Cancer Incidence in Migrants in Australia: Patterns of Three Infection-Related Cancers

Cancer Incidence in Migrants in Australia: Patterns of Three Infection-Related Cancers

Xue Qin Yu[1], Eleonora Feletto[1], Megan A. Smith[1], Susan Yuill[1,2], and Peter D. Baade[3,4,5]

ABSTRACT

Background: Australia provides an ideal population-base for cancer migration studies because of its multicultural society and high-quality cancer registrations. Among migrant groups there is considerable variability in the incidence of infection-related cancers; thus, the patterns of three such cancers were examined among migrant groups relative to Australian-born residents.

Methods: Using national incidence data for cancers of the stomach, liver, and cervix diagnosed during 2005 to 2014, incidence rates were compared for selected migrant groups with the Australian-born population using incidence rate ratios (IRR), from a negative binomial regression model.

Results: Wide variations in incidence between countries/regions of birth were observed for all three cancers ($P < 0.0001$). The patterns were similar for cancers of the stomach and liver, in that migrants from countries/regions with higher incidence rates maintained an increased risk in Australia, with the highest being among South American migrants (IRR = 2.35) for stomach cancer and among Vietnamese migrants (5.44) for liver cancer. In contrast, incidence rates of cervical cancer were lower for many migrant groups, with women from Southern Asia (0.39) and North Africa (0.42) having the lowest rates. The rate of cervical cancer was higher in migrants from New Zealand, Philippines, and Polynesia.

Conclusions: Several Australian migrant groups were found to experience a disproportionate burden of infection-related cancers; further studies of associated risk factors may inform the design of effective interventions to mediate these disparities.

Impact: By identifying these migrant groups, it is hoped that these results will motivate and inform prevention or early detection activities for these migrant groups.

See related commentary Dee and Gomez, p. 1251

Introduction

Key to designing cancer prevention and control initiatives is an evidence-based understanding of the differences in cancer burden by population group and the causes of between-groups differences. Epidemiologic studies are a critical first step in identifying differences in cancer burden and cancer risk factors to guide mitigation strategies. While much is understood about the cancer burden in high-income countries such as Australia (1), such studies provide the opportunity to explore differences by subpopulations, such as migrant groups.

Australia is a well-known multicultural society with 30% (7.6 million) of the population in 2020 being born overseas (2). Long-standing government policies have produced immigration patterns reflective of global events. Before World War II, most migrants to Australia came from the United Kingdom (UK) and Ireland. After the war, migrants first came from continental Europe, and then progressively greater proportions came from South-East Asia since the 1970s (particularly Vietnam and the Philippines), and more recently from China, New Zealand, and India (3). Consequently, Australia now has a highly heterogeneous migrant population, varying markedly in characteristics, for example, proficiency in English, income, cultural beliefs, health services use and lifestyle factors (4), each of which is associated with cancer risk (i.e., they can affect access, either directly or indirectly, to prevention services (5, 6). Migrants from less developed countries reportedly have lower risks for many cancer types due to a 'healthy migrant effect' (7, 8), but rates can be higher for infection-related cancers (9), depending on the level of early life exposure to risk factors in the country of birth. Thus, studies on the rates of infection-related cancers among migrants to Australia may provide useful information for priority prevention and interventions in this country.

Infections are known modifiable causes of cancer, with an estimated 2.2 million new cases of cancer worldwide in 2018, or 13% of cases, attributed to an infectious agent (10). Collectively, the four most important infectious pathogens, *Helicobacter pylori* (*H. pylori*), human papillomavirus (HPV), hepatitis B virus (HBV), and hepatitis C virus (HCV) account for >90% of these infection-attributable cancer cases worldwide (10). The most common related types are cancers of the stomach (*H. pylori*), cervix (HPV), and liver (HBV and HCV). In recent analyses of Global Burden of Disease data, stomach cancer incidence was found to vary markedly globally, with the highest rates (per 100,000 population) in high-income countries in Asia Pacific (29.5) and east Asia (28.6) regions in 2017; in contrast, the corresponding rate for the Oceania region was 13.8 (11). Similar patterns were observed for liver cancer with the highest rates in high-income countries in Asia Pacific (26.4) and east Asia (24.3) in 2015, over twice the rate for Oceania (10.8; ref. 12). More striking variations were found for cervical cancer incidence, with the rates observed in southern Africa and eastern Africa regions (>40) in 2018 being about ten-times higher than in western Asia region (4.1; ref. 13). Due to a lag time of 20 to 30 years between infection with these agents and a diagnosis of cancer (10, 14), migrants typically maintain a similar level of risk

[1]The Daffodil Centre, The University of Sydney, a joint venture with Cancer Council NSW, Sydney, New South Wales, Australia. [2]School of Public Health, University of Sydney, Sydney, New South Wales, Australia. [3]Cancer Research Centre, Cancer Council Queensland, Brisbane, Queensland, Australia. [4]Menzies Health Institute Queensland, Griffith University, Gold Coast Campus, Southport, Queensland, Australia. [5]School of Mathematical Sciences, Queensland University of Technology, Brisbane, Queensland, Australia.

Corresponding Author: Xue Qin Yu, The Daffodil Centre, PO Box 572, Kings Cross, New South Wales 1340, Australia. Phone: 612-9334-1851; Fax: 612-8302-3550; E-mail: xue.yu@sydney.edu.au

Cancer Epidemiol Biomarkers Prev 2022;31:1394–401

doi: 10.1158/1055-9965.EPI-21-1349

associated with infection in their country of birth, even after they migrate (15–17).

In Australia, an estimated 3% of all cancers diagnosed are attributable to infections (18). Despite this relatively low incidence of infection-related cancers (10), these cancers are important due to their low survival rates (stomach and liver), increasing incidence rates (liver), or the need to focus on priority populations to achieve elimination targets (cervix). Australia's comprehensive, high-quality coverage of cancer registration provides an ideal environment for cancer migrant studies. While previous studies have investigated cancer rates among migrants in Australia, they have used state-specific cancer incidence data from the 1980s and 1990s (19–26) and reported on relatively large, heterogenous country of birth groups (e.g., Asia, or other Asia being classified as one birth group; 23–28). Thus, given the marked recent increases in migrant populations, updated cancer profiles among migrant populations in Australia are needed to inform the planning of effective, targeting cancer control policies and guide the implementation of culturally sensitive prevention measures. To update and extend the previous studies, the incidence of three infection-related cancers (stomach, liver, and cervix) was compared among migrants to Australian-born residents.

Materials and Methods

Study population

Aggregated national incidence data for cancers of the stomach, liver and cervix diagnosed between 2005 and 2014 were obtained from the Australian Cancer Database (ACD; ref. 1), containing data from the eight state and territory population-based cancer registries across the country. By law, all cancers diagnosed in Australia must be reported to the relevant jurisdictional register. These data were grouped by 5-year age group, sex, year of diagnosis, and country of birth. Only people aged ≥30 years at diagnosis for stomach and liver cancer, or women aged ≥20 years for cervical cancer, were included in the analysis as cancer diagnoses are rare in younger people especially among migrant populations (22).

Migrants are defined in this study based on their country of birth (regardless of ethnicity, which is not recorded), consistent with the most widely used definition in migrant studies (7). Information on country of birth is routinely collected by cancer registries in Australia, based on the Standard Australian Classification of Countries (SACC; ref. 29). Twelve countries of birth with relatively large populations are reported individually: New Zealand, UK, Ireland, Germany, Italy, Greece, Vietnam, Malaysia, Philippines, China, India, and South Africa. Thirteen regions of birth are also included, with some of the countries included for their relevant regions (**Table 1**). The regions were ordered according to SACC code because the classification is generally based on both geographical proximity and similarity of shared social, cultural, economic, or political characteristics. The seven other regions were excluded from these analyses because of the small corresponding migrant population in Australia, along with those of missing country of birth.

The estimated resident population (ERP) by 5-years age group, sex, calendar year and country of birth was obtained from the Australian Bureau of Statistics (ABS; ref. 30). ABS collects information on country of birth for Australian residents during quinquennial population censuses, with the ERP by country of birth for each between-census year being estimated by interpolation and considering administrative data relating to births, deaths, and overseas migration.

Statistical analyses

To improve precision, region and country-specific estimates are presented only if the expected number of new cases exceeded 50 per cancer type/country (or region) combinations for stomach and liver cancer. A lower cut-point (>20 cases) was used for cervical cancer reflecting its generally lower incidence (13). This is a result of balancing several competing considerations, such as the goal of including more countries/regions in the study and minimizing the number of small counts in each country, which may cause privacy concerns. The expected cases among migrants for a specific region/country were calculated by multiplying the age-specific rates for Australian-born cases by the age, country-specific population of migrants. Data for

Table 1. List of countries included in each region of birth group.

Region of birth (SACC)[a]	Individual countries[a]
Polynesia (1500)	Cook Island, Fiji, French Polynesia, Niue, Samoa, Samoa American, Tokelau, Tonga, Tuvalu, Wallis & Futuna, Pitcairn Islands, Polynesia (excludes Hawaii), nec
Western Europe (2300)	Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Monaco, Netherlands, Switzerland
Southern Europe (3100)	Andorra, Gibraltar, Holy See, Italy, Malta, Portugal, San Marino, Spain
South Eastern Europe (3200)	Albania, Bosnia & Herzegovina, Bulgaria, Croatia, Cyprus, the former Yugoslav Republic of Macedonia, Greece, Moldova, Romania, Slovenia, Montenegro, Serbia, Kosovo
Eastern Europe (3300)	Belarus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Russian Federation, Slovakia, Ukraine
North Africa (4100)	Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Western Sahara, Spanish North Africa, South Sudan
Middle East (4200)	Bahrain, Gaza Strip & West Bank, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen
South-East Asia (5000)	Myanmar, Cambodia, Laos, Thailand Vietnam, Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Timor-Leste
North-East Asia (6000)	China, Hong Kong (SAR of China), Macau (SAR of China), Mongolia, Taiwan, Japan, North Korea, South Korea
Southern Asia (7100)	Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
Northern America (8100)	Bermuda, Canada, St Pierre and Miquelon, United States of America
South America (8200)	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Falkland Islands, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela, South America, nec
Southern & East Africa (9200)	Angola, Botswana, Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mayotte, Mozambique, Namibia, Reunion, Rwanda, St Helena, Seychelles, Somalia, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe, Southern & Eastern Africa nec

Abbreviation: nec, not elsewhere classified.
[a]Based on the SACC 2016 (March 2017 release).

males and females were combined for stomach and liver cancers because of the anticipated small numbers for certain migrant groups and their similar association between these infections and the cancers of interest.

Incidence rate ratios (IRR) were calculated for each individual migrant group relative to the Australian-born population, using a negative binomial regression model (for each individual cancer type) adjusted for age group, year of diagnosis, and sex (stomach and liver cancers), with the log of the population as offset variable. This was done separately for countries and regions. All analyses were performed using SAS version 9.4 and the figures were produced using R 4.0.5.

Data availability

The data analyzed in this study were provided by the Australian Institute of Health and Welfare with the approval from cancer registry data custodian in each state and territory of Australia. Data may be shared on request to the corresponding author with permission of the Australian Institute of Health and Welfare.

Results

The size of the migrant population in Australia had nearly doubled between 1986 (3.2 million) and 2016 (6.2 million) and represented a larger proportion of the national population (increasing from 20.6% in 1986 to 26.6% in 2016) (3). During the study period (2005–2014), 19,419, 14,741, and 7,185 cases were included in the analysis for stomach cancer, liver cancer, and cervical cancer respectively (**Table 2**). Overall, 3.5% of records had missing country of birth data (2.2% for men vs. 4.8% for women), ranging from 2.0% for liver cancer to 8.5% for cervical cancer.

Stomach cancer (Fig. 1A and B)

Of the 13 regions, migrants from 10 regions had higher incidence rates of stomach cancer than Australian-born population (**Table 2**), with the highest rates among migrants from South America (IRR = 2.35), North-East Asia (2.15), and Polynesia (2.08). Migrants from Southern Asia were the only group that had significantly lower incidence (0.75). The countries of birth with the highest three IRRs were China (1.99), Italy (1.72) and Greece (1.71).

Liver cancer (Fig. 2A and B)

Of the 13 regions, migrants from eight regions had higher incidence of liver cancer than the Australian-born population (**Table 2**), with the highest rates among migrants from South-East Asia (IRR = 3.38), North Africa (3.32) and North-East Asia (2.93). For individual countries, the migrant groups with the highest three IRRs were Vietnam (5.44), China (2.97), and Italy (2.07). Only migrants from South Africa had a significantly lower rate than those locally born (0.67).

Table 2. Adjusted incidence rate ratio (IRR) from negative binomial regression models[a] (separated by country and region of birth) among migrant groups in Australia relative to the Australian born population.

	Stomach cancer (C16)			Liver cancer (C22)			Cervical cancer (C53)		
Place of birth (SACC code)	**Cases (*n*)**	**IRR**	**95% CI**	**Cases (*n*)**	**IRR**	**95% CI**	**Cases (*n*)**	**IRR**	**95% CI**
Country of birth									
Australian-born (1101)	10,900	1.00		8,106	1.00		5,034	1.00	
New Zealand (1201)	333	1.09	(0.95–1.26)	313	1.25	(1.06–1.47)	257	1.35	(1.19–1.53)
United Kingdom (2100)	2,269	1.29	(1.22–1.35)	1,302	0.98	(0.90–1.06)	491	0.94	(0.85–1.03)
Ireland (2201)	119	1.49	(1.18–1.90)	66	1.11	(0.80–1.54)	37	1.27	(0.92–1.76)
Germany (2304)	307	1.34	(1.16–1.56)	187	1.13	(0.92–1.39)	59	0.98	(0.76–1.27)
Italy (3104)	980	1.72	(1.58–1.88)	822	2.07	(1.82–2.35)	67	0.68	(0.53–0.87)
Greece (3207)	526	1.71	(1.53–1.93)	321	1.47	(1.24–1.74)	47	0.77	(0.58–1.04)
Vietnam (5105)	179	1.43	(1.17–1.73)	555	5.44	(4.77–6.21)	74	0.79	(0.62–0.99)
Malaysia (5203)	76	1.02	(0.76–1.37)	98	1.61	(1.23–2.12)	34	0.66	(0.47–0.92)
Philippines (5204)	69	0.91	(0.67–1.25)	107	1.81	(1.40–2.35)	124	1.34	(1.12–1.61)
China (6101)	428	1.99	(1.75–2.26)	482	2.97	(2.58–3.42)	134	0.95	(0.80–1.13)
India (7103)	126	0.96	(0.76–1.21)	101	1.00	(0.76–1.31)	35	0.36	(0.26–0.51)
South Africa (9225)	117	1.34	(1.05–1.71)	47	0.67	(0.46–0.99)	40	0.72	(0.52–0.98)
P value		<0.0001			<0.0001			<0.0001	
Region of birth									
Polynesia (1500)	123	2.08	(1.74–2.49)	118	2.45	(2.02–2.96)	75	1.69	(1.34–2.12)
Western Europe (2300)	615	1.19	(1.10–1.30)	367	0.96	(0.85–1.09)	115	0.87	(0.72–1.05)
Southern Europe (3100)	1246	1.72	(1.62–1.83)	965	1.83	(1.67–2.00)	96	0.68	(0.55–0.83)
South Eastern Europe (3200)	1250	1.85	(1.74–1.97)	676	1.34	(1.22–1.48)	162	0.91	(0.78–1.07)
Eastern Europe (3300)	526	1.78	(1.63–1.95)	205	0.98	(0.84–1.14)	98	1.21	(0.99–1.49)
North Africa (4100)	89	1.15	(0.93–1.42)	194	3.32	(2.85–3.88)	11	0.42	(0.23–0.77)
Middle East (4200)	274	1.47	(1.30–1.66)	222	1.47	(1.27–1.70)	63	0.63	(0.49–0.81)
South-East Asia (5000)	440	1.10	(1.00–1.21)	1073	3.38	(3.12–3.67)	343	1.00	(0.90–1.13)
North-East Asia (6000)	665	2.15	(1.98–2.33)	699	2.93	(2.67–3.22)	209	0.87	(0.75–1.01)
Southern Asia (7100)	161	0.75	(0.64–0.87)	181	1.06	(0.91–1.24)	59	0.39	(0.30–0.50)
Northern America (8100)	72	0.94	(0.75–1.19)	58	0.93	(0.71–1.21)	32	0.66	(0.47–0.94)
South America (8200)	159	2.35	(2.01–2.75)	76	1.42	(1.12–1.79)	30	0.70	(0.49–1.00)
Southern & East Africa (9200)	178	1.19	(1.02–1.38)	120	0.99	(0.82–1.20)	73	0.75	(0.60–0.95)
P value		<0.0001			<0.0001			<0.0001	

[a]Adjusted for age group at diagnosis, sex, and year of diagnosis in a negative binomial regression model with Australian-born population as a reference.

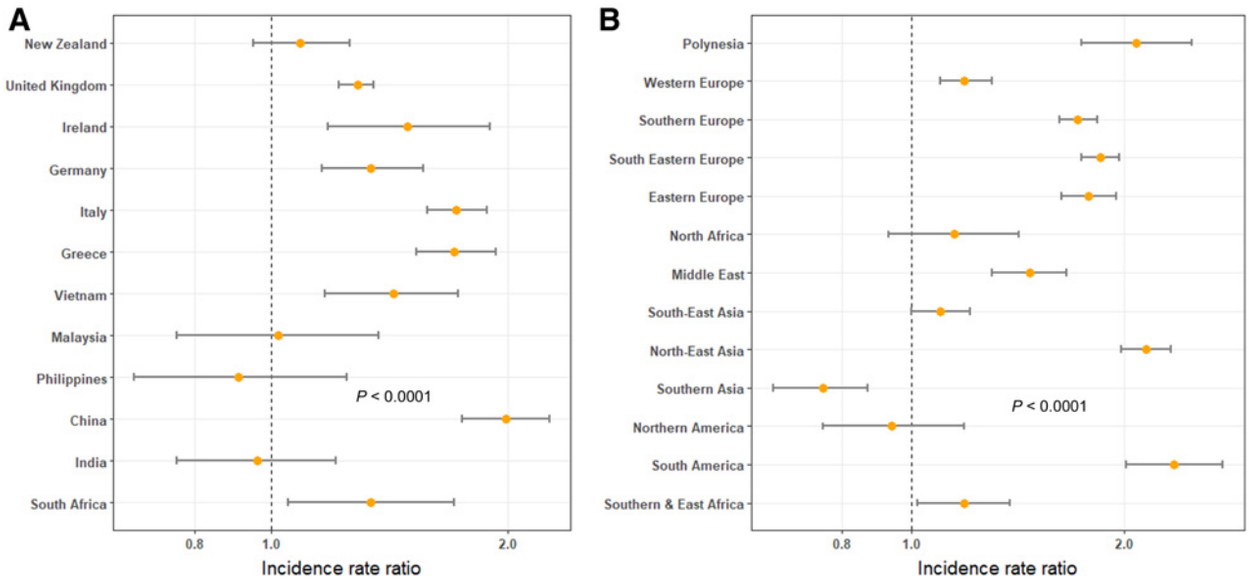

Figure 1.
Adjusted incidence rate ratio[a] and 95% CIs for stomach cancer relative to the Australian-born; (**A**) by country of birth[b] (**B**) by region of birth.[b]
[a]Adjusted for age group at diagnosis, sex and year of diagnosis in a negative binomial regression model with Australian-born population as a reference.
[b]Countries/Regions ordered by SACC code (see **Table 2** for details).

Cervical cancer (Fig. 3A and B)

In contrast to stomach and liver cancer, cervical cancer incidence was lower among many migrant women than Australian-born women (**Table 2**), including five individual countries and six regions of birth. Women from Southern Asia (IRR = 0.39) and North Africa regions (0.42) had less than half the risk of Australian-born women. The rate of cervical cancer was higher in migrants from New Zealand, the Philippines, and Polynesia, with the latter having the highest IRR (1.69).

Discussion

In this nationwide study, Australian migrants who were born in higher incidence countries or regions (11, 12) were found to have

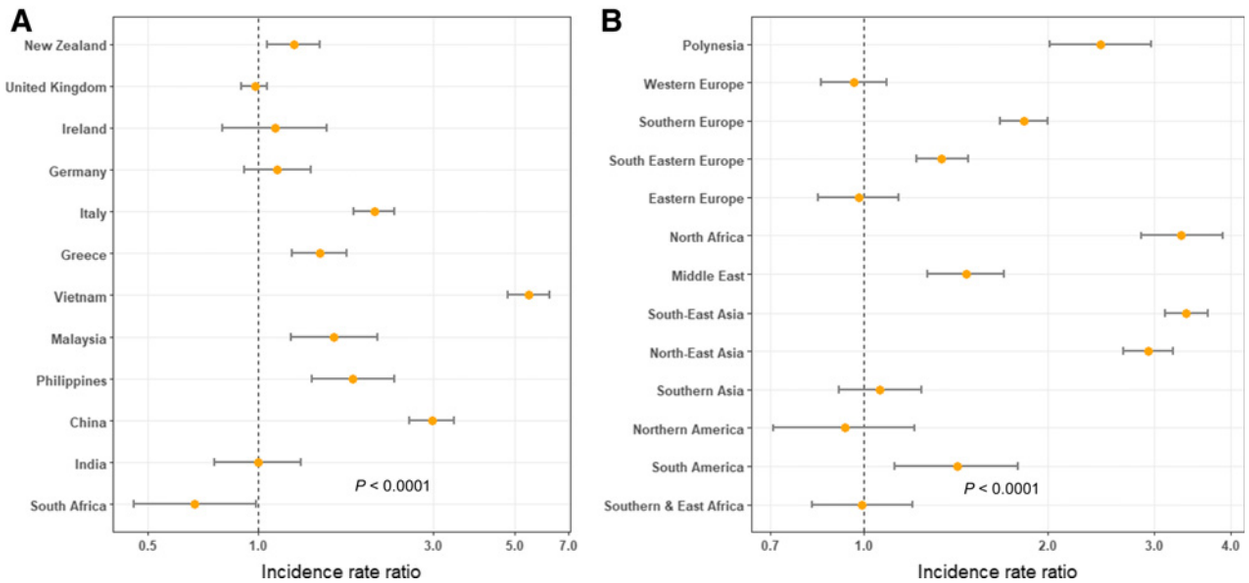

Figure 2.
Adjusted incidence rate ratio[a] and 95% CIs for liver cancer relative to the Australian-born; (**A**) by country of birth[b] (**B**) by region of birth.[b]
[a]Adjusted for age group at diagnosis, sex, and year of diagnosis in a negative binomial regression model with Australian-born population as a reference.
[b]Countries/Regions ordered by SACC code (see **Table 2** for details).

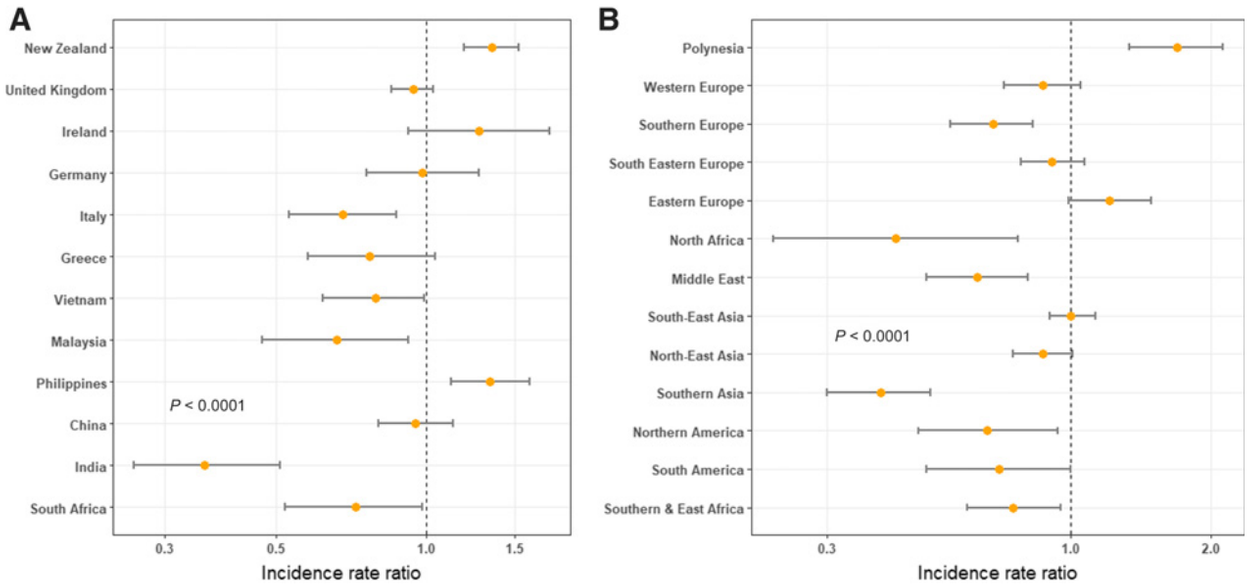

Figure 3.

Adjusted incidence rate ratio[a] and 95% CIs for cervical cancer relative to the Australian-born; (**A**) by country of birth[b] (**B**) by region of birth.[b]
[a]Adjusted for age group at diagnosis, and year of diagnosis in a negative binomial regression model with Australian-born population as a reference.
[b]Countries/Regions ordered by SACC code (see **Table 2** for details).

higher incidence rates for cancers of the stomach and liver than the Australian-born residents. However, in contrast to prior European studies that reported cervical cancer incidence was more common among migrant groups than among the host populations (7), migrant women from many countries in our study were found to have lower incidence of cervical cancer than Australian-born women. This held even when they came from countries with very high incidence such as Southern and East Africa (13).

International migrants experience a health transition, and their cancer risk in the host country reflects some combination of the underlying risk in the country of origin and their new country, which may be due to attributes of migrants themselves as well as differences in genetic background (31). Given this transition, these updated cancer profiles among migrants in Australia provide important information to guide education and prevention activities.

Variation in the prevalence of *H. pylori* infection, the strongest known risk factor for stomach cancer (32), may help to explain some of the differences in the incidence of stomach cancer among migrant groups in Australia. Based on a recent meta-analysis of prevalence of *H. pylori* infection globally, Australia had a relatively low prevalence (25%), while the corresponding prevalence in China or North-East Asia was over twice of that in Australia (56% and 54%, respectively; ref. 32). The doubling of stomach cancer incidence rates among Chinese migrants and those from North-East Asia compared with Australian-born population is consistent with the difference in prevalence. Other risk factors, such as greater intake of salted, pickled, or smoked foods among these migrant groups may also contribute to the differences observed (33), however data to support those hypotheses are not readily available.

The higher rates for liver cancer observed among many migrant groups in Australia are consistent with findings from previous studies of the global patterns of liver cancer incidence (12, 33). The over five-fold higher rate for liver cancer among Vietnamese migrants to Australia could be mainly due to their early life exposure to HBV and HCV infection, the most important risk factors for liver cancer (34), in Vietnam where these infections are endemic with a very high prevalence of chronic HBV (68%) in the general population (35). The highest IRRs for liver cancer among migrants from China and Vietnam are consistent with almost two-fifths of people infected with HBV in Australia being born in those two countries (36). Similarly, the higher rates observed for other endemic countries in North Africa, Eastern and South-East Asia and Europe (Italy and Greece), were largely attributable to the high prevalence of chronic HBV and/or HCV infections in these countries (12, 33). The introduction of HBV vaccines in some high-risk regions (such as China, Singapore, Thailand or Taiwan) may also play a role in the observed patterns among the Australian migrant groups, however its impact is likely to be limited since the vaccine programs in those countries were restricted to new-born, infants and adolescents since 1990s (37). Higher rates for liver cancer have also been reported among migrants from these endemic countries to other western countries, such as those from South-East Asia and North Africa to Canada (16), UK, Sweden, France, and the Netherlands (7). The significantly lower liver cancer rate we observed among South African migrants to Australia may suggest that they retained the low population rates observed in South Africa. However, South African incidence rates may underreport liver cancer as it can be either inconclusively diagnosed or not recorded in a cancer registry in sub-Saharan Africa (38).

As with cancers of the stomach and liver (11, 12), the incidence of cervical cancer varies widely throughout the world, with rates differing by a factor of >30 between the highest and the lowest countries (13). However, the main driver of this marked geographical variation is access to cervical screening (10), which helps to prevent cervical cancer, and thus lower incidence. The relatively smaller variation in cervical cancer we observed between migrant groups within Australia than has been reported between countries may be due to the effect of

screening in Australia, since free access to cervical screening is offered to all age-eligible women in Australia (39). However, women from countries with no organized population-based cervical screening are less likely to have been screened before migrating to Australia, and may be less aware of cervical screening in Australia or reluctant to have a cervical screening in Australia, particularly recent arrivals (5). This may be one reason for higher incidence in some migrant groups, such as women born in Polynesia or Philippines. There are no recent data on screening participation by women living in Australia but born in these countries, but lower cervical screening rates have previously been reported for Filipino women (38%) compared with native Norwegian women (68%; ref. 40).

Many migrant women in Australia in this study were found to have a lower incidence of cervical cancer than the native-born population, consistent with findings from a Canadian study (41). Our observation of lower rates among migrant women from the Middle East and North Africa, also observed in the Canadian study (41), are consistent with the findings in a recent worldwide analysis (13). The lower rates for these migrant women were probably due to the lower prevalence of HPV infection in their countries of origin (42). This, in turn, could be explained by cultural factors related to sexual behavior (43), where they typically have fewer sexual partners due to the importance placed on modesty and premarital virginity (44). Some of the observed differences, however, are not readily explained by possible differences in either screening participation or HPV exposure, including the higher rates for women born in New Zealand (there are no recent data on screening participation by or other risk factors among women born in New Zealand living in Australia), and the lower rates for Southern Asia and Southern Europe (both less likely to screen than Australian-born women; ref. 13).

While exposure to the infectious pathogens before migration likely plays a major role in the observed patterns of incidence among migrants to Australia, acculturation, the process by which migrants adopt the behavioral and lifestyle practices of the native-born Australians, may also play an important role. Results from two previous NSW studies (23, 45), together with the current study, all showed higher incidence for liver cancer among Vietnamese migrants. While not directly comparable, the results from these separate studies suggest a gradual decrease in the magnitude of the relative risk over time, from 10 to 27 times higher in the cohort diagnosed in 1972 to 1990 (23), 12 times higher in the cohort diagnosed in 1991 to 2001 (45) and >5 times higher in the current study. These are consistent with the previous Australian studies showing that the risk of migrants being diagnosed with liver cancer gradually decreased as the duration of stay increased (8, 28), suggesting that access to better medical treatment (antiviral therapy) in Australia and reduction in other factors which affect the risk of developing liver cancer, such as the HBV vaccine, may play a part (46). Other known risk factors such as tobacco smoking, type II diabetes, and obesity may also affect the risk of liver cancer (34). Given the prevalence of these factors is generally lower among more affluent populations (47), this may, in part, explain some of the relatively lower incidence observed among South African migrants, who based on occupation data from the 2011 Australian Census (48), were more likely to be employed in occupations classified as professionals or managers, with a much higher average weekly family income ($2,416 vs. $1,492 for Australian-born).

This study has several strengths. First, recent national cancer incidence data (with high standards of completeness and quality; ref. 49) were used to provide more contemporary insights into the risk profile of migrants to Australia. The population size is sufficiently large for us to report cancer profiles for many smaller migrant groups including those from Polynesia region, which showed higher risk for all three cancers of interest. As there are very limited data on cancer registration in the Polynesia region, these rates may provide estimates for these cancers for their countries of origin as most of the migrants have moved to Australia in the last two decades (50). In addition, the larger cohort sizes enable more reliable, robust estimates to be calculated. For example, the higher rate of liver cancer for Vietnamese migrants in our study was based on a much larger cohort ($n = 550$) than the previous NSW study ($n = 24$; ref. 23). Second, the annual ERP data by country of birth were used which enables more accurate rate estimates than the quinquennial census population data as previous studies (20–24, 26), which could lead to a biased estimate of the population at risk (7).

Limitations

Migrants are always a selected group of the population whose socioeconomic, occupational, and behavioral characteristics related to the risk of being diagnosed with cancer may differ from those in their country of birth (8). Thus, their cancer rates may be different from that of their country of origin. Although the well-established relationship between infection of these relevant agents and these three cancers (51), information on HBV or HCV, HPV or *H. pylori* infection in early life exposures were not readily available, thus limiting our ability to draw conclusion of causation from this study. However, some Australian studies suggest that the prevalence of these infections were higher among specific migrant groups in Australia (36, 52). In the case of *H. pylori* infection, for example, in a large nation-wide, population-based study, migrants from the Asia-Pacific region have been found to have higher risk of infection than those born in Australia/New Zealand (52). Another limitation is the exclusion of the records (8.5%) of unknown country of birth for cervical cancer. More complete data on country of birth would be highly desirable but are rarely available at the population level. Finally, data on age at migration or the length of residence in Australia were not available within the ACD.

While, on average, recent migrants to Australia have higher education levels and are more likely to be in paid work than the Australian-born population (53, 54), it is recognized that many migrants face additional challenges in accessing health and social services, often due to language and cultural differences, and various institutional and structural barriers (40, 55). Combined, it is likely that these factors may impact on migrants accessing the required screening and other diagnostic services.

The higher incidence rates of stomach and liver cancer observed for certain migrant populations in Australia may suggest a role for targeted cancer control preventions among these migrant populations. Previous work has called for a comprehensive program for HBV and HCV management to be implemented in Australia, including education and surveillance to people at higher risk, and appropriate antiviral therapy (46, 56). Combined, these targeted strategies have the potential to detect liver cancer at an earlier stage, and to prevent liver cancer in people living with chronic HBV or HCV infection by antiviral therapy among high-risk migrant populations. Initiatives to improve liver cancer outcomes are currently being explored, and incorporate the rising risk associated with nonalcoholic fatty liver disease and metabolic syndrome (57–60).

Several migrant groups, particularly for women originating from the Philippines, and Polynesia region, have higher incidence of cervical cancer. For women who arrive as adults, cervical screening is the most effective form of cervical cancer prevention. Thus, to achieve the goal

of cervical cancer elimination in Australia (61), it is important to increase cervical screening participation rates and ensure timely follow-up of screen-detected abnormalities for those migrant women with higher rates of cervical cancer. To this end, culturally tailored education programs have been shown to be effective in improving knowledge and intentions to participate in cancer screening among culturally diverse communities in Australia (62). For those arriving as children, HPV vaccination is already available up until age 19 (vaccination at older ages has limited impact in preventing cancer, as the causal HPV infection is likely acquired at a relatively young age; ref. 63), and very strong herd effects have been documented in Australia (64). It is important that those migrating to Australia are made aware of the opportunity to be vaccinated (if under age 20) or screened (from aged 25). The option to undergo cervical screening on a self-collected sample from July 2022 is also likely to help reduce barriers for women who are uncomfortable about undergoing a speculum exam by a medical practitioner to collect a screening sample (65).

In conclusion, health disparities experienced by migrant populations in Australia have largely been understudied because of an incomplete reporting of migrant status in national health-related datasets and difficulty in obtaining relevant population denominator data. By identifying population subgroups having a higher burden of one or more of these three cancer types, the results of this study provide a crucial first step toward reducing this inequitable burden.

Authors' Disclosures

E. Feletto reports grants from Australian Government Department of Health, Australian National Health and Medical Research Council, The Prevention Centre, and Medicine Research Futures Fund outside the submitted work. M.A. Smith reports grants from Australian National Health and Medical Research Council and Cancer Institute NSW during the conduct of the study. No disclosures were reported by the other authors.

Authors' Contributions

X. Yu: Conceptualization, data curation, software, formal analysis, validation, investigation, visualization, methodology, writing–original draft, writing–review and editing. **E. Feletto:** Conceptualization, validation, writing–review and editing. **M.A. Smith:** Validation, writing–review and editing. **S. Yuill:** Writing–review and editing. **P.D. Baade:** Conceptualization, validation, writing–review and editing.

Acknowledgments

We thank the Australian Institute of Health and Welfare for providing the data for this study and the data custodian in each state and territory of Australia for their approval to release the data, and Ankur Kohar for assistance in producing high-quality figures.

The costs of publication of this article were defrayed in part by the payment of page charges. This article must therefore be hereby marked *advertisement* in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.

Received November 23, 2021; revised February 8, 2022; accepted March 7, 2022; published first March 23, 2022.

References

1. Australian Institute of Health and Welfare. Australian Cancer Database (ACD). Canberra, Australia: AIHW; 2019.
2. Australian Bureau of Statistics. 2021 Migration, Australia. Available from: https://www.abs.gov.au/statistics/people/population/migration-australia/latest-release#:~:text=In%202020%2C%20there%20were%20over,in%20Australia's%20population%20in%202020.
3. Parliamentary Library. Top 10 countries of birth for the overseas-born population since 1901. Department of Parliamentary Services, Canberra 2018.
4. Australian Bureau of Statistics. 2017 Cultural diversity in Australia, 2016. Available from: https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2071.0~2016~Main%20Features~Cultural%20Diversity%20Article~60.
5. Alam Z, Shafiee Hanjani L, Dean J, Janda M. Cervical cancer screening among immigrant women residing in Australia: a systematic review. Asia Pac J Public Health 2021;33:816–27.
6. National Cancer Institute. 2021 Risk factors for cancer. Available from: https://www.cancer.gov/about-cancer/causes-prevention/risk.
7. Arnold M, Razum O, Coebergh JW. Cancer risk diversity in non-western migrants to Europe: an overview of the literature. Eur J Cancer 2010;46:2647–59.
8. McCredie M. Cancer epidemiology in migrant populations. Recent Results Cancer Res 1998;154:298–305.
9. Van Hemelrijck WMJ, Rosskamp M, De Schutter H, Verdoodt F, Vanthomme K. Cancer risk among individuals of migrant origin in Belgium during the 2000s - evidence of migration as a 'cancer risk transition'? Soc Sci Med 2021;269:113591.
10. de Martel C, Georges D, Bray F, Ferlay J, Clifford GM. Global burden of cancer attributable to infections in 2018: a worldwide incidence analysis. Lancet Glob Health 2020;8:e180–e90.
11. The global, regional, and national burden of stomach cancer in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease study 2017. Lancet Gastroenterol Hepatol 2020;5:42–54.
12. Akinyemiju T, Abera S, Ahmed M, Alam N, Alemayohu MA, Allen C, et al. The burden of primary liver cancer and underlying etiologies from 1990 to 2015 at the Global, Regional, and National Level: results from the Global Burden of Disease Study 2015. JAMA Oncol 2017;3:1683–91.
13. Arbyn M, Weiderpass E, Bruni L, de Sanjose S, Saraiya M, Ferlay J, et al. Estimates of incidence and mortality of cervical cancer in 2018: a worldwide analysis. Lancet Glob Health 2020;8:e191–203.
14. Chan CK, Aimagambetova G, Ukybassova T, Kongrtay K, Azizan A. Human papillomavirus infection and cervical cancer: epidemiology, screening, and vaccination-review of current perspectives. J Oncol 2019;2019:3257939.
15. Hemminki K, Forsti A, Khyatti M, Anwar WA, Mousavi M. Cancer in immigrants as a pointer to the causes of cancer. Eur J Public Health 2014;24:64–71.
16. McDermott S, Desmeules M, Lewis R, Gold J, Payne J, Lafrance B, et al. Cancer incidence among Canadian immigrants, 1980–1998: results from a national cohort study. J Immigr Minor Health 2011;13:15–26.
17. Pabla BS, Shah SC, Corral JE, Morgan DR. Increased incidence and mortality of gastric cancer in immigrant populations from high to low regions of incidence: a systematic review and meta-analysis. Clin Gastroenterol Hepatol 2020;18:347–59.
18. Antonsson A, Wilson LF, Kendall BJ, Bain CJ, Whiteman DC, Neale RE. Cancers in Australia in 2010 attributable to infectious agents. Aust N Z J Public Health 2015;39:446–51.
19. McCredie M, Coates M, Grulich A. Cancer incidence in migrants to New South Wales (Australia) from the Middle East, 1972–91. Cancer Causes Control 1994;5:414–21.
20. McCredie M, Coates MS, Ford JM. Cancer incidence in migrants to New South Wales from England, Wales, Scotland and Ireland. Br J Cancer 1990;62:992–5.
21. McCredie M, Coates MS, Ford JM. Cancer incidence in European migrants to New South Wales. Ann Oncol 1990;1:219–25.
22. McMichael AJ, McCall MG, Hartshorne JM, Woodings TL. Patterns of gastro-intestinal cancer in European migrants to Australia: the role of dietary change. Int J Cancer 1980;25:431–7.
23. Grulich AE, McCredie M, Coates M. Cancer incidence in Asian migrants to New South Wales, Australia. Br J Cancer 1995;71:400–8.
24. McCredie M, Coates MS, Ford JM. Cancer incidence in migrants to New South Wales. Int J Cancer 1990;46:228–32.
25. McMichael AJ, Bonett A. Cancer profiles of British and southern-European Migrants. Exploring South Australia's cancer registry data. Med J Aust 1981;1:229–32.

26. McMichael AJ, Bonett A, Roder D. Cancer incidence among migrant populations in South Australia. Med J Aust 1989;150:417–20.
27. Feletto E, Sitas F. Quantifying disparities in cancer incidence and mortality of Australian residents of New South Wales (NSW) by place of birth: an ecological study. BMC Public Health 2015;15:823.
28. McCredie M, Williams S, Coates M. Cancer mortality in East and Southeast Asian migrants to New South Wales, Australia, 1975–1995. Br J Cancer 1999;79: 1277–82.
29. Australian Bureau of Statistics. 2016 Standard Australian Classification of Countries (SACC). Available from http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/1269.0Main%20Features12016?opendocument&tabname=Summary&prodno=1269.0&issue=2016&num=&view.
30. Australian Bureau of Statistics. Estimated resident population, country of birth, age and sex - as at 30 June 1996 to 2019. ABS, Canberra 2019.
31. Spallek J, Zeeb H, Razum O. What do we have to know from migrants' past exposures to understand their health status? a life course approach. Emerg Themes Epidemiol 2011;8:6.
32. Hooi JKY, Lai WY, Ng WK, Suen MMY, Underwood FE, Tanyingoh D, et al. Global prevalence of helicobacter pylori infection: systematic review and meta-analysis. Gastroenterology 2017;153:420–9.
33. Kamangar F, Dores GM, Anderson WF. Patterns of cancer incidence, mortality, and prevalence across five continents: defining priorities to reduce cancer disparities in different geographic regions of the world. J Clin Oncol 2006;24: 2137–50.
34. El-Serag HB. Hepatocellular carcinoma. N Engl J Med 2011;365:1118–27.
35. Pham T, Bui L, Kim G, Hoang D, Tran T, Hoang M. Cancers in Vietnam-burden and control efforts: a narrative scoping review. Cancer Control 2019;26: 1073274819863802.
36. MacLachlan JH, Allard N, Towell V, Cowie BC. The burden of chronic hepatitis B virus infection in Australia, 2011. Aust N Z J Public Health 2013;37:416–22.
37. Lim SG, Mohammed R, Yuen MF, Kao JH. Prevention of hepatocellular carcinoma in hepatitis B virus infection. J Gastroenterol Hepatol 2009;24: 1352–7.
38. Kew MC. Epidemiology of hepatocellular carcinoma in sub-Saharan Africa. Ann Hepatol 2013;12:173–82.
39. Australian Institute of Health and Welfare. Analysis of cancer outcomes and screening behaviour for national cancer screening programs in Australia. Canberra, Australia: AIHW; 2018.
40. Leinonen MK, Campbell S, Ursin G, Trope A, Nygard M. Barriers to cervical cancer screening faced by immigrants: a registry-based study of 1.4 million women in Norway. Eur J Public Health 2017;27:873–9.
41. Aston O, Sutradhar R, Rabeneck L, Paszat L. Risk of invasive cervical cancer among immigrants in Ontario, Canada. J Obstet Gynaecol Can 2019;41:21–8.
42. Tornesello ML, Giorgi Rossi P, Buonaguro L, Buonaguro FM, HPV Prevalence Italian Working Group. Prevalence Italian Working Group. Human papillomavirus infection and cervical neoplasia among migrant women living in Italy. Front Oncol 2014;4:31.
43. Gustafsson L, Ponten J, Bergstrom R, Adami HO. International incidence rates of invasive cervical cancer before cytological screening. Int J Cancer 1997;71:159–65.
44. Johnson CE, Mues KE, Mayne SL, Kiblawi AN. Cervical cancer screening among immigrants and ethnic minorities: a systematic review using the Health Belief Model. J Low Genit Tract Dis 2008;12:232–41.
45. Supramaniam R, O'Connell DL, Tracey E, Sitas F. Cancer incidence in New South Wales migrants 1991 to 2001. Sydney: The Cancer Council NSW; 2006.
46. Carville KS, Cowie BC. Recognising the role of infection: Preventing liver cancer in special populations. Cancer Forum 2012;36:23–6.
47. Volaco A, Cavalcanti AM, Filho RP, Precoma DB. Socioeconomic status: the missing link between obesity and diabetes mellitus? Curr Diabetes Rev 2018;14: 321–6.
48. Australian Bureau of Statistics. 2020 2011 QuickStats country of birth. Available from: https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/2105_0.
49. Bray F, Colombet M, Mery L, Pineros M, Znaor A, Zanetti R, et al. Cancer incidence in five continents. Lyon, France: International Agency for Research on Cancer; 2017.
50. Batley J. What does the 2016 census reveal about Pacific Islands communities in Australia? Canberra, Australia: Australian National University; 2017.
51. IARC Working Group on the Evaluation of Carcinogenic Risks to humans. Biological agents. Volume 100 B. A review of human carcinogens. IARC Monogr Eval Carcinog Risks Hum 2012;100:1–441.
52. Pandeya N, Whiteman DC., Australian Cancer S. Prevalence and determinants of Helicobacter pylori sero-positivity in the Australian adult community. J Gastroenterol Hepatol 2011;26:1283–9.
53. Australian Bureau of Statistics. 2017 Educational qualifications in Australia. Available from: https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2071.0~2016~Main%20Features~Educational%20Qualifications%20Data%20Summary%20~65.
54. Australian Bureau of Statistics. 2019 Characteristics of recent migrants. Available from: https://www.abs.gov.au/statistics/people/people-and-communities/characteristics-recent-migrants/latest-release.
55. Keygnaert I, Ivanova O, Guieu A, Van Parys A-S, Leye E, Roelens K. What is the evidence on the reduction of inequalities in accessibility and quality of maternal health care delivery for migrants? Copenhagen, Denmark: WHO Regional Office for Europe; 2016.
56. Robotin MC, George J, Supramaniam R, Sitas F, Penman AG. Preventing primary liver cancer: how well are we faring towards a national hepatitis B strategy? Med J Aust 2008;188:363–5.
57. Cancer Council NSW. 2020 Transforming liver cancer outcomes in New South Wales. Available from: https://www.cancercouncil.com.au/news/transforming-liver-cancer-outcomes-in-new-south-wales/.
58. Sheppard-Law S, Zablotska-Manos I, Kermeen M, Holdaway S, Lee A, George J, et al. Utilisation of hepatocellular carcinoma screening in Australians at risk of hepatitis B virus-related carcinoma and prescribed anti-viral therapy. J Clin Nurs 2018;27:2673–83.
59. Srivastava A, Gailer R, Tanwar S, Trembling P, Parkes J, Rodger A, et al. Prospective evaluation of a primary care referral pathway for patients with non-alcoholic fatty liver disease. J Hepatol 2019;71:371–8.
60. Adams LA, Roberts SK, Strasser SI, Mahady SE, Powell E, Estes C, et al. Nonalcoholic fatty liver disease burden: Australia, 2019–2030. J Gastroenterol Hepatol 2020;35:1628–35.
61. Hall MT, Simms KT, Lew JB, Smith MA, Brotherton JM, Saville M, et al. The projected timeframe until cervical cancer elimination in Australia: a modelling study. Lancet Public Health 2019;4:e19–27.
62. Cullerton K, Gallegos D, Ashley E, Do H, Voloschenko A, Fleming M, et al. Cancer screening education: can it change knowledge and attitudes among culturally and linguistically diverse communities in Queensland, Australia? Health Promot J Austr 2016;27:140–7.
63. Burger EA, de Kok I, Groene E, Killen J, Canfell K, Kulasingam S, et al. Estimating the natural history of cervical carcinogenesis using simulation models: a CISNET Comparative Analysis. J Natl Cancer Inst 2020;112: 955–63.
64. Drolet M, Benard E, Perez N, Brisson M, Group HPVVIS. Population-level impact and herd effects following the introduction of human papillomavirus vaccination programmes: updated systematic review and meta-analysis. Lancet 2019;394:497–509.
65. Department of Health. 2021 Landmark changes improving access to life saving cervical screenings. Available from: https://www.health.gov.au/ministers/the-hon-greg-hunt-mp/media/landmark-changes-improving-access-to-life-saving-cervical-screenings.