



OPEN ACCESS

EXTENDED REPORT

Spectrum of lymphomas across different drug treatment groups in rheumatoid arthritis: a European registries collaborative project

Louise K Mercer,¹ Anne C Regierer,² Xavier Mariette,³ William G Dixon,¹ Eva Baecklund,⁴ Karin Hellgren,⁵ Lene Dreyer,^{6,7} Merete Lund Hetland,^{8,9} René Cordtz,^{6,7} Kimme Hyrich,^{1,10} Anja Strangfeld,² Angela Zink,^{2,11} Helena Canhao,¹² M Victoria Hernandez,¹³ Florence Tubach,¹⁴ Jacques-Eric Gottenberg,¹⁵ Jacques Morel,¹⁶ Jakub Zavada,¹⁷ Florenzo Iannone,¹⁸ Johan Askling,⁵ Joachim Listing²

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/annrheumdis-2017-211623>).

For numbered affiliations see end of article.

Correspondence to

Dr Anne C Regierer, Deutsches Rheuma-Forschungszentrum Berlin, Ein Leibniz Institut, Programmbereich Epidemiologie, Charitéplatz 1, 10117 Berlin, Germany; Anne.Regierer@drfz.de

LKM and ACR contributed equally.

Received 10 April 2017
Revised 13 June 2017
Accepted 19 July 2017
Published Online First
19 August 2017

ABSTRACT

Background Lymphomas comprise a heterogeneous group of malignant diseases with highly variable prognosis. Rheumatoid arthritis (RA) is associated with a twofold increased risk of both Hodgkin's lymphoma (HL) and non-Hodgkin's lymphoma (NHL). It is unknown whether treatment with biologic disease-modifying antirheumatic drugs (bDMARDs) affect the risk of specific lymphoma subtypes.

Methods Patients never exposed to (bionative) or ever treated with bDMARDs from 12 European biologic registers were followed prospectively for the occurrence of first ever histologically confirmed lymphoma. Patients were considered exposed to a bDMARD after having received the first dose. Lymphomas were attributed to the most recently received bDMARD.

Results Among 124 997 patients (mean age 59 years; 73.7% female), 533 lymphomas were reported. Of these, 9.5% were HL, 83.8% B-cell NHL and 6.8% T-cell NHL. No cases of hepatosplenic T-cell lymphoma were observed. Diffuse large B-cell lymphoma (DLBCL) was the most frequent B-cell NHL subtype (55.8% of all B-cell NHLs). The subtype distributions were similar between bionative patients and those treated with tumour necrosis factor inhibitors (TNFi). For other bDMARDs, the numbers of cases were too small to draw any conclusions. Patients with RA developed more DLBCLs and less chronic lymphocytic leukaemia compared with the general population.

Conclusion This large collaborative analysis of European registries has successfully collated subtype information on 533 lymphomas. While the subtype distribution differs between RA and the general population, there was no evidence of any modification of the distribution of lymphoma subtypes in patients with RA treated with TNFi compared with bionative patients.

INTRODUCTION

Malignant lymphomas ('lymphomas') comprise a heterogeneous group of malignant diseases with presumably distinct aetiologies. Whereas the 5-year overall survival across all lymphomas is approximately 60%, there is great variation in survival depending on the lymphoma subtype, ranging from life expectancy comparable to the general population in nodular lymphocyte predominant Hodgkin's

lymphoma (HL) to 5-year survival of <40% for T-cell lymphomas.¹ Furthermore, clinical characteristics and therapy approaches vary to a great extent according to subtype. The age-standardised incidence rate (IR) in Europe of approximately 25/100 000² makes lymphoma one of the 10 most common cancer types in the general population. There are significant gender and age-dependent differences, with men having higher IRs in most subtypes and being diagnosed at younger ages.¹

In rheumatoid arthritis (RA) the overall incidence of lymphoma is approximately doubled compared with that in the general population.³⁻⁹ The association between RA disease activity and lymphoma risk is considered one reason for this increased risk.¹⁰

Evidence that chronic immune stimulation/chronic inflammation has a pathogenic effect in lymphomagenesis comes from the publication by Baecklund *et al.*¹⁰ This study described an 'excess' risk strongly linked to the cumulative activity of the disease, especially for diffuse large B-cell lymphoma (DLBCL), the most common type of aggressive B-cell lymphomas.¹⁰ Moreover, an association of methotrexate (MTX) treatment with Epstein-Barr virus (EBV)-positive lymphoproliferative disorders has been described.¹¹ Furthermore, a possible association between the use of tumour necrosis factor inhibitors (TNFi) and a rare but prognostically unfavourable hepatosplenic subtype of T-cell lymphoma has been reported.¹²

A number of European and other rheumatology registers have reported on the overall risk of lymphoma in patients with RA treated or not with TNFi^{5 13 14} and did not find a further risk increase related to the treatment. However, the influence of TNFi is a matter of debate as recent reports from Asia and French data on Crohn's disease have shown a higher lymphoma risk in TNFi-treated patients.¹⁵⁻¹⁷

The notion that RA disease activity may be a strong risk determinant suggests that the overall lymphoma risk in TNFi-treated RA compared with the general population may represent a composite wherein a decreased risk for a disease-related lymphoma subset may be replaced by an increased risk for a treatment-related subtype. However, there is no definitive evidence for any influence of



CrossMark

To cite: Mercer LK, Regierer AC, Mariette X, *et al.* *Ann Rheum Dis* 2017;**76**:2025-2030.

RA treatment on subtype distribution. In contrast to estimations of overall lymphoma risk in RA, which can be accomplished in individual registers, any analysis of subtype distribution requires large data sets and hence an international collaboration of RA registers.

The main aim of this collaborative analysis was, therefore, to explore whether there might be a switch in the subtype distribution of lymphomas in RA linked to specific antirheumatic treatments; if so, the finding would support the above-mentioned 'exchange of risks.' To this end, patients with RA never exposed to bDMARDs (bionative) were compared with patients with RA treated with bDMARDs, mainly TNFi, with respect to lymphoma subtypes across several European RA registries. To place the RA results into context, a second rationale of the study was to analyse the size and direction of any shift in the spectrum of lymphoma subtypes in patients with RA compared with the general population.

PATIENTS AND METHODS

Participating registers

Twelve European biologic registers from nine countries participated in this collaborative project of the European League Against Rheumatism (EULAR) Registers and Observational Drug Studies (RODS) Study Group: the French biologics register 'autoimmunity and rituximab' (AIR),¹⁸ the Swedish ARTIS linkage of the Swedish Rheumatology Quality Register (SRQ) to other nationwide registers,¹³ the Czech biologics register ATTRA,¹⁹ the Registro Español de Acontecimientos Adversos de Terapias Biológicas en Enfermedades Reumáticas (BIOBADASER),²⁰ the British Society for Rheumatology Biologics Register for Rheumatoid Arthritis (BSRBR-RA),⁵ the Danish Rheumatologic database (DANBIO),²¹ the Italian biologics register (GISEA),²² the French biologics register 'Orencia and RA' (ORA),¹⁸ the German biologics register 'Rheumatoid arthritis observation of biologic therapy' (RABBIT),²³ the French Research Axed on Tolerance of biOtherapies (RATIO),²⁴ the French Register Tocilizumab and RA (REGATE), and the Portuguese rheumatic diseases register (Reuma.pt).²⁵ To participate, registers were required to have at least one lymphoma reported and consequently several other European biologic registers were not able to contribute.

Patients

Patients were required to have physician-diagnosed RA and to be prospectively followed up in one of the participating European RA registers. Patients with a history of lymphoma prior to registration were excluded. Patients diagnosed with a histology-confirmed lymphoma after study registration were included in the analysis. These patients were stratified according to their exposure status as follows: (1) bionative group: patients who were bionative at the diagnosis of the lymphoma; and (2) patients who were not bionative at the diagnosis of the lymphoma were stratified into four groups according to the biologic disease-modifying antirheumatic drug (bDMARD) they had received most recently prior to the development of the lymphoma: TNFi, rituximab, tocilizumab or abatacept.

Outcome

The primary endpoint was the spectrum of lymphoma subtypes. The definition of lymphoma included HL and non-Hodgkin's lymphoma (NHL), but not plasma cell neoplasias. The subtypes were defined according to the pathology reports. The WHO 2008 classification of lymphomas was used to classify the respective subtype of lymphoma.²⁶ Crude IRs were also calculated.

Three registries received reports of histologically confirmed lymphoma through linkage of all participants to their national cancer registry: DANBIO, ARTIS and BSRBR-RA. The remaining registers (as well as BSRBR-RA) received reports of lymphoma from the patient's rheumatologist. For BSRBR-RA, histologically confirmed lymphomas were included if reported from either record linkage or rheumatologist.

Statistical analysis

The spectrum of lymphoma subtypes was compared between RA cohorts in two steps. In the first step, the portion of HL and NHL classified into B-cell lymphoma (B-NHL) and T-cell lymphoma (T-NHL) was compared by χ^2 test and exact multinomial 95% CIs. HL, B-NHL and T-NHL with incomplete subtype information were included in this first step, whereas lymphomas not otherwise specified were excluded.

To describe the consistency of the findings, the results of analyses based on registers with at least 30 lymphomas each in the bionative cohort and the biologic-treated cohort are shown separately. In the second step, the subtype distributions of B-NHL were compared. In this comparison, B-NHLs with missing further subtype specification were excluded.

To compare the spectra of lymphomas observed within the RA cohorts with the spectrum of lymphoma subtypes in the general population, data from the HAEMACARE project were used.² HAEMACARE is a European cancer register-based project intended to improve the standardisation and availability of population-based data on haematological malignancies in Europe. It covers approximately 30% of the European population. Forty-eight cancer registers, operating in 20 countries, had incidence data for at least one of the predefined study years (2000–2002) and were hence included in the HAEMACARE analysis.²

To use these data for the comparison with the RA cohorts, we had to consider that the spectrum of lymphoma subtypes, especially the portion of HL versus NHL, depends on the underlying age distribution of the population being investigated. In the general population, approximately 50% of HL cases, but only 10% of NHL cases, are diagnosed in subjects aged 45 or below. In the HAEMACARE cohort, the percentage of subjects with age ≤ 45 years was clearly higher (55%) than that in our RA cohorts (16%). Therefore, a lower proportion of incident HL cases are expected in our cohorts. For that reason, we used direct standardisation methods and calculated the expected numbers of HL, B-NHL and T-NHL in a general population in which the age group ≤ 45 years has the same proportion as in our sample. These expected numbers were used to calculate percentages of the corresponding subtypes and were compared with those observed in the RA cohorts. No adjustment was made when the spectra of B-cell lymphoma were compared.

RESULTS

Baseline characteristics of more than 120 000 patients with RA included in the analysis are shown in [table 1](#). In total, 533 lymphoma cases were identified. Since patient-years (pyrs) were not available in the RATIO and GISEA registries, we excluded the 27 lymphoma cases from RATIO and the 12 cases from GISEA in the calculation of the IR. A total of 494 lymphoma cases were reported in 584 236 pyrs in the remaining registers, corresponding to an overall crude IR of 85 per 100 000 pyrs (95% CI 77 to 92). The crude IR was similar between bionative and TNFi-treated patients with RA, whereas a lower incidence was reported in patients exposed to rituximab ([table 1](#)).

Table 1 Baseline characteristics and crude incidence rate of lymphomas among biologic-naïve, TNFi, rituximab, tocilizumab or abatacept-treated patients with RA

	Bionai�ve	TNFi	Rituximab	Tocilizumab	Abatacept	Total
No. of patients	71 088	47 864*	9094	2029	1708*	124 997*
Follow-up time (pyrs)	322 167	242 260*	29810	2827	3352*	584 236*
Female (%)	72.1	74.8	79.0	80.1	78.0	73.7
Age mean (mean range)	61.1 (57–62)	55.0 (50–57)	57.9 (58–58)	55.9 (55–57)	57.5 (56–58)	58.5 (50–62)
No. of lymphomas	288	230	6	6	3	533
Incidence per 100 000 pyrs (95% CI)	89 (79–100)	81 (70–94)	20 (7–44)	177 (57–413)	60 (7–216)	85 (77–92)

*Because of the type of the register these data are missing from RATIO and GISEA, 38 incident TNFi-exposed lymphoma cases (RATIO: 27, GISEA: 11) and one abatacept-exposed patient (GISEA) were for that reason excluded from the calculation of the incidence rate. GISEA, Italian Group for the Study of Early Arthritis; pyrs, patient-years; RA, rheumatoid arthritis; RATIO, French Research Axed on Tolerance of biOtherapies; TNFi, tumour necrosis factor inhibitor.

Spectrum of lymphoma subtypes in patients with RA

The spectrum of lymphoma subtypes was analysed in multiple steps, corresponding to progressively more detailed classifications (tables 2 and 3).

To compare possible influences of the treatment on the subtype distribution of lymphomas we compared patients with RA by treatment groups. There were no significant differences in the distribution of HL versus B-NHL versus T-NHL between bionai ve patients and TNFi-treated patients (table 2). Similar results were found in each of two biologic registers (ARTIS and BSRBR-RA) with more than 30 lymphomas in both the bionai ve and TNFi groups, as well as in the subgroup of the remaining registers (table 2). Results of the remaining registers are provided in online supplementary table S1.

B-NHL cases were further stratified by subtype (table 3). The most frequent subtype in patients with RA was DLBCL, followed by follicular lymphoma and chronic lymphocytic leukaemia (CLL). No significant difference in B-NHL subtypes was observed between bionai ve and TNFi-treated patients (table 3).

The small numbers of HL and T-NHL cases did not allow further subtype analysis. No case of hepatosplenic T-cell lymphoma was detected.

Comparison between RA and the general population

After standardisation for age, the distribution of HL versus B-NHL versus T-NHL observed in the RA group with 9.5% HL, 83.8% B-NHL and 6.8% T-NHL was similar to the values estimated from the general population data (10.1% HL, 82.6% B-NHL and 7.3% T-NHL, table 2).

Comparison within the B-NHL subtype, however, showed that DLBCL was significantly over-represented in subjects with RA compared with the general population (56% of all B-NHL in RA vs 30% in the general population; table 3); whereas CLL was significantly less frequent (16% of all B-NHL in RA vs 38% in the general population; table 3).

DISCUSSION

The main aim of this collaborative study was to compare the distribution of lymphoma subtypes between TNFi-treated and bionai ve patients with RA. Interestingly, we did not find any significant differences in these subtype distributions, neither when comparing the broader groups of HL versus B-NHL versus T-NHL nor when comparing among the B-NHL subtypes. This is reassuring as it does not indicate any bidirectional effect

Table 2 Lymphoma subtype distribution (Hodgkin's, B-cell and T-cell lymphomas) in patients with RA in treatment groups. ARTIS and BSRBR-RA, both with more than 30 lymphomas in the bionai ve and TNFi groups, are shown separately to describe the robustness of the results

	N total	Hodgkin's			B cell			T cell			NOS
		n	%	95% CI	n	%	95% CI	n	%	95% CI	N excluded
Bionai�ve											
ARTIS	197	13	6.6	3.3 to 11.8	174	88.3	82.1 to 93.0	10	5.1	2.6 to 8.8	19
BSRBR	30	5	16.7	5.1 to 37.0	22	73.3	50.9 to 88.6	3	10.0	1.8 to 29.1	4
Other	31	3	9.7	1.8 to 28.6	24	77.4	55.3 to 91.2	4	12.9	3.2 to 32.5	7
Total	258	21	8.1	4.7 to 12.9	220	85.3	79.3 to 90.0	17	6.6	3.6 to 11.2	30
TNFi											
ARTIS	52	6	11.5	4.0 to 26.2	40	76.9	61.1 to 88.3	6	11.5	4.0 to 26.2	7
BSRBR	77	11	14.3	6.5 to 25.9	63	81.8	69.4 to 90.6	3	3.9	0.7 to 12.1	10
Other	73	7	9.6	3.6 to 20.4	61	83.6	71.3 to 91.8	5	6.9	2.0 to 17.0	11
Total	202	24	11.9	7.0 to 18.3	164	81.2	74.1 to 87.3	14	6.9	3.3 to 12.3	28
Rituximab	6	0	0	0 to 50.0	5	83.3	32.9 to 99.7	1	16.7	0.3 to 67.2	0
Tocilizumab	5	0	0	0 to 56.0	5	100	44.0 to 100	0	0	0 to 56.0	1
Abatacept	3	0	0	0 to 74.4	3	100	25.6 to 100	0	0	0 to 74.4	0
RA total	474	45	9.5	6.6 to 13.2	397	83.8	79.3 to 87.6	32	6.8	4.3 to 10.0	59

BSRBR-RA, British Society for Rheumatology Biologics Register for Rheumatoid Arthritis; NOS, not otherwise specified; RA, rheumatoid arthritis; TNFi, tumour necrosis factor inhibitor.

Table 3 B-cell non-Hodgkin's lymphoma subtypes

	Chronic lymphocytic leukemia/ small cell lymphoma		Lymphoplasmacytic lymphoma (Waldenström macroglobulinaemia)		Marginal zone lymphoma		Follicular lymphoma		Mantle cell lymphoma		Diffuse large B-cell lymphoma		Burkitt lymphoma	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Bionative	28	15.2 (9.2 to 23.2)	4	2.2 (0.4 to 6.8)	1	0.5 (0 to 4.1)	33	17.9 (11.3 to 26.6)	5	2.7 (0.6 to 7.6)	113	61.4 (51.5 to 70.8)	0	0 (0 to 3.0)
TNF	26	17.2 (10.1 to 26.8)	6	4.0 (1.1 to 10.1)	10	6.6 (2.6 to 13.6)	34	22.5 (14.3 to 32.6)	0	0 (0 to 3.6)	75	49.7 (38.6 to 60.8)	0	0 (0 to 3.6)
RTX	5	20.0 (1.4 to 79.6)	1	20.0 (1.4 to 79.6)	0	0 (0 to 62.9)	1	20.0 (1.4 to 79.6)	0	0 (0 to 62.9)	2	40.0 (2.8 to 90.6)	0	0 (0 to 62.9)
TOC	5	40.0 (2.8 to 90.6)	0	0 (0 to 62.9)	0	0 (0 to 62.9)	0	0 (0 to 62.9)	0	0 (0 to 62.9)	3	60.0 (9.4 to 97.3)	0	0 (0 to 62.9)
ABA	3	0 (0 to 80.7)	0	0 (0 to 80.7)	0	0 (0 to 80.7)	2	66.7 (5.0 to 99.8)	0	0 (0 to 80.7)	1	33.3 (0.2 to 95.0)	0	0 (0 to 80.7)
RA total	348	16.4 (11.6 to 22.2)	11	3.2 (1.3 to 6.4)	11	3.2 (1.3 to 6.4)	70	20.1 (14.7 to 26.4)	5	1.4 (0.3 to 4.0)	194	55.8 (48.4 to 62.9)	0	0 (0 to 1.6)
General population	28 747	38.3 (37.6 to 39.1)	1859	6.5 (6.1 to 6.9)	950	3.3 (3.0 to 3.6)	4881	17.0 (16.4 to 17.6)	1012	3.5 (3.2 to 3.8)	8538	29.7 (29.0 to 30.4)	488	1.7 (1.5 to 1.9)

ABA, abatacept; RA, rheumatoid arthritis; RTX, rituximab; TNFi, tumour necrosis factor inhibitor; TOC, tocilizumab.

of treatments by reducing the risk for some subtypes while increasing the risk of other subtypes. By contrast, the spectrum of lymphoma subtypes in our RA cohort showed significant differences from the spectrum described in the general population in Europe.² This has been suggested in previous studies,^{10 27} and it is now confirmed by our analysis which is the largest to date. It is of great clinical importance as different lymphoma subtypes show different clinical behaviour, including wide heterogeneity in both prognosis and the preferred treatment approach.

The analysis of the spectrum of lymphoma subtypes is also of importance because there are hints that certain subtypes might be associated with certain therapies, for example, very rare cases of EBV-associated lymphoproliferative disease with MTX¹¹ and hepatosplenic T-cell lymphomas with TNFi.¹² Hepatosplenic T-cell lymphoma is a rare subtype with a very unfavourable prognosis and poor response to currently available treatment options. It occurs more often in chronically immunocompromised patients. There has been a safety concern regarding its occurrence in patients treated with TNFi, especially in young male patients with Crohn's disease.¹² However, a very thorough analysis of all T-cell lymphoma cases reported to the Food and Drug Administration between 2003 and 2010 suggested an increased T-cell NHL risk from TNFi use in combination with thiopurines but not from TNFi alone.²⁸ We did not find any cases of hepatosplenic T-cell NHL in our RA patient cohorts in over 240 000 pyrs of follow-up in patients with RA exposed to TNFi, in 320 000 bionative pyrs or in the 36 000 pyrs in patients exposed to rituximab, abatacept or tocilizumab. Whether there were cases hidden among the group of 12 'T-cell NHL not otherwise specified,' of which five cases were in the TNFi group, remains speculative.

In a recent Swedish cohort, an increased risk of HL in patients with RA compared with the general population and compared with previously reported RA cohorts has been described.⁶ There is a strong association between chronic inflammation and development of HL.^{6 29} In our analysis, there was a slight numerical but not statistically significant increase in the proportion of HLs between bionative and TNFi-treated patients.

The development of lymphomas can occur over a prolonged period of time, with several months or years elapsing between the onset of lymphomagenesis and diagnosis. Therefore, clinical trials with their short follow-up times are not an appropriate method of studying these malignancies, whereas registers provide a unique opportunity to do so. In addition to the large sample size of 533 lymphoma cases, the largest published RA-lymphoma cohort to date, the strength of our study is the usage of clearly stated definitions for the subtypes of lymphomas. All registers used the same template to define subtypes based on the WHO 2008 classification.³⁰ Ideally, central pathological review of lymphoma specimens would have been preferable to standardise the lymphoma subtype classification; however, for feasibility reasons, this was not possible.

Another strength is the long follow-up time for individual patients, which is the prerequisite for analysing these safety events. Thanks to the use of unselected patients without any exclusion criteria we are confident that our results are representative of patients with RA from across Europe.

Despite the huge data set of more than 120 000 patients we were not able to analyse all different RA treatments separately for subtype distribution due to small numbers. For example, only six, six and three lymphomas occurred in patients treated with rituximab, tocilizumab and abatacept, respectively, at lymphoma diagnosis. Another limitation is the fact that the bionative patients are older than the bDMARD group (mean age 61

vs 55). Since age is an important factor in lymphomagenesis, the comparison between the treatment groups might be affected by this age difference.

Due to feasibility reasons, the patients were grouped into treatment groups according to the bDMARD that they have received most recently before the lymphoma diagnosis. A potential limitation is that we cannot exclude an influence of bDMARDs used prior to the last one. Furthermore, we could not analyse any potential influence of additional therapies with MTX or other conventional synthetic DMARDs.

The attribution of rare events such as lymphoma in RA to the respective RA treatment is complex. First, there is an increased lymphoma risk in patients with RA compared with the general population.^{3 4 31} Second, the disease activity of RA has been identified as being of utmost importance for the development of lymphoma.¹⁰ However, disease activity changes over time and is in itself dependent on the RA treatment. In addition, disease activity is one of the strongest factors in the treatment decision; therefore, there is a considerable confounding by indication when analysing this context. Hence, the bionative patients are different from the bDMARD-treated patients, since bDMARDs are used in those patients with more severe disease. It is therefore reassuring that in the bDMARD group with an even higher a priori lymphoma risk due to higher cumulative disease activity the risk is not higher than in the bionative patients.

We were confronted with other limitations typical for collaborative studies on register data, namely that collating data from different registers does not alter the quality of data from each register. We therefore depended on the validity of each subcohort. The impact of a possible heterogeneity in the results of the registers was partly examined in a descriptive manner by showing results of the two largest registers ARTIS and BSRBR separately. Separate results of all registers are furthermore shown in online supplementary table S1.

CONCLUSION

The evidence is growing that the risk of lymphoma in RA is more dependent on RA itself and especially the disease activity than on the RA treatment.^{5 13} Furthermore, our results are reassuring as the spectrum of lymphoma subtypes seems not to be altered by TNFi.

Author affiliations

¹Arthritis Research UK Centre for Epidemiology, University of Manchester, Manchester, UK

²Epidemiology Unit, German Rheumatism Research Centre, Berlin, Germany

³Department of Rheumatology, Université Paris-Sud, Hôpitaux Universitaires Paris-Sud, Le Kremlin Bicêtre, Paris, France

⁴Department of Medical Sciences, Uppsala University, Uppsala, Sweden

⁵Clinical Epidemiology Unit, Karolinska Institutet, Stockholm, Sweden

⁶Center for Rheumatology and Spine Diseases, Gentofte University Hospital, Rigshospitalet, Hellerup, Denmark

⁷The Parker Institute, Frederiksberg, Denmark

⁸DANBIO, Copenhagen Center for Arthritis Research, Centre of Head and Orthopaedics, Rigshospitalet, Copenhagen, Denmark

⁹Department of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

¹⁰Musculoskeletal Biomedical Research Unit, National Institute of Health Research Manchester, Central Manchester NHS Foundation Trust, Manchester Academic Health Science, Manchester, UK

¹¹Charité-Universitätsmedizin Berlin, Berlin, Germany

¹²EpiDoC Unit, Universidade Nova de Lisboa, CEDOC, NOVA Medical School and National School of Public Health, Lisbon, Portugal

¹³Department of Rheumatology, Hospital Clinic of Barcelona, Barcelona, Spain

¹⁴Département de BIOSPIM, Département BIOSPIM Hôpital Pitié-Salpêtrière, AP-HP, Sorbonne Universités, Université Pierre et Marie Curie, Paris, France

¹⁵Department of Rheumatology, CHU Strasbourg, Strasbourg, France

¹⁶Department of Rheumatology, University of Montpellier and Teaching Hospital Lapeyronie, Montpellier, France

¹⁷Institute of Rheumatology, First Faculty of Medicine, Charles University, Prague, Czech Republic

¹⁸Rheumatology Unit, University of Bari, Bari, Italy

Acknowledgements We thank Axel Finckh (Rheumatology Division, University of Geneva, Geneva, Switzerland) and Piet van Riel (Department of Rheumatic Diseases, Radboud University Nijmegen Medical Centre) for valuable discussions regarding this project.

Contributors Study concept and design: LKM and JL. Acquisition of data and critical revision of the manuscript for important intellectual content: LKM, AR, XM, WGD, EB, KH, LD, MLH, RC, KH, AS, AZ, HC, MVH, FT, JEG, JM, JZ, FI, JA and JL. Drafting the manuscript: LKM, AR and JL. Final approval of the version published: LKM, AR, XM, WGD, EB, KH, LD, MLH, RC, KH, AS, AZ, HC, MVH, FT, JEG, JM, JZ, FI, JA and JL.

Funding Individual registries had entered into agreements with pharmaceutical companies (AbbVie, BMS, Hospira, MSD, Pfizer, Roche, UCB, Samsung and Eli Lilly). The pharmaceutical companies funding these registers were, however, not involved in the planning of the project, the statistical analyses, the interpretation of the results or the decision to publish.

Competing interests AR received speaker fees (less than \$10 000) from Celgene and Janssen. XM received honorarium (less than \$10 000) from BMS, Pfizer and UCB. LD has received speaker fees from UCB and MSD. KH received grant/research support from Pfizer and honoraria (less than \$10 000) from Abbvie and Pfizer. AS received speaker fees (less than \$10 000) from BMS, MSD, Pfizer, Roche and Sanofi-Aventis. AZ received grant/research support from Abbvie, Amgen, BMS, MSD, Roche, Pfizer and UCB for the German biologics register RABBIT and speaker fees (less than \$10 000) from BMS, MSD, Novartis, Pfizer, Roche, Sanofi and UCB. JEG received honorarium (less than \$10 000) from Abbvie, BMS, MSD, Pfizer, Roche and UCB. JM received less than \$10 000 for honoraria and consultancies from Roche. JZ received honorarium (less than \$10 000) from Abbvie and Hospira. FI received personal fees from Actelion, Celgene, Janssen, Pfizer, AbbVie, UCB and MSD outside the submitted work. JA received grant/research support from AstraZeneca, Merck, Lilly and Pfizer, and has received grant support from Abbvie, Pfizer, Merck, Roche, BMS and UCB for the ARTIS register. JL received honoraria (less than \$10 000) from Novartis-Sandoz and Pfizer.

Patient consent Obtained.

Ethics approval Local ethics committee.

Provenance and peer review Not commissioned; externally peer reviewed.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2017. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

REFERENCES

- Smith A, Crouch S, Lax S, *et al.* Lymphoma incidence, survival and prevalence 2004-2014: sub-type analyses from the UK's Haematological Malignancy Research Network. *Br J Cancer* 2015;112:1575-84.
- Sant M, Allemanni C, Tereanu C, *et al.* Incidence of hematologic malignancies in Europe by morphologic subtype: results of the HAEMACARE project. *Blood* 2010;116:3724-34.
- Smedby KE, Hjalgrim H, Askling J, *et al.* Autoimmune and chronic inflammatory disorders and risk of non-Hodgkin lymphoma by subtype. *J Natl Cancer Inst* 2006;98:51-60.
- Ekström K, Hjalgrim H, Brandt L, *et al.* Risk of malignant lymphomas in patients with rheumatoid arthritis and in their first-degree relatives. *Arthritis Rheum* 2003;48:963-70.
- Merger LK, Galloway JB, Lunt M, *et al.* Risk of lymphoma in patients exposed to antitumour necrosis factor therapy: results from the British Society for Rheumatology Biologics Register for Rheumatoid Arthritis. *Ann Rheum Dis* 2017;76:497-503.
- Hellgren K, Baecklund E, Backlin C, *et al.* Rheumatoid Arthritis and Risk of Malignant Lymphoma: Is the Risk Still Increased? *Arthritis Rheumatol* 2017;69:700-8.
- Dreyer L, Mellemkjær L, Andersen AR, *et al.* Incidences of overall and site specific cancers in TNF α inhibitor treated patients with rheumatoid arthritis and other arthritides - a follow-up study from the DANBIO Registry. *Ann Rheum Dis* 2013;72:79-82.

- 8 Smitten AL, Simon TA, Hochberg MC, *et al.* A meta-analysis of the incidence of malignancy in adult patients with rheumatoid arthritis. *Arthritis Res Ther* 2008;10:R45.
- 9 Thomas E, Brewster DH, Black RJ, *et al.* Risk of malignancy among patients with rheumatic conditions. *Int J Cancer* 2000;88:497–502.
- 10 Baecklund E, Iliadou A, Askling J, *et al.* Association of chronic inflammation, not its treatment, with increased lymphoma risk in rheumatoid arthritis. *Arthritis Rheum* 2006;54:692–701.
- 11 Salloum E, Cooper DL, Howe G, *et al.* Spontaneous regression of lymphoproliferative disorders in patients treated with methotrexate for rheumatoid arthritis and other rheumatic diseases. *J Clin Oncol* 1996;14:1943–9.
- 12 Parakkal D, Sifuentes H, Semer R, *et al.* Hepatosplenic T-cell lymphoma in patients receiving TNF- α inhibitor therapy: expanding the groups at risk. *Eur J Gastroenterol Hepatol* 2011;23:1150–6.
- 13 Askling J, Baecklund E, Granath F, *et al.* Anti-tumour necrosis factor therapy in rheumatoid arthritis and risk of malignant lymphomas: relative risks and time trends in the Swedish Biologics Register. *Ann Rheum Dis* 2009;68:648–53.
- 14 Wolfe F, Michaud K. The effect of methotrexate and anti-tumor necrosis factor therapy on the risk of lymphoma in rheumatoid arthritis in 19,562 patients during 89,710 person-years of observation. *Arthritis Rheum* 2007;56:1433–9.
- 15 Chiu YM, Lang HC, Lin HY, *et al.* Risk of tuberculosis, serious infection and lymphoma with disease-modifying biologic drugs in rheumatoid arthritis patients in Taiwan. *Int J Rheum Dis* 2014;17(Suppl 3):9–19.
- 16 Harigai M, Nanki T, Koike R, *et al.* Risk for malignancy in rheumatoid arthritis patients treated with biological disease-modifying antirheumatic drugs compared to the general population: A nationwide cohort study in Japan. *Mod Rheumatol* 2016;26:642–50.
- 17 Lemaître M, J.K. A.R. Lymphoma in patients with Inflammatory Bowel Disease; a French nationwide observational cohort study. *UEGW*, 2016:2016.
- 18 Mariette X, Gottenberg JE, Ravaud P, *et al.* Registries in rheumatoid arthritis and autoimmune diseases: data from the French registries. *Rheumatology* 2011;50:222–9.
- 19 Horák P, Skácelová M, Hejduk K, *et al.* Abatacept and its use in the treatment of rheumatoid arthritis (RA) in the Czech Republic—data from the ATTRA registry. *Clin Rheumatol* 2013;32:1451–8.
- 20 Carmona L, Descalzo MA, Ruiz-Montesinos D, *et al.* Safety and retention rate of off-label uses of TNF antagonists in rheumatic conditions: data from the Spanish registry BIOBADASER 2.0. *Rheumatology* 2011;50:85–92.
- 21 Ibfelt EH, Jensen DV, Hetland ML. The Danish nationwide clinical register for patients with rheumatoid arthritis: DANBIO. *Clin Epidemiol* 2016;8:737–42.
- 22 Sebastiani M, Anelli MG, Atzeni F, *et al.* Efficacy and safety of rituximab with and without methotrexate in the treatment of rheumatoid arthritis patients: results from the GISEA register. *Joint Bone Spine* 2014;81:508–12.
- 23 Strangfeld A, Eveslage M, Schneider M, *et al.* Treatment benefit or survival of the fittest: what drives the time-dependent decrease in serious infection rates under TNF inhibition and what does this imply for the individual patient? *Ann Rheum Dis* 2011;70:1914–20.
- 24 Mariette X, Tubach F, Bagheri H, *et al.* Lymphoma in patients treated with anti-TNF: results of the 3-year prospective French RATIO registry. *Ann Rheum Dis* 2010;69:400–8.
- 25 Romão VC, Santos MJ, Polido-Pereira J, *et al.* Comparative Effectiveness of Tocilizumab and TNF Inhibitors in Rheumatoid Arthritis Patients: Data from the Rheumatic Diseases Portuguese Register, Reuma.pt. *Biomed Res Int* 2015;2015:1–13.
- 26 Swerdlow SH, Campo E, Harris NL, *et al.* *WHO Classification of Tumours of Haematopoietic and Lymphoid Tissues*. 4th edn, 2008.
- 27 Baecklund E, Sundström C, Ekblom A, *et al.* Lymphoma subtypes in patients with rheumatoid arthritis: increased proportion of diffuse large B cell lymphoma. *Arthritis Rheum* 2003;48:1543–50.
- 28 Deepak P, Sifuentes H, Sherid M, *et al.* T-cell non-Hodgkin's lymphomas reported to the FDA AERS with tumor necrosis factor-alpha (TNF- α) inhibitors: results of the REFURBISH study. *Am J Gastroenterol* 2013;108:99–105.
- 29 Hollander P, Rostgaard K, Smedby KE, *et al.* Autoimmune and Atopic Disorders and Risk of Classical Hodgkin Lymphoma. *Am J Epidemiol* 2015;182:624–32.
- 30 Jaffe ES. The 2008 WHO classification of lymphomas: implications for clinical practice and translational research. *Hematology Am Soc Hematol Educ Program* 2009:523–31.
- 31 Hellgren K, Smedby KE, Feltelius N, *et al.* Do rheumatoid arthritis and lymphoma share risk factors?: a comparison of lymphoma and cancer risks before and after diagnosis of rheumatoid arthritis. *Arthritis Rheum* 2010;62:1252–8.