Abstract

Background: It is not known whether improvements in cancer survival over recent decades have benefited children from different geographic locations equally. This is the first study to produce national survival estimates for childhood cancer in Australia by remoteness of residence and area-based socioeconomic status.

Methods: The study utilized population-based data from the Australian Paediatric Cancer Registry for children diagnosed with cancer from 1996 onward who were at risk of mortality between January 2001 and December 2006 (n = 6,289). Remoteness was specified according to the Australian Standard Geographical Classification Remoteness Areas, whereas an index of area disadvantage was obtained from census information. Five-year relative survival estimates were produced by the period method for all cancers and the most common diagnostic groups, with corresponding age-sex adjusted mortality hazard ratios calculated using Poisson regression.

Results: Overall, children with cancer from remote/very remote areas had a significantly lower survival rate than their counterparts in major cities (HR = 1.55, 95% CI = 1.08–2.23). Survival was also lower for children with leukemia living in inner regional (HR = 1.52, 95% CI = 1.11–2.08) or outer regional areas (HR = 1.53, 95% CI = 1.03–2.28). There was weak evidence (Pgrad = 0.051) of a trend toward poorer survival by greater area disadvantage for all childhood cancers.

Conclusions: Some variation in prognosis by place of residence was present for children with cancer in Australia, particularly among leukemia patients.

Impact: Treatment, clinical or area-related factors that contribute to these survival differentials need to be identified.

Introduction

There has been an increasing focus over recent years on differentials in survival among adult cancer patients according to their place of residence at the time of diagnosis. Several Australian studies have shown that the chance of survival following a cancer diagnosis generally decreases the further a person lives from a major population center and that, for certain cancers, survival also tends to be lower among those living in more socioeconomically disadvantaged areas (1–3). Although the specific factors behind these disparities may vary by type of cancer and are yet to be fully identified (4, 5), it is likely that late detection or limited access to appropriate and coordinated treatment services for those living in rural/remote regions play some role.

In contrast, very little is known about geographic differentials in survival among children diagnosed with cancer. Childhood cancer survival has improved significantly during the last few decades (6–8), with most of these gains being achieved through advances in therapy that have been implemented as a result of collaborative clinical trials (9, 10). However, it is unclear whether these improved rates of survival apply equally regardless of where a child lives. This has restricted the ability of health planners to appropriately target and prioritize childhood cancer services.

The purpose of this study was, therefore, to examine and quantify the effects of remoteness of residence and an area-based measure of socioeconomic disadvantage on childhood cancer survival in Australia.

Materials and Methods

Australian pediatric cancer registry

Deidentified unit record data containing information on all children aged 0 to 14 years who were diagnosed...
with cancer in Australia between 1996 and 2006 were accessed from the Australian Paediatric Cancer Registry (APCR), one of the few national, population-based registries of childhood cancer in the world (6). The APCR operates with the assistance of each state and territory cancer registry and all major children’s hospitals in Australia. Data quality in the APCR is high, with 95% of cases determined by histologic verification (11).

Basic demographics were recorded at diagnosis, such as sex, age, place of usual residence, and Indigenous status, which is defined as those who self-identify as being of Australian Aboriginal or Torres Strait Islander origin. Mortality was confirmed via record linkage between the APCR and the Australian National Death Index.

Unlike adult cancers, childhood cancers are primarily categorized based on the type of cancer tissue (morphology) rather than where the cancer occurs in the body. The diagnostic group for each child was allocated according to the third edition of the International Classification of Childhood Cancers (ICCC-3; ref. 12). All invasive cancers were included, as well as intracranial and intraspinal tumors of benign or uncertain behavior. Results were calculated for all cancers combined and for the 3 largest diagnostic groups: lymphomas, tumors of the central nervous system, and lymphomas. The subgroup of lymphoid leukemia was also analyzed separately. Remaining cancer types were aggregated to enable sufficient numbers for some analyses.

Relative survival was calculated from the observed probability of all cause survival among childhood cancer patients divided by the expected probability of survival within the corresponding Australian population stratified by age, sex, and calendar year (15). Estimates were calculated by using actuarial techniques based on the period method (16), which provides more timely estimates of survival than the traditional cohort approach and has been shown to be particularly useful in monitoring childhood cancer survival (17, 18).

Children diagnosed with cancer between 1996 and 2006 were considered “at risk” of mortality if they constituted a prevalent case for at least some time during the period January 1, 2001 to December 31, 2006. Patients who were still alive at December 31, 2006 were censored at that date. The Ederer II method (19) was used to calculate expected survival in the general population.

Poisson models

To assess whether differences in relative survival were statistically significant, generalized linear models with a Poisson error structure were constructed to model excess mortality associated with childhood cancer up to 5 years after diagnosis, as described by Dickman and colleagues (15). Results were expressed as adjusted hazard ratios (HRs) along with 95% CIs. Sex, age group at diagnosis (<1, 1–4, 5–9, and 10–14 years) and either remoteness or area disadvantage were included in each model, all specified as categorical variables. The selected baseline categories for remoteness and area disadvantage were those with the highest number of cases, that is, “major cities” and “middle SES,” respectively. The significance of the gradient in the adjusted HRs across the variables of interest (denoted as $P_{grad}$) was investigated by rerunning the models and fitting remoteness or area disadvantage as a continuous variable. An interaction term for remoteness and area disadvantage was entered in a separate model. Each model was checked for convergence.

Given that large variations in population structure by Indigenous status have been reported across the remoteness categories (20), combined with differences in the health of Indigenous and non-Indigenous children across a range of indicators (21), additional analysis was
restricted to children who were identified as being non-Indigenous to assess the impact that this might have on any remoteness differentials. Stage at diagnosis is another important determinant of survival among children with some specific cancers (6, 22), and further modeling to adjust for stage was carried out on the subset of cases for which these data were collected.

Analyses were conducted by using SAS version 9.2 for Windows. Approval for this work was obtained from the cancer registries in all Australian states and territories and all hospitals that contributed to the data collection, as well as the ethics committees of the Queensland Institute of Medical Research and the University of Queensland.

Results

A total of 6,827 cases of childhood cancer were diagnosed in Australia between 1996 and 2006. Patients with inadequate or missing information on address at diagnosis were removed from the analysis ($n = 20, 0.3\%$). Cases diagnosed on the basis of death certificate only or autopsy with histology were also excluded ($n = 26, 0.4\%$), as were those with a reported survival time of less than 1 day ($n = 25, 0.4\%$).

Of the remaining 6,756 cases, 93\% ($n = 6,289$) were at risk of mortality during the period 2001 to 2006. Over half of the eligible children were males (54\%) and the median age at diagnosis was 5 years 8 months. Leukemias constituted 34\% of these cases, followed by tumors of the central nervous system (22\%) and lymphomas (10\%).

Five-year relative survival for all cancers combined was highest among children living in major cities (82\%) and lowest (73\%) among children in remote/very remote areas (Table 1). The corresponding gradient for the adjusted HRs across the remoteness categories was statistically significant ($P_{\text{grad}} = 0.017$). In particular, childhood cancer patients from remote/very remote areas were 55\% more likely to die within 5 years of diagnosis compared with children in major cities (Table 1).

A significant difference in the adjusted HRs by remoteness category was also found for leukemias ($P_{\text{grad}} = 0.009$). Unlike all cancers combined, this appeared to be more of a dichotomous relationship driven by the higher rate of 5-year survival among children with leukemia in major cities compared with children living in inner regional and outer regional localities, resulting in adjusted HRs of 1.52 and 1.53 for these areas, respectively. No significant evidence of geographic variation in survival emerged for children diagnosed with lymphomas, tumors of the central nervous system, other solid tumors, or the diagnostic subgroup of lymphoid leukemias.

When the models were rerun for known non-Indigenous children only (full results not shown), the differentials in survival by remoteness only changed slightly for all childhood cancers combined ($n = 5,564$) and for leukemias ($n = 1,961$). For example, although the trend was no longer statistically significant ($P_{\text{grad}} = 0.072$), the HR for non-Indigenous children from remote/very remote areas benchmarked against their counterparts in major cities remained similar for all cancers ($HR = 1.51, 95\% CI = 0.99–2.30$). Significant variation persisted for survival by remoteness category among non-Indigenous children with leukemia ($P_{\text{grad}} = 0.015$), because of differences between inner regional ($HR = 1.51, 95\% CI = 1.08–2.09$) and outer regional areas ($HR = 1.49, 95\% CI = 0.98–2.26$) compared with major cities.

In terms of area disadvantage, 5-year relative survival for all children with cancer was 83\% among those from the least disadvantaged areas and 78\% among those from the most disadvantaged areas. The resulting gradient for the adjusted HRs was marginally nonsignificant ($P_{\text{grad}} = 0.051$; Table 2). Although the patterns tended to be similar, no significant association between survival and area disadvantage was found for any of the various diagnostic groups.

There was no statistical interaction between remoteness and area disadvantage in the survival estimates for all childhood cancers combined ($P = 0.976$) or for any of the diagnostic groupings (leukemias: $P = 0.612$; tumors of the central nervous system: $P = 0.801$; other solid tumors: $P = 0.657$). The model for lymphoma which involved an interaction term did not converge because of an insufficient number of cases.

For those cases which included information on stage at diagnosis, survival rates were uniform across all categories of remoteness and area disadvantage after also adjusting for sex and age at diagnosis (Tables 1 and 2, respectively). Furthermore, the distribution of stage within the relevant diagnostic groups, including the proportion of cases with unknown stage, was similar when stratified by either remoteness ($P = 0.323$) or area disadvantage ($P = 0.273$; Table 3), and differences in survival between early and later stage cancers were approximately the same, regardless of place of residence (Table 4). Five-year relative survival for stage I/II childhood cancers collectively was between 94\% and 98\% within each remoteness or area disadvantage category, in contrast to estimates of around 70\% for stage III/IV cancers.

Discussion

National, population-based survival estimates for childhood cancer by degree of remoteness of residence from major cities and area disadvantage have not been published previously for Australia. The results shown here indicate that survival was generally poorer for children with cancer who lived in more isolated parts of the country. For leukemia, a demarcation in survival occurred between children residing in major cities compared with those living elsewhere. There was only minor evidence of any differences in survival associated with area disadvantage for all childhood cancers combined.

Literature regarding the relationship between geography and childhood cancer survival is limited. Schilling...
and colleagues (23) found some disparity in survival for children diagnosed with acute lymphoid leukemia by National Health Service region in England and Wales from the early 1970s onward, although the differences diminished by the mid-1980s. Tseng and colleagues (24) looked at survival for cases of childhood glioma in

<table>
<thead>
<tr>
<th>Diagnostic group/subgroup Remoteness category</th>
<th>Number of &quot;at risk&quot; cases</th>
<th>Five-year relative survival (%; 95% CI)</th>
<th>Adjusted HR (95% CI)</th>
<th>( P_{\text{grad}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Major cities</td>
<td>3757</td>
<td>81.6 (80.0–83.1)</td>
<td>1.00</td>
<td>0.017</td>
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<td>Inner regional</td>
<td>1565</td>
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<td>1.12 (0.94–1.34)</td>
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<tr>
<td>Outer regional</td>
<td>771</td>
<td>79.2 (75.6–82.4)</td>
<td>1.15 (0.92–1.44)</td>
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</tr>
<tr>
<td>Remote/very remote</td>
<td>196</td>
<td>73.3 (65.2–79.8)</td>
<td>1.55 (1.08–2.23)</td>
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</tr>
<tr>
<td>Leukemias</td>
<td></td>
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<tr>
<td>Major cities</td>
<td>1284</td>
<td>86.2 (83.7–88.4)</td>
<td>1.00</td>
<td>0.009</td>
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<td>Inner regional</td>
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<td>1.52 (1.11–2.08)</td>
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<td>79.6 (73.0–84.8)</td>
<td>1.53 (1.03–2.28)</td>
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<tr>
<td>Remote/very remote</td>
<td>64</td>
<td>80.8 (66.2–89.6)</td>
<td>1.57 (0.76–3.24)</td>
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<td>Lymphoid leukemias</td>
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<tr>
<td>Major cities</td>
<td>1031</td>
<td>89.1 (86.5–91.2)</td>
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<td>0.101</td>
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<td>83.5 (78.6–87.4)</td>
<td>1.50 (1.00–2.24)</td>
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<td>86.1 (78.9–91.0)</td>
<td>1.29 (0.74–2.24)</td>
<td></td>
</tr>
<tr>
<td>Remote/very remote</td>
<td>51</td>
<td>83.7 (66.4–92.6)</td>
<td>1.62 (0.65–4.06)</td>
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</tr>
<tr>
<td>Lymphomas</td>
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</tr>
<tr>
<td>Major cities</td>
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<td>0.808</td>
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<td>89.8 (79.0–95.2)</td>
<td>1.02 (0.38–2.72)</td>
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<tr>
<td>Tumors of the central nervous system</td>
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</tr>
<tr>
<td>Major cities</td>
<td>799</td>
<td>70.7 (66.8–74.3)</td>
<td>1.00</td>
<td>0.997</td>
</tr>
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<td>78.5 (70.4–86.6)</td>
<td>0.73 (0.47–1.13)</td>
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<tr>
<td>Remote/very remote</td>
<td>35</td>
<td>56.4 (37.4–71.7)</td>
<td>1.62 (0.87–3.00)</td>
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<tr>
<td>Other solid tumors</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Major cities</td>
<td>1281</td>
<td>80.9 (78.1–83.4)</td>
<td>1.00</td>
<td>0.225</td>
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<td>0.85 (0.61–1.17)</td>
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<tr>
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<td>77.3 (70.8–82.6)</td>
<td>1.18 (0.82–1.69)</td>
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<tr>
<td>Remote/very remote</td>
<td>77</td>
<td>69.5 (55.3–80.0)</td>
<td>1.62 (0.91–2.88)</td>
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<tr>
<td>Cases with stage at diagnosis</td>
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</tr>
<tr>
<td>Major cities</td>
<td>759</td>
<td>82.0 (78.3–85.1)</td>
<td>1.00</td>
<td>0.279</td>
</tr>
<tr>
<td>Inner regional</td>
<td>315</td>
<td>82.8 (77.0–87.2)</td>
<td>0.88 (0.58–1.34)</td>
<td></td>
</tr>
<tr>
<td>Outer regional</td>
<td>204</td>
<td>84.2 (76.9–89.3)</td>
<td>0.77 (0.46–1.29)</td>
<td></td>
</tr>
</tbody>
</table>

*aIncludes children who were diagnosed between January 1, 1996 and December 31, 2006 and who were "at risk" at some time between January 1, 2001 and December 31, 2006.

*bSurvival calculated using the period method.

*cHRs for all cancers, leukemias, lymphoid leukemias, lymphomas, tumors of the central nervous system, and other solid tumors were adjusted for sex and age group at diagnosis. HRs for cases with stage at diagnosis were adjusted for sex, age group at diagnosis, and stage at diagnosis.

*dThe remoteness category "remote/very remote" has been combined with "outer regional."

*eDiagnostic group includes intracranial/intraspinal tumors of benign or uncertain behavior.

*fThe diagnostic group "other solid tumors" includes neuroblastoma, retinoblastoma, renal tumors, hepatic tumors, malignant bone tumors, soft tissue sarcomas, germ cell tumors, other malignant epithelial neoplasms and melanomas and other unspecified malignant neoplasms.

*gIncludes cases where stage at diagnosis was available within the diagnostic groups of lymphomas, neuroblastoma and renal tumors, and the diagnostic subgroup of rhabdomyosarcomas.
England and Wales and reported that there was no geographic effect, in contrast to what they observed among adult glioma patients, possibly reflecting higher levels of standardized treatment and participation in clinical trials among children. Another large study which focused on childhood cancer throughout Europe identified that variations in treatment regimens and the delivery of health services were likely to contribute to differentials in survival between countries (25).

Within Australia, a country with vast areas of very low density population, the consequences of remoteness are more pronounced than for many parts of the world. Major challenges regarding access to diagnostic, treatment, and support services invariably confront cancer patients who come from these isolated areas (26–28). This may mean extended periods away from home for all or part of the family while medical care for a child with cancer is being sought, causing

<table>
<thead>
<tr>
<th>Diagnostic group/subgroup</th>
<th>Area disadvantage</th>
<th>Number of &quot;at risk&quot; cases</th>
<th>Five-year relative survival (%)</th>
<th>Adjusted HR</th>
<th>Pgrad</th>
</tr>
</thead>
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<td>All cancers</td>
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<td></td>
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<td>Least disadvantaged</td>
<td></td>
<td>1279</td>
<td>82.6 (79.9–85.0)</td>
<td>0.86 (0.71–1.05)</td>
<td>0.051</td>
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<tr>
<td>Middle SES</td>
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<td>4095</td>
<td>80.3 (78.8–81.7)</td>
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<tr>
<td>Most disadvantaged</td>
<td></td>
<td>914</td>
<td>78.5 (75.0–81.5)</td>
<td>1.10 (0.90–1.36)</td>
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<tr>
<td>Leukemias</td>
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<tr>
<td>Least disadvantaged</td>
<td></td>
<td>434</td>
<td>85.2 (80.6–88.8)</td>
<td>0.88 (0.61–1.25)</td>
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<td>1374</td>
<td>83.5 (80.9–85.7)</td>
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<td></td>
<td>306</td>
<td>81.4 (75.5–86.0)</td>
<td>1.12 (0.77–1.63)</td>
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<td>Lymphoid leukemias</td>
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<tr>
<td>Least disadvantaged</td>
<td></td>
<td>344</td>
<td>89.0 (84.1–92.4)</td>
<td>0.87 (0.54–1.39)</td>
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<td>Middle SES</td>
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<td>1096</td>
<td>87.0 (84.4–89.3)</td>
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<tr>
<td>Most disadvantaged</td>
<td></td>
<td>237</td>
<td>85.5 (79.1–90.1)</td>
<td>1.17 (0.71–1.92)</td>
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<td>Lymphomas</td>
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<tr>
<td>Least disadvantaged</td>
<td></td>
<td>134</td>
<td>94.2 (86.4–97.6)</td>
<td>0.62 (0.21–1.84)</td>
<td>0.236</td>
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<td>Middle SES</td>
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<td>427</td>
<td>90.8 (86.9–93.7)</td>
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<tr>
<td>Most disadvantaged</td>
<td></td>
<td>87</td>
<td>87.9 (76.6–94.0)</td>
<td>1.34 (0.54–3.30)</td>
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<td>Tumors of the central nervous system</td>
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<td>Least disadvantaged</td>
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<td>288</td>
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<td>Middle SES</td>
<td></td>
<td>882</td>
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<td>Most disadvantaged</td>
<td></td>
<td>187</td>
<td>72.1 (63.7–78.9)</td>
<td>0.87 (0.60–1.28)</td>
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<td>Other solid tumors</td>
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<tr>
<td>Least disadvantaged</td>
<td></td>
<td>423</td>
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<tr>
<td>Most disadvantaged</td>
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<td>334</td>
<td>76.7 (70.4–81.9)</td>
<td>1.25 (0.88–1.77)</td>
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<tr>
<td>Cases with stage at diagnosis</td>
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<tr>
<td>Least disadvantaged</td>
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<td>255</td>
<td>83.5 (76.7–88.5)</td>
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<tr>
<td>Most disadvantaged</td>
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<td>185</td>
<td>81.3 (73.2–87.2)</td>
<td>0.94 (0.56–1.57)</td>
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</table>

*Includes children who were diagnosed between January 1, 1996 and December 31, 2006 and who were "at risk" at some time between January 1, 2001 and December 31, 2006.

*Survival calculated using the period method.

*HRs were adjusted for sex and age group at diagnosis for all cancers, leukemias, lymphoid leukemias, lymphomas, tumors of the central nervous system, and other solid tumors. HRs were adjusted for sex, age group at diagnosis, and stage at diagnosis for cases with stage at diagnosis.

*Diagnostic group includes intracranial/intraspinal tumors of benign or uncertain behavior.

*The diagnostic group "other solid tumors" includes neuroblastoma, retinoblastoma, renal tumors, hepatic tumors, malignant bone tumors, soft tissue sarcomas, germ cell tumors, other malignant epithelial neoplasms and melanomas and other unspecified malignant neoplasms.

*Includes cases where stage at diagnosis was available within the diagnostic groups of lymphomas, neuroblastoma and renal tumors, and the diagnostic subgroup of rhabdomyosarcomas.
financial strain as well as the disruption of normal family and social routines (29, 30). Such difficulties could in turn have a bearing on survival to an extent that might not be evident in geographic studies within other countries. Another issue which is known to influence survival in more remote localities is the higher proportion of indigenous people living in those areas (20). Lower cancer survival rates have been documented for Indigenous adults (31–33). However, we found that the variation in survival by remoteness remained fairly similar when Indigenous children and those with unknown Indigenous status were excluded from the analysis. In particular, a significant differential persisted for

Table 3. Distribution of stage at diagnosis for selected childhood cancersa by remoteness or area disadvantage, Australia, 1996 to 2006b

<table>
<thead>
<tr>
<th>Stages I/II</th>
<th>Stages III/IV</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
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</tbody>
</table>

Remoteesss category
- Major cities: 365 (41.0), 394 (44.3), 131 (14.7), 0.323
- Inner regional: 139 (38.3), 176 (48.5), 48 (13.2)
- Outer regionalc: 101 (44.3), 103 (45.2), 24 (10.5)

Area disadvantage
- Least disadvantaged: 128 (41.7), 127 (41.4), 52 (16.9), 0.273
- Middle SES: 395 (41.2), 442 (46.1), 121 (12.6)
- Most disadvantaged: 82 (38.1), 103 (47.9), 30 (14.0)

aIncludes the diagnostic groups of lymphomas, neuroblastoma and renal tumors, and the diagnostic subgroup of rhabdomyosarcomas.
bIncludes children who were diagnosed between January 1, 1996 and December 31, 2006 and who were *at risk* at some time between January 1, 2001 and December 31, 2006.
cThe remoteness category "remote/very remote" has been combined with "outer regional."

Table 4. Five relative-survival for selected childhood cancersa by stage at diagnosis and remoteness or area disadvantage, Australia, 2001 to 2006

<table>
<thead>
<tr>
<th>Stages I/II</th>
<th>Stages III/IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of <em>at risk</em> casesb</td>
<td>Five-year relative survivalcd (%; 95% CI)</td>
</tr>
</tbody>
</table>

Remoteesss category
- Major cities: 365 cases, 94.5 (90.7–96.8) survival, 394 cases, 71.1 (65.3–76.2) survival
- Inner regional: 139 cases, 97.6 (91.6–99.4) survival, 176 cases, 70.4 (61.3–77.8) survival
- Outer regionalc: 101 cases, 98.2 (89.2–99.8) survival, 103 cases, 71.7 (60.0–80.5) survival

Area disadvantage
- Least disadvantaged: 128 cases, 97.0 (89.0–99.3) survival, 127 cases, 71.2 (60.1–79.7) survival
- Middle SES: 395 cases, 95.3 (92.0–97.3) survival, 442 cases, 70.6 (65.2–75.4) survival
- Most disadvantaged: 82 cases, 97.2 (84.1–99.6) survival, 103 cases, 71.4 (59.8–80.2) survival

aIncludes the diagnostic groups of lymphomas, neuroblastoma and renal tumors, and the diagnostic subgroup of rhabdomyosarcomas.
bIncludes children who were diagnosed between January 1, 1996 and December 31, 2006 and who were "at risk" at some time between January 1, 2001 and December 31, 2006.
cThe remoteness category "remote/very remote" has been combined with "outer regional."
non-Indigenous leukemia patients. This suggests that factors other than Indigenous status contribute to the inequity in outcomes for children diagnosed with leukemia. It also seems unlikely that the remaining differences in survival for inner regional areas could be completely explained by lack of access to diagnostic and treatment services. Additional work is clearly required to identify other possible causes of the poorer outcomes among childhood leukemia patients residing outside major cities.

A small study from Queensland (Australia; ref. 34) that was published in the early 1980s showed an association between social class and survival among children with acute lymphoid leukemia, despite similar treatments being received. Comparing with our results, several more recent papers (mostly from the United Kingdom; refs. 23, 24, 35–37) have reported that only small differences in outcome were observed by SES. Based on these later studies, it seems that access to services and the treatment received are, in general, only minimally influenced by a child’s socioeconomic background, at least within more developed countries. It may also be that survival for children is less affected by some of the health risk behaviors that are more common among adults from disadvantaged areas, such as smoking, high alcohol consumption, poor diet, and physical inactivity (24).

Remoteness and area disadvantage were shown not to have a significant effect on stage at diagnosis for selected childhood cancers in Australia, indicating that these ecological characteristics have little influence on the time to diagnosis. There is still the possibility of variation by remoteness and area disadvantage in the time between diagnosis and treatment, which could have an effect on survival. We plan to investigate this issue when comprehensive time to treatment data become available within the APCR, although the hypothesis does not appear to be supported in other countries. A review conducted by Dang-Tan and colleagues (38) found that some of the key issues associated with longer diagnosis delays for pediatric cancer patients include older age of the child, lower levels of education for the parents, presentation with nonspecific symptoms, type and site of cancer (particularly brain and bone tumors), earlier cancer stage, and first health contact being with a general practitioner. Neither community type (urban versus rural) or population size were significant in a subsequent analysis of patient-and health care service-related delays using Canadian data, and there was also no clear correlation between family income and the interval to initiation of treatment (39). The authors concluded that a better understanding of the factors that influence time to diagnosis and treatment is required to formulate effective policies and programs to ensure optimal outcomes for children with cancer (38, 39).

One of the benefits of this study was the high level of data quality maintained by the APCR combined with complete coverage of children with cancer throughout Australia. Therefore, the survival estimates presented here were not subject to selection bias, as can happen with clinical trials. It would have been preferable to have information available on personal indicators of SES for the parents of children with cancer; however, other authors have suggested that the use of area-based data as a proxy for individual SES may be more meaningful when considering the health of children (40). The relatively small number of cases for some cancers meant that we were unable to calculate separate results for each of the ICCCC-3 diagnostic groups, and also necessitated the aggregation of the remoteness variable into broader categories on occasion, which restricted our ability to detect finer geographic patterns in favor of statistical precision. Finally, there was a limited range of clinical variables that could be used for adjustment of the survival estimates in the multivariate models. It is possible that taking these factors into account may have diminished the relationship we have reported between remoteness of residence and survival (41).

In summary, despite the lower incidence of childhood cancer in remote areas of Australia (42), overall survival from cancer is poorer. For leukemia, the disparities in survival extend to all children living outside major cities. Given the comparatively high rates of survival that are now achievable for most types of childhood cancer, action is required to address inequities that exist for children who do not live in major cities. A priority for future research will be to investigate the potential contribution to these survival differentials made by type and timing of treatment as well as other clinical and area-related characteristics, to guide any recommended changes in the provision of services.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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Differentials in Survival for Childhood Cancer in Australia by Remoteness of Residence and Area Disadvantage

Danny R. Youlden, Peter D. Baade, Patricia C. Valery, et al.


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