA	NA
Drug survival split for biological naivety						
Studies included biologic-naïve patients	5 [28, 36, 67, 73, 76]	4 [28, 31, 73, 76]	1 [73]	2 [28, 67]	0	0
Patients included	3670	3133	195	1980	0	0
Heterogeneity, I^2 (%)	40.9	87.4	NA	13.7	NA	NA
Year 1	0.66 (0.54–0.79)	0.70 (0.46–1.00)	0.72[a]	0.76 (0.66–0.86)	NA	NA
Year 2	0.49 (0.35–0.68)	0.58 (0.33–1.00)	0.64[a]	0.67 (0.48–0.94)	NA	NA
Year 3	0.40 (0.27–0.59)	0.48 (0.24–0.98)	0.61[a]	0.64 (0.41–0.98)	NA	NA
Studies included biologic-experienced patients	4 [28, 67, 73, 76]	4 [28, 31, 73, 76]	1 [73]	2 [28, 67]	0	0
Patients included	3969	3512	122	1813	0	0
Heterogeneity, I^2 (%)	4.6	79.8	NA	0.0	NA	NA
Year 1	0.55 (0.42–0.71)	0.61 (0.40–0.92)	0.66[a]	0.72 (0.62–0.83)	NA	NA
Year 2	0.36 (0.24–0.56)	0.45 (0.23–0.85)	0.55[a]	0.60 (0.44–0.81)	NA	NA
Year 3	0.25 (0.16–0.39)	0.34 (0.18–0.64)	0.52[a]	0.53 (0.33–0.83)	NA	NA

EHR electronic health record, *NA* not available

[a]Drug survival estimate instead of summary drug survival estimate

−0.40, −0.08), respectively, IXE-GUS at years 2 and 3; −0.13 (95% CI −0.27, −0.00) and −0.16 (95% CI −0.31, −0.00), respectively], and higher rates at years 1, 2 and 3 for ineffectiveness-related drug survival compared with SEC [estimated difference and 95% CI SEC-GUS at years 1, 2 and 3; −0.06 (95% CI −0.11, −0.01), −0.16 (−95% CI 0.23, −0.09) and −0.25 (95% CI −0.36, −0.15), respectively]. At 3 years, the ineffectiveness-related drug survival of IXE was significantly higher than that of SEC [estimated difference and 95% CI −0.18 (−0.32, −0.03)]. An overview of all pairwise comparisons is displayed in Table 9 of the ESM.

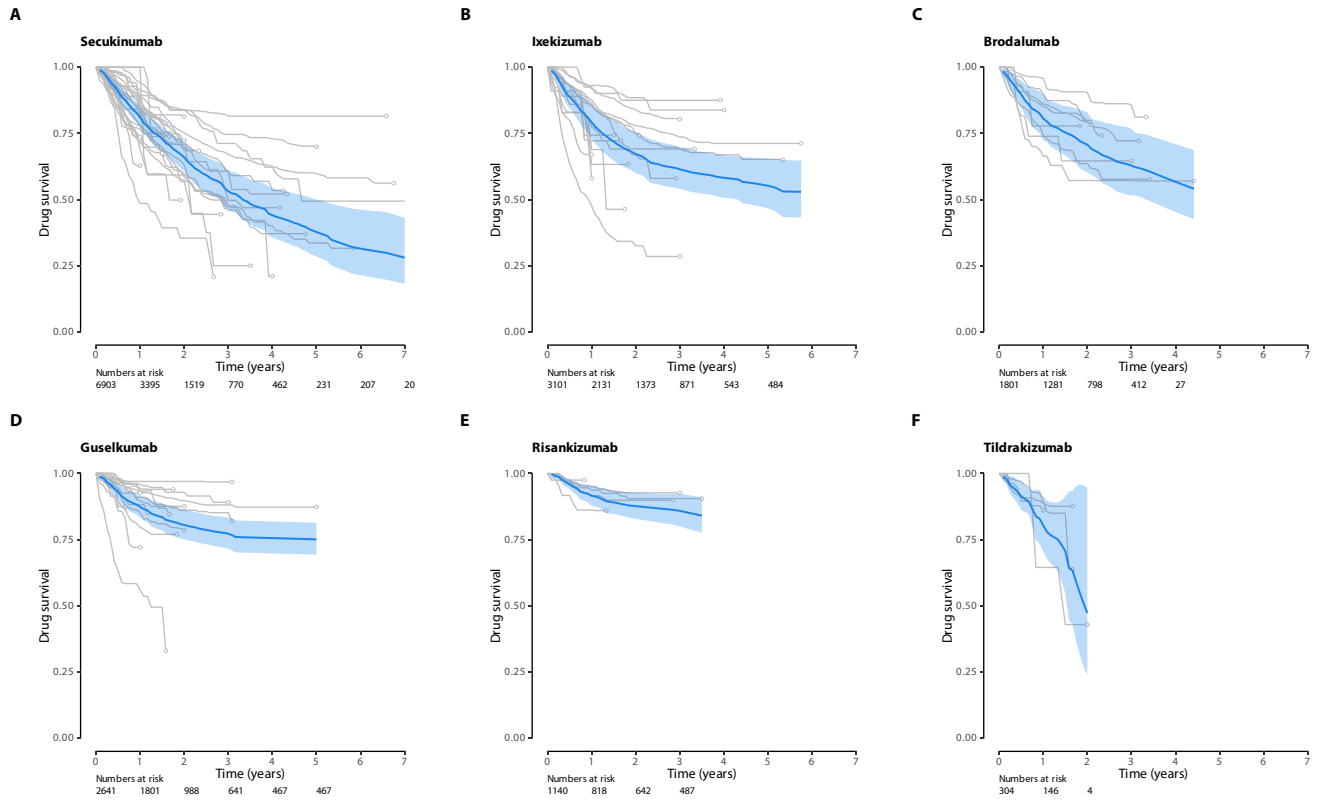

Fig. 2 Non-parametric random-effects summary drug survival curves with 95% confidence intervals for overall survival. Summary drug survival curves in blue, separate studies in grey. **A** Secukinumab [24–26, 33, 34, 39–41, 44, 46, 48, 50, 51, 53, 62, 64, 68, 70, 72, 74, 80–85], **B** ixekizumab [23, 32, 33, 39, 40, 42–44, 46, 49, 62, 70, 81, 84, 85], **C** brodalumab [39, 40, 58, 62, 84–87], **D** guselkumab [29, 30, 33, 35, 37, 43, 44, 50, 59, 70, 84, 85, 88, 89], **E** risankizumab [27, 50, 84, 85, 90], **F** tildrakizumab [27, 50, 84, 91]. The numbers of at-risk patients in the whole cohort at the beginning of each year are reported

4 Discussion and Conclusions

This systematic review and meta-analysis was performed to investigate the drug survival of IL-17 and IL-23 inhibitors in patients with psoriasis. A total of 69 studies including 48,704 patients were systematically reviewed to assess the drug survival of IL-17 and IL-23 inhibitors. Detailed summary drug survival curves were constructed to provide insight into the drug survival curves per drug over time, analysed separately for different discontinuations reasons (ineffectiveness and adverse events) and biologic naivety. Summary drug survival estimates, also for ineffectiveness-related drug survival, were similar for SEC, IXE and BRO, but ineffectiveness-related drug survival of IXE was significantly higher than drug survival of SEC at 3 years, indicating that patients on IXE are less likely to discontinue their drug because of ineffectiveness than patients on SEC. Risankizumab had the highest SSE for overall drug survival at 1, 2 and 3 years. Guselkumab had the highest SSE at 1, 2 and 3 years for almost all differentiated (e.g. ineffectiveness-related and adverse event-related drug survival) outcomes compared with the other biologics. Note that in the differentiated outcomes, such as ineffectiveness-related drug survival, not all biologics were consistently present. In line with previous findings, drug survival for biologic-naive patients was superior to that of biologic-experienced patients. Estimates of drug survival based on pharmacy/claims databases were substantially lower, indicating a worse performance of these drugs compared to the analyses based on registry/EHR data. By utilising the method by Combescure et al. in our meta-analysis, we were able to implement drug survival probabilities from each month of the full reported follow-up duration, constructing precise drug survival estimates.

In previous systematic reviews and meta-analyses on the efficacy of biologics for the treatment of psoriasis, favourable outcomes have been reported. [8–10] However, analyses were performed at specific timepoints (e.g. at 1 and 2 years), which results in an under-representation of studies reporting drug survival at other timepoints. As stated, to overcome this limitation the Combescure method was used, which permits inclusion of the full drug survival curves. Mourad and Gniadecki performed a comparative meta-analysis of hazard ratios specifically for the drug survival of biological

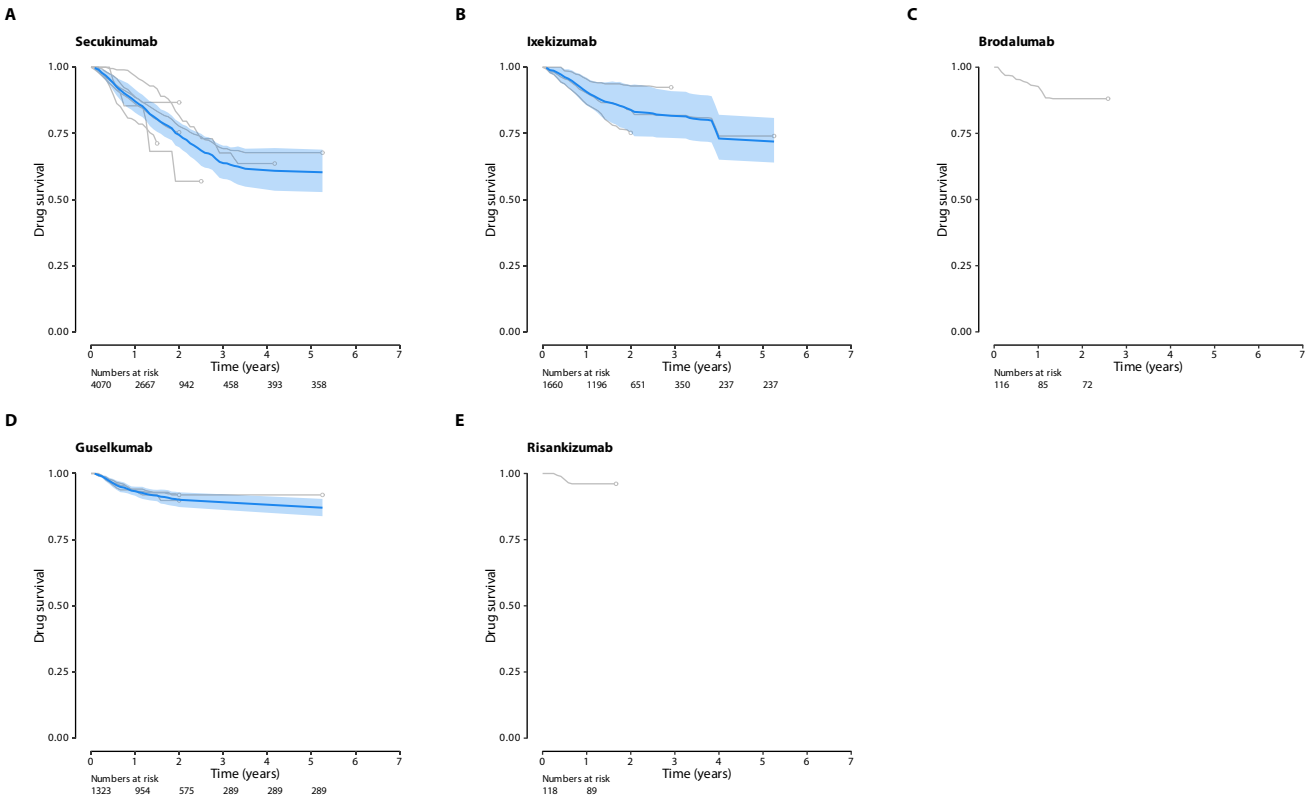

Fig. 3 Non-parametric random-effects summary drug survival curves with 95% confidence intervals for ineffectiveness-related drug survival. Summary drug survival curves in blue, separate studies in grey. **A** Secukinumab [24, 34, 65, 71, 77, 83], **B** ixekizumab [23, 71, 77], **C** brodalumab [71] (drug survival estimate instead of summary drug survival estimate), **D** guselkumab, **E** risankizumab [71] (drug survival estimate instead of summary drug survival estimate). The numbers of at-risk patients in the whole cohort at the beginning of each year are reported

treatment. The 2-year and 5-year drug survival data at that time were insufficient to compare drug survival for the IL-17 and IL-23 inhibitors yet. Their 1-year pairwise comparisons showed a superiority of SEC over IXE [10]. Prior extensive reviews on the drug survival of tumor necrosis factor-α inhibitors and ustekinumab reported lower pooled annual drug survival rates for the tumor necrosis factor-α inhibitors etanercept, adalimumab and infliximab after 1 (all < 0.74) and 3 years (all <0.54) compared to our IL-17 and IL-23 rates (all point estimates ≥ 0.8). For ustekinumab, similar drug survival rates to our results for SEC, IXE and BRO were reported. Guselkumab and RIS overall drug survival rates in our study were substantially higher than previously reported etanercept, adalimumab, infliximab and ustekinumab rates up to 5 years [8, 9]. Guselkumab and RIS drug survival rates were also statistically significantly higher than SEC, IXE and BRO rates in this meta-analysis, which is possibly related to the upstream effect of IL-23 inhibitors in the IL-23/IL-17 cytokine pathway [78].

Remarkably, summary drug survival estimates of pharmacy/claims databases were noticeably lower than these estimates from registry/EHR databases (e.g. 2-year overall summary drug survival estimate for SEC pharmacy/claims data of 0.49 (95% CI 0.41–0.59) vs 0.66 (95% CI 0.61–0.72) in registry/EHR data), and the I^2 statistic for heterogeneity was higher in pharmacy/claims database studies compared with registry/EHR studies. As the total number of patients in the many registry/EHR studies is comparable to the total number of patients in the pharmacy/claims studies, the difference in drug survival outcomes is not likely explained by a difference in precision of the estimate. In pharmacy/claims database studies, the administrative claims for medication are used, and the actual medication use of the patient is not verified at a physician and patient level. Missing information on the cause of discontinuation and the exact date of discontinuation might pose possible hazards in the interpretation of data from pharmacy/claims databases. Events that are not related to the drug performance, for example, insurance issues, relocation or factors such as family planning, cannot be distinguished from drug-related issues. As for detailed drug survival analyses, the nature and timing of discontinuation events are utterly important and may outweigh the advantage of including large populations from claims databases. Moreover, especially for claims databases, results are

generalisable to the insured population, but not necessarily to uninsured patients, or patients with other insurance types.

The study's literature search was constrained to English-language publications, potentially introducing language bias. Drug survival studies reporting on bimekizumab were not yet available. Tildrakizumab was included in our study, however at the time of our search, only short-term follow-up drug survival studies were available. RoB assessments using the QUIPS and ROBINS-I tool led to a subset of studies with high/serious RoB, which were excluded in separate sensitivity analyses. There were no studies which could be classified as low RoB using both tools, this should be taken into consideration when interpreting results. Furthermore, most studies included in this review reported on overall drug survival. It should be kept in mind that several discontinuation reasons underlie this outcome which may not all be related to the performance of the drug itself, like wish for pregnancy or financial reasons [77, 79]. The coverage and reimbursement policies of health insurance plans and formularies can influence drug survival rates. Restrictions imposed by insurance companies, such as prior authorisation requirements or limited formulary options, may create barriers to accessing certain medications. Patients who face difficulties in obtaining insurance coverage for a prescribed medication may be more likely to discontinue treatment. This further underscores the importance of drug survival analyses with a focus on specific discontinuation reasons (ineffectiveness, adverse events). It is crucial to register financial reasons separately in order to prevent them from influencing drug survival rates with regard to ineffectiveness and adverse events. In future studies, we would strongly encourage reporting drug survival separately for different discontinuation reasons (instead of combining all reasons in an overall drug survival) and effect modifiers.

Furthermore, we want to highlight that a given drug is always both prescribed and discontinued in a landscape of competing drugs. The quantity of available alternatives likely affects the decisions made by doctors. When the selection of alternative options is restricted, doctors are likely more inclined to maintain their patients on a specific drug. In contrast, when many treatment options are available, treating physicians as well as patients could decide easier for switching to a consecutive biological treatment. In addition to doctors adjusting their prescription practices, patients' perspectives can also evolve, as they might strive for higher therapeutic objectives, potentially leading to earlier consideration of switching. In the current study timeframe however, there were consistently multiple 'older' biologic alternatives (such as ustekinumab, adalimumab, etanercept, infliximab) as well as the small-molecule apremilast available alongside the newest biologics included, which also entered the market rapidly during the studied period. The number of patients who continued with their IL-17/IL-23 inhibitor because there were no alternatives available was considered very low, thereby minimising the potential impact of drug availability on our findings.

This meta-analysis showed that investigated IL-17 and IL-23 inhibitors had high drug survival rates, with highest rates for GUS and RIS drug survival. Attention for effect modifiers (biologic naivety), and source of data (registry/EHR data vs pharmacy/claims databases) is relevant when interpreting drug survival studies.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40265-024-02028-1.

Declarations

Funding No external funding was received for the preparation of this article.

Conflict of interest Sarah E. Thomas carries out clinical trials for Janssen and Novartis and received speaking fees from Eli Lilly and AbbVie. All funding is not personal but goes to the independent Research Fund of the Department of Dermatology, Radboud University Medical Centre (Radboudumc), Nijmegen, the Netherlands. Liana Barenbrug and Gerjon Hannink have no conflicts of interest that are directly relevant to the content of this article. Marieke M.B. Seyger received grants from/was involved in clinical trials from AbbVie, Amgen, Celgene, Eli Lilly, Janssen, Leo Pharma and Pfizer. She served as a consultant for AbbVie, Eli Lilly, Janssen, Leo Pharma, Novartis, Pfizer and UCB; fees were paid directly to the Department of Dermatology, Radboud University Medical Centre (Radboudumc), Nijmegen, the Netherlands. Elke M.G.J. de Jong has received research grants for the independent research fund of the Department of Dermatology, Radboud University Medical Centre (Radboudumc), Nijmegen, the Netherlands, from AbbVie, BMS, Janssen Pharmaceutica, Leo Pharma, Novartis and UCB for research on psoriasis and has acted as a consultant and/or paid speaker for and/or participated in research sponsored by companies that manufacture drugs used for the treatment of psoriasis or eczema including AbbVie, Amgen, Almirall, Boehringer Ingelheim, Celgene, Galapagos, Janssen Pharmaceutica, Leo Pharma, Lilly, Novartis, Sanofi and UCB. All funding is not personal but goes directly to the Department of Dermatology, Radboud University Medical Centre (Radboudumc), Nijmegen, the Netherlands. Juul M.P.A. van den Reek carried out clinical trials for AbbVie, Celgene, Almirall and Janssen and has received speaking fees/attended advisory boards from AbbVie, Janssen, BMS, Almirall, LEO Pharma, Novartis, UCB and Eli Lilly and reimbursement for attending or chairing a symposium from Janssen, Pfizer, Celgene and AbbVie. All funding is not personal but goes to the independent research fund of the Department of Dermatology, Radboud University Medical Centre (Radboudumc), Nijmegen, the Netherlands.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Availability of data and material The underlying datasets and scripts are available for review upon request.

Code availability Not applicable.

Author contributions All authors contributed to the study conception and design. The literature search, data collection and analysis were performed by Sarah Thomas, Liana Barenbrug and Gerjon Hannink. The first draft of the manuscript was written by Sarah Thomas and Liana Barenbrug. Gerjon Hannink, Marieke Seyger, Elke de Jong, and Juul van den Reek critically revised the manuscript. All authors read and approved the final manuscript.

References

1. Griffiths CEM, Armstrong AW, Gudjonsson JE, et al. Psoriasis. Lancet. 2021;397(10281):1301–15. https://doi.org/10.1016/s0140-6736(20)32549-6.
2. Menter A, Strober BE, Kaplan DH, et al. Joint AAD-NPF guidelines of care for the management and treatment of psoriasis with biologics. J Am Acad Dermatol. 2019;80(4):1029–72. https://doi.org/10.1016/j.jaad.2018.11.057.
3. Nast A, Smith C, Spuls PI, et al. EuroGuiDerm Guideline on the systemic treatment of psoriasis vulgaris. Part 1: treatment and monitoring recommendations. J Eur Acad Dermatol Venereol. 2020;34(11):2461–98. https://doi.org/10.1111/jdv.16915.
4. EMA. Bimzelx (bimekizumab). 2021. https://www.ema.europa.eu/en/documents/overview/bimzelx-epar-medicine-overview_en.pdf. Accessed 9 Apr 2024.
5. Kennedy-Martin T, Curtis S, Faries D, et al. A literature review on the representativeness of randomized controlled trial samples and implications for the external validity of trial results. Trials. 2015;3(16):495. https://doi.org/10.1186/s13063-015-1023-4.
6. Yiu ZZN, Mason KJ, Barker J, et al. A standardization approach to compare treatment safety and effectiveness outcomes between clinical trials and real-world populations in psoriasis. Br J Dermatol. 2019;181(6):1265–71. https://doi.org/10.1111/bjd.17849.
7. van den Reek J, Kievit W, Gniadecki R, et al. Drug survival studies in dermatology: principles, purposes, and pitfalls. J Invest Dermatol. 2015;135(7):1–5. https://doi.org/10.1038/jid.2015.171.
8. Lin PT, Wang SH, Chi CC. Drug survival of biologics in treating psoriasis: a meta-analysis of real-world evidence. Sci Rep. 2018;8(1):16068. https://doi.org/10.1038/s41598-018-34293-y.
9. No DJ, Inkeles MS, Amin M, et al. Drug survival of biologic treatments in psoriasis: a systematic review. J Dermatolog Treat. 2018;29(5):460–6. https://doi.org/10.1080/09546634.2017.1398393.
10. Mourad AI, Gniadecki R. Biologic drug survival in psoriasis: a systematic review & comparative meta-analysis. Front Med (Lausanne). 2020;7: 625755. https://doi.org/10.3389/fmed.2020.625755.
11. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;29(372): n71. https://doi.org/10.1136/bmj.n71.
12. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372: n160. https://doi.org/10.1136/bmj.n160.
13. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA. 2000;283(15):2008–12. https://doi.org/10.1001/jama.283.15.2008.
14. Ouzzani M, Hammady H, Fedorowicz Z, et al. Rayyan: a web and mobile app for systematic reviews. Syst Rev. 2016;5(1):210. https://doi.org/10.1186/s13643-016-0384-4.
15. Hayden JA, van der Windt DA, Cartwright JL, et al. Assessing bias in studies of prognostic factors. Ann Intern Med. 2013;158(4):280–6. https://doi.org/10.7326/0003-4819-158-4-201302190-00009.
16. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;12(355): i4919. https://doi.org/10.1136/bmj.i4919.
17. Combescure C, Foucher Y, Jackson D. Meta-analysis of single-arm survival studies: a distribution-free approach for estimating summary survival curves with random effects. Stat Med. 2014;33(15):2521–37. https://doi.org/10.1002/sim.6111.
18. Jackson D, White IR, Riley RD. Quantifying the impact of between-study heterogeneity in multivariate meta-analyses. Stat Med. 2012;31(29):3805–20. https://doi.org/10.1002/sim.5453.
19. Williamson PR, Smith CT, Hutton JL, et al. Aggregate data meta-analysis with time-to-event outcomes. Stat Med. 2002;21(22):3337–51. https://doi.org/10.1002/sim.1303.
20. Tierney JF, Stewart LA, Ghersi D, et al. Practical methods for incorporating summary time-to-event data into meta-analysis. Trials. 2007;7(8):16. https://doi.org/10.1186/1745-6215-8-16.
21. Mourad A, Straube S, Armijo-Olivo S, et al. Factors predicting persistence of biologic drugs in psoriasis: a systematic review and meta-analysis. Br J Dermatol. 2019;181(3):450–8. https://doi.org/10.1111/bjd.17738.
22. Klein JP, Logan B, Harhoff M, et al. Analyzing survival curves at a fixed point in time. Stat Med. 2007;26(24):4505–19. https://doi.org/10.1002/sim.2864.
23. Caldarola G, Chiricozzi A, Megna M, et al. Real-life experience with ixekizumab in plaque psoriasis: a multi-center, retrospective, 3-year study. Expert Opin Biol Ther. 2023;23(4):365–70. https://doi.org/10.1080/14712598.2023.2193288.
24. Caldarola G, Mariani M, Pirro F, et al. Comparison of short- and long-term effectiveness of ixekizumab and secukinumab in real-world practice. Expert Opin Biol Ther. 2021;21(2):279–86. https://doi.org/10.1080/14712598.2021.1849133.
25. Costa De Lima E, Gollo Mazzotti N, Palominos P, et al. Drug survival of biological therapy in south brazilian psoriasis patients. J Dermatol Nurses Assoc. 2020;12(2).
26. Daudén E, de Lima GPG, Armesto S, et al. Multicenter retrospective study of secukinumab drug survival in psoriasis patients in a daily practice setting: a long-term experience in Spain. Dermatol Ther (Heidelb). 2021;11(6):2207–15. https://doi.org/10.1007/s13555-021-00606-9.
27. Elgaard CDB, Iversen L, Hjuler KF. Guselkumab, tildrakizumab, and risankizumab in a real-world setting: drug survival and effectiveness in the treatment of psoriasis and psoriatic arthritis. J Dermatolog Treat. 2023;34(1):2133531. https://doi.org/10.1080/09546634.2022.2133531.
28. Fitzgerald T, Zhdanava M, Pilon D, et al. Long-term psoriasis control with guselkumab, adalimumab, secukinumab, or ixekizumab

in the USA. Dermatol Ther (Heidelb). 2023;13(4):1053–68. https://doi.org/10.1007/s13555-023-00910-6.
29. Galluzzo M, Marcelli L, Vellucci L, et al. Guselkumab for treatment of moderate-to-severe plaque psoriasis: real-life effectiveness and drug-survival for up to 148 weeks. Expert Opin Biol Ther. 2023;23(4):371–81. https://doi.org/10.1080/14712598.2023.2194485.
30. Gerdes S, Asadullah K, Hoffmann M, et al. Real-world evidence from the non-interventional, prospective, German multicentre PERSIST study of patients with psoriasis after 1 year of treatment with guselkumab. J Eur Acad Dermatol Venereol. 2022;36(9):1568–77. https://doi.org/10.1111/jdv.18218.
31. Gulliver W, Gooderham MJ, Zhu B, et al. Treatment persistence of ixekizumab in adults with moderate-to-severe plaque psoriasis participating in the Canadian Patient Support Program. Dermatol Ther (Heidelb). 2023;13(1):235–44. https://doi.org/10.1007/s13555-022-00853-4.
32. Gulliver W, Penney M, Power R, et al. Moderate-to-severe plaque psoriasis patients treated with ixekizumab: early real-world outcomes and adverse events. J Dermatol Treat. 2022;33(1):354–60. https://doi.org/10.1080/09546634.2020.1755009.
33. Gooderham MJ, Lynde C, Turchin I, et al. Real-world, long-term treatment patterns of commonly used biologics in Canadian patients with moderate-to-severe chronic plaque psoriasis. J Dermatol. 2022;49(1):95–105. https://doi.org/10.1111/1346-8138.16214.
34. Goon PKC, Banfield CC, Bello O, et al. Real-world NHS drug survival and efficacy data for Secukinumab in chronic plaque psoriasis. J Eur Acad Dermatol Venereol. 2020;34(11):e716–8. https://doi.org/10.1111/jdv.16538.
35. Herranz-Pinto P, Alonso-Pacheco ML, Feltes-Ochoa R, et al. Real-world performance of a new strategy for off-label use of guselkumab in moderate to severe psoriasis: super-responder patients as the epitome of efficacy and optimisation. Clin Drug Investig. 2023;43(7):517–27. https://doi.org/10.1007/s40261-023-01280-9.
36. Huang YH, Tang CH, Goh CH, et al. Persistence and adherence to biologics in patients with psoriasis in Taiwan: a new biologics user cohort study. Front Pharmacol. 2022;13: 880985. https://doi.org/10.3389/fphar.2022.880985.
37. Hugo J, Kojanova M, Turkova B, et al. Long-term efficacy, safety, and drug survival of guselkumab in patients with psoriasis: real-world data from the Czech Republic BIOREP Registry. Dermatol Ther (Heidelb). 2023;13(3):787–801. https://doi.org/10.1007/s13555-023-00893-4.
38. Iznardo H, Vilarrasa E, López-Ferrer A, et al. Real-world drug survival of guselkumab, ixekizumab and secukinumab for psoriasis. Br J Dermatol. 2021;185(3):660–2. https://doi.org/10.1111/bjd.20416.
39. Kishimoto M, Komine M, Kamiya K, et al. Drug survival of biologic agents for psoriatic patients in a real-world setting in Japan. J Dermatol. 2020;47(1):33–40. https://doi.org/10.1111/1346-8138.15146.
40. Kojanova M, Hugo J, Velackova B, et al. Efficacy, safety, and drug survival of patients with psoriasis treated with IL-17 inhibitors: brodalumab, ixekizumab, and secukinumab: real-world data from the Czech Republic BIOREP registry. J Dermatolog Treat. 2022;29:1–11. https://doi.org/10.1080/09546634.2022.2082354.
41. Lee EB, Amin M, Egeberg A, et al. Drug survival of secukinumab for psoriasis in a real-world setting. J Dermatolog Treat. 2019;30(2):150–1. https://doi.org/10.1080/09546634.2018.1473838.
42. Lee EB, Pithadia DJ, Reynolds KA, et al. Real-world drug survival of ixekizumab for psoriasis. J Am Acad Dermatol. 2019;81(1):270–2. https://doi.org/10.1016/j.jaad.2019.01.034.
43. Lee EB, Reynolds KA, Pithadia DJ, et al. Drug survival of guselkumab for psoriasis in a real-world setting: a single-center retrospective chart review. J Dermatolog Treat. 2020;31(4):342–3. https://doi.org/10.1080/09546634.2019.1605133.
44. Li Y, Lu JJ, Zhong XY, et al. Drug survival outcomes associated with the real-world use of ixekizumab, secukinumab, guselkumab, and adalimumab for the treatment of plaque psoriasis in China: a 52-week single-center retrospective study. Clin Cosmet Investig Dermatol. 2022;15:2245–52. https://doi.org/10.2147/ccid.S387759.
45. Lockshin B, Cronin A, Harrison RW, et al. Drug survival of ixekizumab, TNF inhibitors, and other IL-17 inhibitors in real-world patients with psoriasis: the Corrona Psoriasis Registry. Dermatol Ther. 2021;34(2): e14808. https://doi.org/10.1111/dth.14808.
46. Lunder T, Zorko MS, Kolar NK, et al. Drug survival of biological therapy is showing class effect: updated results from Slovenian National Registry of psoriasis. Int J Dermatol. 2019;58(6):631–41. https://doi.org/10.1111/ijd.14429.
47. Lytvyn Y, Zaaroura H, Mufti A, et al. Drug survival of guselkumab in patients with plaque psoriasis: a 2 year retrospective, multicenter study. JAAD Int. 2021;4:49–51. https://doi.org/10.1016/j.jdin.2021.05.003.
48. Mashor M, Wong KW, Tey KE, et al. A retrospective study on drug survival of biologic among patients with psoriasis seen in tertiary hospital in Johor Malaysia. Med J Malaysia. 2022;77(6):689–95.
49. Mastorino L, Dapavo P, Burzi L, et al. Drug survival, effectiveness and safety of ixekizumab for moderate-to-severe psoriasis up to 5 years. J Eur Acad Dermatol Venereol. 2023. https://doi.org/10.1111/jdv.19682.
50. Mastorino L, Dapavo P, Susca S, et al. Drug survival and clinical effectiveness of secukinumab, ixekizumab, brodalumab, guselkumab, risankizumab, tildrakizumab for psoriasis treatment. J Dtsch Dermatol Ges. 2024;22(1):34–42. https://doi.org/10.1111/ddg.15251.
51. Mendes-Bastos P, Morais P, Ferreira P, et al. Persistence, effectiveness, and real-world outcomes in psoriasis patients treated with secukinumab in Portugal. Dermatol Ther. 2022;35: e15510. https://doi.org/10.1111/dth.15510.
52. Mucherino S, Rafaniello C, Serino M, et al. Drug utilization and measurement of medication adherence: a real world study of psoriasis in Italy. Pharmaceutics. 2023;15(12):2647. https://doi.org/10.3390/pharmaceutics15122647.
53. Nguyen HT, Pham NTU, Tran TNA, et al. Long-term effectiveness and drug survival of secukinumab in Vietnamese patients with psoriasis: results from a retrospective ENHANCE study. Dermatol Ther (Heidelb). 2023;13(2):465–76. https://doi.org/10.1007/s13555-022-00867-y.
54. Oh S, Choi S, Yoon HS. Available alternative biologics and disease groups influence biologic drug survival in patients with psoriasis and psoriatic arthritis. Ann Dermatol. 2022;34(5):321–30. https://doi.org/10.5021/ad.22.003.
55. Ortolan A, Lorenzin M, Leo G, et al. Secukinumab drug survival in psoriasis and psoriatic arthritis patients: a 24-month real-life study. Dermatology. 2022;238(5):897–903. https://doi.org/10.1159/000522008.
56. Pilon D, Fitzgerald T, Zhdanava M, et al. Risk of treatment discontinuation among patients with psoriasis initiated on ustekinumab and other biologics in the USA. Dermatol Ther. 2022;12(4):971–87. https://doi.org/10.1007/s13555-022-00707-z.
57. Pina Vegas L, Penso L, Claudepierre P, et al. Long-term persistence of first-line biologics for patients with psoriasis and psoriatic arthritis in the French health insurance database. JAMA Dermatol. 2022;158(5):513–22. https://doi.org/10.1001/jamadermatol.2022.0364.

58. Rompoti N, Politou M, Stefanaki I, et al. Brodalumab in plaque psoriasis: real-world data on effectiveness, safety and clinical predictive factors of initial response and drug survival over a period of 104 weeks. J Eur Acad Dermatol Venereol. 2023;37(4):689–97. https://doi.org/10.1111/jdv.18825.
59. Ruiz-Villaverde R, Rodriguez-Fernandez-Freire L, Armario-Hita JC, et al. Guselkumab: mid-term effectiveness, drug survival, and safety in real clinical practice. Dermatol Ther. 2021;34(2): e14798. https://doi.org/10.1111/dth.14798.
60. Ruiz-Villaverde R, Rodriguez-Fernandez-Freire L, Galán-Gutierrez M, et al. Drug survival, discontinuation rates, and safety profile of secukinumab in real-world patients: a 152-week, multicenter, retrospective study. Int J Dermatol. 2020;59(5):633–9. https://doi.org/10.1111/ijd.14819.
61. Schmitt-Egenolf M, Freilich J, Stelmaszuk-Zadykowicz NM, et al. Drug persistence of biologic treatments in psoriasis: a Swedish national population study. Dermatol Ther (Heidelb). 2021;11(6):2107–21. https://doi.org/10.1007/s13555-021-00616-7.
62. Schots L, Soenen R, Blanquart B, et al. Blocking interleukin-17 in psoriasis: real-world experience from the PsoPlus cohort. J Eur Acad Dermatol Venereol. 2023;37(4):698–710. https://doi.org/10.1111/jdv.18827.
63. Shalom G, Cohen AD, Feldhamer I, et al. Drug survival in patients with psoriasis is associated with the availability of biologic medications. J Eur Acad Dermatol Venereol. 2020;34(7):1524–8. https://doi.org/10.1111/jdv.16205.
64. Sotiriou E, Bakirtzi K, Vakirlis E, et al. Long-term drug survival of secukinumab in real life in the era of novel biologics: a 5-year, retrospective study, including difficult-to-treat areas. J Eur Acad Dermatol Venereol. 2022;36(8):e626–7. https://doi.org/10.1111/jdv.18087.
65. Sotiriou E, Tsentemeidou A, Vakirlis E, et al. Secukinumab survival and long-term efficacy in patients with plaque psoriasis: real-life data from a tertiary hospital in Greece. J Eur Acad Dermatol Venereol. 2019;33(2):e82–4. https://doi.org/10.1111/jdv.15231.
66. Sruamsiri R, Iwasaki K, Tang W, et al. Persistence rates and medical costs of biological therapies for psoriasis treatment in Japan: a real-world data study using a claims database. BMC Dermatol. 2018;18(1):5. https://doi.org/10.1186/s12895-018-0074-0.
67. Sullivan J, Hannam S, Puig A, et al. Real-world treatment persistence of four commonly prescribed biologic therapies for moderate to severe psoriasis in Australia. Australas J Dermatol. 2023;64(4):504–13. https://doi.org/10.1111/ajd.14153.
68. Tada Y, Morita A, Yamanaka K, et al. Real-world retention rates and effectiveness of secukinumab in psoriasis: results from a multicenter cohort study (RAILWAY). J Dermatol. 2023;50(11):1415–26. https://doi.org/10.1111/1346-8138.16926.
69. Tada Y, Soliman AM, Ishii K, et al. Real-world discontinuation and switching patterns for interleukin-inhibitor treatments in patients with moderate-to-severe psoriasis in Japan. Dermatol Ther (Heidelb). 2024;14(1):99–114. https://doi.org/10.1007/s13555-023-01064-1.
70. Thein D, Rosenø NAL, Maul JT, et al. Drug survival of adalimumab, secukinumab, and ustekinumab in psoriasis as determined by either dose escalation or drug discontinuation during the first 3 years of treatment: a nationwide cohort study. J Invest Dermatol. 2023;143(11):2211-8.e4. https://doi.org/10.1016/j.jid.2023.04.009.
71. Torres T, Puig L, Vender R, et al. Drug survival of IL-12/23, IL-17 and IL-23 inhibitors for psoriasis treatment: a retrospective multi-country, multicentric cohort study. Am J Clin Dermatol. 2021;22(4):567–79. https://doi.org/10.1007/s40257-021-00598-4.
72. Torres T, Balato A, Conrad C, et al. Secukinumab drug survival in patients with psoriasis: a multicenter, real-world, retrospective study. J Am Acad Dermatol. 2019;81(1):273–5. https://doi.org/10.1016/j.jaad.2019.02.031.
73. Wang C, Torisu-Itakura H, Hanada T, et al. Treatment persistence of interleukin-17 inhibitor class drugs among patients with psoriasis in Japan: a retrospective database study. J Dermatolog Treat. 2023;34(1):2229465. https://doi.org/10.1080/09546634.2023.2229465.
74. Wang Y, Wang X, Yu Y, et al. A retrospective study to assess the efficacy, safety, and drug survival of secukinumab in plaque psoriasis patients in China. Dermatol Ther. 2021;34(5): e15081. https://doi.org/10.1111/dth.15081.
75. Foley P, Manuelpillai N, Dolianitis C, et al. Secukinumab treatment demonstrated high drug survival and sustained effectiveness in patients with severe chronic plaque psoriasis: 21-month analysis in Australian routine clinical practice (SUSTAIN study). Australas J Dermatol. 2022;63(3):303–11. https://doi.org/10.1111/ajd.13895.
76. Hendrix N, Marcum ZA, Veenstra DL. Medication persistence of targeted immunomodulators for plaque psoriasis: a retrospective analysis using a U.S. claims database. Pharmacoepidemiol Drug Saf. 2020;29(6):675–83. https://doi.org/10.1002/pds.5021.
77. Yiu ZZN, Becher G, Kirby B, et al. Drug survival associated with effectiveness and safety of treatment with guselkumab, ixekizumab, secukinumab, ustekinumab, and adalimumab in patients with psoriasis. JAMA Dermatol. 2022;158(10):1131–41. https://doi.org/10.1001/jamadermatol.2022.2909.
78. Torres T. Selective IL-23 inhibitors: the new kids on the block in the treatment of psoriasis. Actas Dermosifiliogr (Engl Ed). 2018;109(8):674–6. https://doi.org/10.1016/j.ad.2018.03.016.
79. Garcia-Doval I, Dávila-Seijo P. How real are "real-life studies" in psoriasis, and the uncertain meaning of drug persistence. Br J Dermatol. 2019;180(1):15–6. https://doi.org/10.1111/bjd.17104.
80. Chatzimichail G, Günther J, Ständer S, et al. Drug survival of secukinumab, ustekinumab, and certolizumab pegol in psoriasis: a 2-year, monocentric, retrospective study. J Dermatolog Treat. 2022;33(3):1749–53. https://doi.org/10.1080/09546634.2020.1854428.
81. Graier T, Salmhofer W, Jonak C, et al. Biologic drug survival rates in the era of anti-interleukin-17 antibodies: a time-period-adjusted registry analysis. Br J Dermatol. 2021;184(6):1094–105. https://doi.org/10.1111/bjd.19701.
82. Rompoti N, Sidiropoulou P, Panagakis P, et al. Real-world data from a single Greek centre on the use of secukinumab in plaque psoriasis: effectiveness, safety, drug survival, and identification of patients that sustain optimal response. J Eur Acad Dermatol Venereol. 2020;34(6):1240–7. https://doi.org/10.1111/jdv.16202.
83. van den Reek J, van Vugt LJ, van Doorn MBA, et al. Initial results of Sscukinumab drug survival in patients with psoriasis: a multicentre daily practice cohort study. Acta Derm Venereol. 2018;98(7):648–54. https://doi.org/10.2340/00015555-2900.
84. Torres T, Puig L, Vender R, et al. Drug survival of interleukin (IL)-17 and IL-23 inhibitors for the treatment of psoriasis: a retrospective multi-country, multicentric cohort study. Am J Clin Dermatol. 2022;23(6):891–904. https://doi.org/10.1007/s40257-022-00722-y.
85. Yanase T, Tsuruta N, Yamaguchi K, et al. Survival rates of systemic interventions for psoriasis in the Western Japan Psoriasis Registry: a multicenter retrospective study. J Dermatol. 2023;50(6):753–65. https://doi.org/10.1111/1346-8138.1673.7.
86. Elgaard CDB, Iversen L, Hjuler KF. Single-centre real-world study on drug survival and effectiveness of brodalumab for treatment of psoriasis and psoriatic arthritis. Drugs R D. 2023;23(2):155–63. https://doi.org/10.1007/s40268-023-00422-w.
87. Gargiulo L, Ibba L, Malagoli P, et al. Brodalumab for the treatment of plaque psoriasis in a real-life setting: a 3 years multicenter retrospective study-IL PSO (Italian landscape psoriasis). Front

Med (Lausanne). 2023;10:1196966. https://doi.org/10.3389/fmed.2023.1196966.
88. Mälkönen T, Nuutinen P, Hallinen T, et al. Guselkumab treatment outcomes and persistence in a nationwide real-world cohort of patients with plaque psoriasis. Acta Derm Venereol. 2022;102:adv00631. https://doi.org/10.2340/actadv.v101.910.
89. Van Muijen ME, Thomas SE, Vellinga D, et al. Real-world data reveal long drug survival for guselkumab in patients with plaque psoriasis. Acta Derm Venereol. 2022;102:adv00755. https://doi.org/10.2340/actadv.v102.685.
90. Caldarola G, De Luca E, Bavetta M, et al. 2-Year experience with risankizumab in the treatment of plaque psoriasis in Lazio region, Italy. Dermatol Ther. 2023;2023:9832296. https://doi.org/10.1155/2023/9832296.
91. Ruiz-Villaverde R, Rodriguez Fernandez-Freire L, Font-Ugalde P, et al. Tildrakizumab: efficacy, safety and survival in mid-term (52 weeks) in three tertiary hospitals in Andalucia (Spain). J Clin Med. 2022;11(17):5098. https://doi.org/10.3390/jcm11175098.
92. Dapavo P, Siliquini N, Mastorino L, et al. Efficacy, safety, and drug survival of IL-23, IL-17, and TNF-alpha inhibitors for psoriasis treatment: a retrospective study. J Dermatolog Treat. 2022;33(4):2352–7. https://doi.org/10.1080/09546634.2021.1961998.
93. Egeberg A, Roseno NAL, Aagaard D, et al. Drug survival of biologics and novel immunomodulators for rheumatoid arthritis, axial spondyloarthritis, psoriatic arthritis, and psoriasis: a nationwide cohort study from the DANBIO and DERMBIO registries. Semin Arthritis Rheum. 2022;53: 151979. https://doi.org/10.1016/j.semarthrit.2022.151979.
94. Blauvelt A, Shi N, Burge R, et al. Comparison of real-world treatment patterns among patients with psoriasis prescribed ixekizumab or secukinumab. J Am Acad Dermatol. 2020;82(4):927–35. https://doi.org/10.1016/j.jaad.2019.11.015.