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Risks of myeloid malignancies in patients with autoimmune conditions

LA Anderson*,1, RM Pfeiffer2, O Landgren2,3, S Gadalla2, SI Berndt2 and EA Engels2
1Centre for Public Health, Queen’s University Belfast, Northern Ireland BT12 6BJ, UK; 2Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rockville, MD 20892, USA; 3Medical Oncology Branch, Center for Cancer Research, National Cancer Institute, Bethesda, MD, USA

Autoimmune conditions are associated with an elevated risk of lymphoproliferative malignancies, but few studies have investigated the risk of myeloid malignancies. From the US Surveillance Epidemiology and End Results (SEER)-Medicare database, 13 486 myeloid malignancy patients (aged 67 + years) and 160 086 population-based controls were selected. Logistic regression models adjusted for gender, age, race, calendar year and number of physician claims were used to estimate odds ratios (ORs) for myeloid malignancies in relation to autoimmune conditions. Multiple comparisons were controlled for using the Bonferroni correction (P<0.0005). Autoimmune conditions, overall, were associated with an increased risk of acute myeloid leukaemia (AML) (OR 1.29) and myelodysplastic syndrome (MDS, OR 1.50). Specifically, AML was associated with rheumatoid arthritis (OR 1.28), systemic lupus erythematosus (OR 1.92), polymyalgia rheumatica (OR 1.73), autoimmune haemolytic anaemia (OR 3.74), systemic vasculitis (OR 6.23), ulcerative colitis (OR 1.72) and pernicious anaemia (OR 1.57). Myelodysplastic syndrome was associated with rheumatoid arthritis (OR1.52) and pernicious anaemia (OR 2.38). Overall, autoimmune conditions were not associated with chronic myeloid leukaemia (OR 1.09) or chronic myeloproliferative disorders (OR 1.15). Medications used to treat autoimmune conditions, shared genetic predisposition and/or direct infiltration of bone marrow by autoimmune conditions, could explain these excess risks of myeloid malignancies.

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The aetiology of myeloid malignancies, a heterogeneous group of disorders including acute myeloid leukaemia (AML), chronic myeloid leukaemia (CML), myelodysplastic syndrome (MDS) and chronic myeloproliferative disorders (MPDs), remains largely unknown. The main risk factors identified for AML are cigarette smoking (Kasim et al, 2005; Xu et al, 2007) and exposure to benzene or ionising radiation (Descatha et al, 2005). Chronic myeloid leukaemia arises from a translocation t(9;22)(q34;q11), known as the Philadelphia chromosome, and is thought to be associated with radiation exposure (Preston-Martin et al, 1989). Myelodysplastic syndrome is a heterogeneous clonal haematological disorder that can progress to AML. Cigarette smoking (Nisse et al, 2001), solvent exposure (Nisse et al, 2001) and agricultural exposures (Strom et al, 2005) have all been associated with an increased risk of MDS, and senescence of the haematopoietic system is thought to play a role in its development (Dalamaga et al, 2002). Less is known about the causes of MPDs, including polycythemia vera and essential thrombocythemia.

Immune perturbations, including autoimmune diseases, have been associated with an increased risk of haematological malignancies. Although reported more commonly for lymphoproliferative neoplasms (Zintzaras et al, 2005; Ekstrom Smedby et al, 2008), increased risks in persons with autoimmune conditions have also been noted for myeloid malignancies, including AML and CML (Zheng et al, 1993; Askling et al, 2005b). Autoimmune conditions, which occur commonly in patients with MDS (Voulgaris et al, 2004), have also been reported to precede MDS (Dalamaga et al, 2002). Using data from the Surveillance Epidemiology and End Results (SEER)-Medicare Assessment of Hematopoietic Malignancy Risk Traits (SMAHRT) study, we investigated whether autoimmune conditions were associated with subsequent risks of AML, CML, MDS and MPDs.

MATERIALS AND METHODS

The SMAHRT study is a population-based case–control study of haematopoietic malignancies using SEER-Medicare data (Warren et al, 2002; Anderson et al, 2008). The SEER program collects data on cancer diagnoses from multiple US sites since 1973 and currently covers ~25% of the US population (Warren et al, 2002). Medicare provides federally funded health insurance for persons aged 65 years and older in the United States. All Medicare beneficiaries are entitled to Part A coverage, which includes hospital inpatient care. Approximately 96% of participants subscribe to Part B coverage, which covers both physician and outpatient services. The SEER-Medicare database has demographic and clinical information from SEER on cancer patients through December 2002, linked to their Medicare enrolment and claims data (Part A claims: 1986–2002; Part B claims: 1991–2002).
controls to ensure that the autoimmune conditions preceded MDS and MPD.

As we conducted 108 separate analyses to investigate the associations between 27 autoimmune conditions and 4 myeloid malignancies, we considered the impact of multiple testing on our findings. Although we indicate associations significant at a nominal significance level of $P = 0.05$, we especially highlight in the tables and in the Discussion section those associations that were significant at a $P$-value of 0.0005, which incorporates a Bonferroni correction.

RESULTS

This study included 13 486 cases with a myeloid malignancy, which comprised 7824 individuals with AML, 2174 with CML, 2471 with MDS and 1017 with MPD. Compared with controls, cases were more likely to be male (except for MPD, in which cases were more likely to be female) and of white race. The median age at diagnosis/selection was similar for the myeloid malignancy cases and controls. For each myeloid neoplasm, cases had more prior physician, outpatient and hospital claims than controls (Table 1).

As shown in Table 2, having any autoimmune condition was associated with an increased risk of AML (OR 1.29). Specifically, AML was associated positively with several autoimmune conditions at the $P < 0.05$ significance level, including rheumatoid arthritis (OR 1.28), systemic lupus erythematosus (OR 1.92), polymyalgia rheumatica (OR 1.73), autoimmune haemolytic anaemia (AIHA) (OR 3.74), systemic vasculitis (OR 6.23), giant cell arteritis (OR 1.61), ulcerative colitis (OR 1.72) and pernicious anaemia (OR 1.57). Chronic myeloid leukaemia was increased with polymyalgia rheumatica (OR 1.79), dermatomyositis/polymyositis (OR 3.97), AIHA (OR 5.23) and coeliac disease (OR 4.19) (Table 2).

Overall, MDS was associated with having an autoimmune condition (OR 1.50) and specifically with rheumatoid arthritis (OR 1.52), Sjögren's syndrome (OR 1.78), systemic lupus erythematosus (OR 1.82), polymyalgia rheumatica (OR 1.47), AIHA (OR 4.12), chronic rheumatic heart disease (OR 1.28), polyarteritis nodosa (OR 4.31), discoid lupus erythematosus (OR 2.06) and pernicious anaemia (OR 2.38). In comparison, MPD was only associated with AIHA (OR 11.9), localised scleroderma (OR 2.34) and Crohn's disease (OR 2.18).

As MDS and MPD are often chronic diseases that may go unreconsidered for several years, we conducted a sensitivity analysis excluding claims within 2 or 5 years of diagnosis. Compared with controls, MDS cases more commonly had rheumatoid arthritis (OR 1.52), polymyalgia rheumatica (OR 1.53) and pernicious anaemia (OR 1.68) reported more than 5 years before the diagnosis/selection (Table 3). Similary, localised scleroderma remained associated significantly with MPD when the 2-year or 5-year period before diagnosis was excluded (ORs 2.73 and 3.27, respectively) (Table 3).

Associations that remained significant after using a Bonferroni correction ($P < 0.0005$) are highlighted in Table 2. These included rheumatoid arthritis, systemic lupus erythematosus, polymyalgia rheumatica, AIHA, systemic vasculitis, ulcerative colitis and pernicious anaemia with AML; dermatomyositis/polymyositis with CML; rheumatoid arthritis and pernicious anaemia with MDS; and AIHA with MPD.

DISCUSSION

In this large study of 13 486 individuals with a myeloid malignancy, we investigated systematically the associations with a range of preceding autoimmune conditions. Overall, having an autoimmune condition was associated with an increased risk of AML and MDS, but not CML or MPD. Given the large number of
comparisons, we focus here on associations that were significant at a P-value cutoff provided by the Bonferroni method (P<0.0005).

We observed significantly increased risks of AML and MDS associated with rheumatoid arthritis. Supporting this observation, Asking et al (2005b) found two-fold increased risks of AML and CML in a large Swedish cohort study of patients hospitalised for rheumatoid arthritis. Although MDS is a chronic condition, we saw an association with rheumatoid arthritis even after excluding the 5-year period before diagnosis/selection, arguing against reverse causality (i.e., that undiagnosed MDS caused rheumatoid arthritis).
### Table 2  Associations between autoimmune conditions and risk of myeloid malignancies

| Autoimmune conditions                      | Selection years 1987–2002 | Selection years 2001–2002 |
|--------------------------------------------|----------------------------|---------------------------|
|                                            | Controls (n = 160 086)     | Myelodysplastic syndromes (n = 2471) | Chronic myeloproliferative disorder (n = 1 017) |
|                                            | Acute myeloid leukaemia (n = 7 824) | Controls (n = 42 886) | |
| Any autoimmune condition                  | 14 056                     | 59 68                     | 17 1 |
| Systemic/connective tissue                | 973                        | 1 09 (0.94–1.27)          | 1 15 (0.97–1.37) |
| Rheumatoid arthritis                      | 34 25                       | 1 23 (0.94–1.62)          | 1 52 (1.27–1.81) |
| Sjögren’s syndrome                        | 261                        | 1 14 (0.42–3.09)          | 1 78 (1.03–3.07) |
| Systemic lupus erythematosus              | 298                        | 1 28 (0.52–3.12)          | 1 82 (1.04–3.16) |
| Sarcoidosis                                | 101                        | < 5 (0.76) (0.11–5.46)    | 1 11 (0.34–3.61) |
| Systemic sclerosis                         | 83                         | 0.94 (0.3–6.80)           | 2 05 (0.85–5.25) |
| Polymyalgia                                | 1 288                      | 1 79 (1.25–2.57)          | 1 47 (1.11–1.96) |
| Ankylosing spondylitis                     | 133                        | 0.53 (0.07–3.84)          | 1 18 (0.47–2.93) |
| Dermatomyositis/polymyositis              | 135                        | 0.91 (0.42–1.96)          | 0.46 (0.11–1.90) |

| Blood                                      |                            |                           |
| Autoimmune haemolytic anaemia             | 52                         | 5 22 (1.82–15.0)          | 1 42 (1.66–10.2) |

| Cardiovascular                            |                            |                           |
| Systemic vasculitis                       | 27                         | < 5 (0.71–17.0)           | 0          |
| Chronic rheumatic heart disease           | 4 099                      | 8                         | 6 09 (0.71–17.0) |
| Giant cell arthritis                      | 427                        | 1 36 (0.09–1.44)          | 1 28 (0.76–2.16) |
| Polymyelitis nodaosa                      | 35                         | < 5 (0.71–17.0)           | 0          |

| Endocrine                                  |                            |                           |
| Addison’s disease                         | 196                        | 1 45 (0.55–4.04)          | 0          |
| Graves’ disease                            | 360                        | 1 65 (0.81–3.35)          | 1 49 (0.51–1.86) |
| Hashimoto’s                                | 290                        | 1 07 (0.40–2.86)          | 1 51 (0.33–19.1) |

| Skin                                       |                            |                           |
| Pemphigus                                  | 26                         | < 5 (0.09–5.13)           | 1 23 (0.44–3.42) |
| Localised schleroderma                     | 178                        | 0.43 (0.06–3.07)          | 0          |
| Discoid lupus erythematosus                | 149                        | 0.76 (0.31–1.89)          | 2 01 (0.16–5.57) |

| Gastrointestinal                           |                            |                           |
| Coeliac disease                            | 54                         | < 5 (0.13–1.50)           | 1 20 (0.77–3.22) |
| Crohn’s disease                            | 316                        | 0.67 (0.21–2.99)          | 0          |
| Ulcerative colitis                         | 504                        | 0.72 (0.30–1.74)          | 1 33 (0.86–2.07) |
| Pernicious anaemia                         | 2008                       | 0.74 (0.48–1.14)          | 2 38 (1.98–2.86) |

| Nervous system                             |                            |                           |
| Multiple sclerosis                         | 185                        | 0.77 (0.19–3.12)          | 0          |
| Myasthenia gravis                          | 115                        | 0.25 (0.04–1.86)          | 0.22 (0.71–2.74) |

CI = confidence interval; OR = odds ratio; SEER = Surveillance Epidemiology and End Results. Observations, in which the number of exposed patients or controls is between one and four, are listed as ‘<5’ to reserve subjects’ anonymity, in accordance with the SEER-Medicare data use agreement. Associations significant at the P<0.05 level are underlined. For consistency across tables, all ORs are shown to two decimal places (or three significant figures if the OR ≥ 10.0). Nonetheless, we note that many estimates are based on few exposed cases. aORs and 95% CIs are adjusted for age (67–69, 70–74, 75–79, 80–84 and 85–99 years), gender, selection year (1987–1996, 1997–1999, 2000–2001, 2002), race (White, non-white) and number of physician claims (0–20, 21–57, 58–127, ≥ 128). aORs and 95% CIs are adjusted for age (67–69, 70–74, 75–79, 80–84 and 85–99 years), gender, selection year (2001, 2002), race (White, non-white) and number of physician claims (0–20, 21–57, 58–127, ≥ 128). aAssociation is significant at P<0.0005 (Bonferroni correction for 108 comparisons).
Several case reports have described AML and MDS occurring in patients with rheumatoid arthritis, mainly after treatment with azathioprine (Alexson and Brandt, 1977; Kwong et al, 1998) or methotrexate (Espinosa et al, 2002; Okamoto et al, 2004). However, non-steroidal anti-inflammatory drugs, used in the treatment of rheumatoid arthritis and other inflammatory conditions included in our study, appear to decrease the risk of myeloid leukaemia (Pogoda et al, 2005), suggesting that their use is unlikely to explain the excess risk of myeloid malignancies. Unfortunately, we lacked treatment information and were, therefore, unable to determine whether the observed increased risks of AML and MDS were related to therapy.

We also observed an increased risk of AML with systemic lupus erythematosus, which might be attributed partly to the use of immune-modulating treatments, such as azathioprine (Alexson and Brandt, 1977; Kwong et al, 1998). Another systemic autoimmune condition associated with an increased risk of AML and CML (and to a lesser extent MDS) was polymyalgia rheumatica. Some studies have reported polymyalgia rheumatica to occur subsequent to diagnosis of MDS (Mok et al, 1996; Espinosa et al, 2002), and polymyalgia rheumatica has been reported to precede AML (Anton, 2007). Giant cell arteritis, a condition closely related to polymyalgia rheumatica, was more weakly associated with AML in our study. Among the other autoimmune conditions affecting the cardiovascular system, only systemic vasculitis remained associated with AML after adjustment for multiple comparisons. To our knowledge, AML has not been reported in patients with systemic vasculitis, though large-vascular arteritis has been reported in patients with MDS (Strom et al, 2004).

In our study, AIHA significantly increased the risk for all of the myeloid malignancies. Autoimmune haemolytic anaemia is considered to be a complication of several lymphoproliferative disorders (Ekstrom Smedby et al, 2008). Although case reports describe AIHA with MDS (Giagounidis et al, 2005), AML (Deutsch et al, 2003) and CML (Arbaje et al, 1990), we found AIHA to occur antecedent to these diagnoses. Consistent with our findings, AIHA was found to be associated with an eight-fold increased risk of AML in a large cohort study in Sweden (Soderberg et al, 2006). As MDS and MPD are indolent and may be present years before diagnosis, it is possible that AIHA arose as a result of these conditions. This explanation is less likely for AML and CML, and it is possible that AIHA acts late in a causal pathway to promote the development of these malignancies.

Ulcerative colitis was associated with an increased risk of AML, in keeping with a Swedish population-based cohort study which found an 80% increase in ulcerative colitis patients (Aslakson et al, 2005a). However, other cohort studies found no such relation between ulcerative colitis and risk of AML (Bernstein et al, 2001; Windier et al, 2004; Hemminki et al, 2008). Pernicious anaemia has been reported antecedent to AML (Hsing et al, 1993), consistent with the association we observed. Dermatomyositis/polymyositis was associated strongly with CML. Although these conditions manifest commonly in cancer patients (Stockton et al, 2001), the association with CML remained elevated even when the 5-year period before diagnosis was excluded, indicating that dermatomyositis/polymyositis may also precede CML.

There are several possible explanations for these associations with myeloid malignancies. First, as mentioned earlier, certain treatments for autoimmune conditions, such as azathioprine, could increase the risk of developing MDS or AML. However, the associations with AML were not specific to autoimmune conditions treated with these medications. Second, some autoimmune conditions could share common genetic predispositions with myeloid malignancies. For example, carriers of the human leucocyte antigen-B27 are predisposed to some autoimmune conditions manifest commonly in cancer patients (Stockton et al, 2001), the association with CML remained elevated even when the 5-year period before diagnosis was excluded, indicating that dermatomyositis/polymyositis may also precede CML.

The SMAHT study has several strengths including the large number of individuals with myeloid malignancies, the population-based sampling of cases and the random selection of controls from the population. The SEER database covers ~25% of the US population (Warren et al, 2002) making our study representative of the elderly US population. In addition, the availability of outpatient, inpatient and physician claims allowed us to investigate the associations between a range of autoimmune conditions and...
myeloid malignancies. Our study also has some limitations. First, the small number of cases and controls with some uncommon autoimmune conditions limit the precision of our estimates, so cautious interpretation is indicated. Second, as claim files were utilised in place of a definite diagnosis, autoimmune conditions which required few physician visits could have been underestimated. Third, despite our exclusion of a 1-year period before cancer diagnosis, some autoimmune conditions could have been the result of the myeloid malignancy. This seems unlikely for AML and CML, but could explain some associations with the more indolent conditions, MDS and MPD. Fourth, as MDS and MPD are a heterogeneous group of diseases, some associations could have been masked by combining these conditions into one category. Unfortunately, we did not have sufficient sample sizes to investigate risk by more specific subtypes. Fifth, cases and controls differed according to some factors, such as race and frequency of Medicare claims, which could have led to differences in the prevalence of autoimmune conditions or our ability to detect their presence. However, we adjusted for these differences in our statistical models. Finally, as some of the numerous associations investigated may have occurred by chance, we therefore used a Bonferroni correction to highlight those associations least likely to be due to chance.

In summary, certain autoimmune conditions were associated with increased risks of MDS, MPD, CML, and in particular AML, possibly due to a common genetic predisposition, the effects of medications used to treat autoimmune conditions, or direct damage of the bone marrow by autoimmune conditions.

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