INDIGENOUS PATIENT MIGRATION PATTERNS AFTER HOSPITALISATION AND THE POTENTIAL IMPACTS ON MORTALITY ESTIMATES

Yuejen Zhao
Principal Health Economist, Health Gains Planning Branch, Department of Health, Northern Territory, PO Box 40596, Casuarina NT, 0811, Australia.
Centre for Remote Health, Flinders University and Charles Darwin University, Alice Springs NT, 0871, Australia. Email: yuejen.zhao@nt.gov.au

John R Condon
Department of Health, Northern Territory, PO Box 40596, Casuarina NT, 0811, Australia.
Menzies School of Health Research, Casuarina NT, 0810, Australia.

Shu Qin Li
Department of Health, Northern Territory, PO Box 40596, Casuarina NT, 0811, Australia.

Steven Guthridge
Department of Health, Northern Territory, PO Box 40596, Casuarina NT, 0811, Australia.
Centre for Remote Health, Flinders University and Charles Darwin University, Alice Springs NT, 0871, Australia.

Ramakrishna Chondur
Department of Health, Northern Territory, PO Box 40596, Casuarina NT, 0811, Australia.

ABSTRACT: This study analysed interregional migration for Indigenous patients in the Northern Territory, Australia. Individual-level linked hospitalisation data between July 1998 and June 2011 were used to describe the migration patterns and associated factors. Micro-simulations were conducted to assess the impacts on mortality estimates. Indigenous patients were 35% more likely to migrate from remote to urban areas after hospitalisation than in the reverse direction (risk ratio 1.35, 95% confidence interval 1.30–1.41). The likelihood was positively associated with hospitalisations, age and the Central Australia region. Indigenous patients with diabetes, renal disease or chronic obstructive pulmonary disease had higher risks of urban migration. Non-Indigenous patients were included for comparison. The micro-simulations indicated the patient migration may result in a 6% under-estimation of Indigenous mortality in remote and very remote areas and 3% over-estimation of mortality in urban areas. The results are pertinent to a sound understanding of health outcomes across remoteness categories.

KEY WORDS: Hospital services; Health and inequality; Micro-simulation; Migration; Mortality.

1. INTRODUCTION

Migration and health are interrelated (International Organization for Migration, 2005). Health can influence migration decisions and migration may impact on an individual's health. Health status influences migration in complex ways. Good health at younger ages tends to promote migration from remote to regional/urban areas for education, employment and business opportunities. People in poor health at older ages tend to migrate to urban areas seeking better access to health care (Bentham, 1988; Norman *et al.*, 2005). Place of birth versus residence has attracted much attention, and many studies have shown that place of birth is a more important factor than place of residence (Vigotti *et al.*, 1988; Fascioli *et al.*, 1995). The cause-effect relationships between migration and health are also interchangeable. Migration causes ill-health, whereas health status also influences the decisions on migration (Saarela and Finnäs, 2008). Migrants may also differ in mortality and morbidity from non-migrants. Various studies have investigated rural to urban movements and focused on the potential negative impacts of migration on the population. The negative impacts may be due to the stress of the movement as well as the adoption of a less healthy lifestyle (Verheij *et al.*, 1998). Atherly and colleagues (2003) used health-related migration patterns to assess primary care workforce shortages in remote and rural areas and to inform the development of primary care services. Health data

have also been used to estimate general migration statistics (Chappell *et al.*, 2000). Patient migration has been regarded as an important factor in local health services planning and economic development (Wismar *et al*., 2011) and may be associated with a lack of local services, lack of capacity to address regional health care needs, patients' perception of service quality, and medically-induced demand (Hodgkin, 1996). In this study, the term patient migration is used to describe people travelling from one residence to another to access hospital care (Kirch, 2004).

Patient migration may bias comparisons of health status measures (such as mortality rates) between urban, regional and remote areas, if people with serious chronic conditions migrate from regional and remote to urban areas shortly before their death. In Australia, most studies have found that mortality rates are higher in remote and very remote areas than in regional and metropolitan areas (see, for example, Wilkinson *et al*., 2000; Cass *et al.*, 2001; Wakerman, 2008; Begg *et al.*, 2008), while two studies have reported that mortality rates for Indigenous people (Aboriginal and/or Torres Strait Islander) in the Northern Territory (NT) were lower in very remote areas than in other areas (Rowley *et al.*, 2008; Andreasyan and Hoy, 2010). However, patient migration may have affected these results, because people with serious chronic illnesses may have migrated from very remote areas to be closer to hospital and other health and support services in less remote service centres.

Little is known about the impact of patient migration on population-based mortality rates. To the best of our knowledge, there have been no comprehensive studies that have measured Indigenous patient migration patterns and the impact on mortality estimation. This study aims to understand the patterns, underlying factors and consequences of Indigenous patient migration within the NT. We investigate whether Indigenous patients in the NT have migrated from very remote areas to access health services, especially during the last few years prior to death, and if so, the extent of this patient migration and its impact on mortality rates by remoteness category.

One of the obstacles in evaluating patient migration patterns has been a lack of suitable data. In the NT, the five public hospitals have used a single client information system (Caresys, the NT public hospitals' patient administration and clinical information system), with a common unique personal identifier, namely the hospital registration number (HRN), since 1992. A summary of each inpatient episode is recorded in Caresys and stored in the NT hospital morbidity dataset (HMD), in which all inpatient episodes for each person can be linked. Place of residence at

the time of each inpatient episode is also recorded. Indigenous identification is known to be very accurate (Foley *et al.*, 2012). Thirty percent of the NT population are Indigenous, and 56% of the NT Indigenous population live in very remote areas (Australian Bureau of Statistics, 2007). Only a very small proportion of the NT Indigenous population use the one private NT hospital. Hospitalisation is frequent for NT Indigenous people; in 2008-2009 their average annual public hospital admission rate was 1.7 inpatient episodes per person (Australian Institute of Health and Welfare, 2010). The NT HMD is therefore a suitable data source to examine patient migration trends among the NT Indigenous people.

2. METHOD

NT public hospital inpatient episodes for patients discharged between 1 July 1998 and 30 June 2011 were used for the analysis. The HMD included admission date, discharge date, discharge mode (ie. whether died in hospital), usual resident locality, age, sex, Indigenous status, HRN and diagnosis.

Inclusion Criteria

All NT Indigenous and non-Indigenous residents with at least two hospitalisations in the study period were included. Patient mobility was assessed using changes in the Statistical Local Area (SLA) of residence between episodes, considering only intra-Territory regional migration, assuming the Indigenous population was closed to interstate migration. Interstate residents, NT residents who moved interstate, and those transferred to an interstate hospital were excluded.

Patient migration estimates were derived by counting moves, based on changes in residential address between inpatient episodes. Usual residence is recorded at the time of each hospital admission as the address where the patient lives or intends to live for at least three months. Residential addresses were translated in Caresys into locality codes (suburbs within cities and towns, remote communities, cattle stations, mine sites, etc). The individual episode data previously coded to respective year SLAs of the Australian Standard Geographic Classifications were rebased to 2006 SLAs, which contain 96 SLAs for the NT. The HMD contains the locality codes, which were mapped to SLAs for this project using a concordance file developed by the NT Department of Health (DoH). The Accessibility/Remoteness Index of

Australia (ARIA) score was used to determine remoteness. ARIA describes remoteness based on road distance between each locality and service centres of various sizes (Commonwealth Department of Health and Aged Care, 1999). The road distances are converted to a continuous measure, ranging from 0 for least remote to 12 to most remote. For each SLA, the average ARIA score was determined using ARIA values of all localities within the SLA. The average ARIA scores for the SLA were then assigned to each inpatient episode. Discharge mode was used to identify in-hospital deaths.

Measuring Migration

Migration was measured using a net transition model as the difference in ARIA scores of the residential locality between the first inpatient episode and the last episode. Suppose that a patient migrates m times during the study period. The remoteness is changed in ARIA scores: $A_0 \rightarrow A_1 \rightarrow \ldots \rightarrow A_m$, where A_{j-1} and A_j represent the starting and finishing ARIA scores for the jth hospitalisation (j=1, …, m). The net transition is measured by

$$(A_0 - A_1) + (A_1 - A_2) + \ldots + (A_{m-1} - A_m) = A_0 - A_m. \quad (1)$$

The ratio is measured by

$$(A_0 / A_1) \cdot (A_1 / A_2) \cdot \ldots \cdot (A_{m-1} / A_m) = A_0 / A_m. \quad (2)$$

It is clearly seen in equations (1) and (2) that all the ARIA scores are algebraically eliminated except for first (A_0) and last (A_m). The transition was therefore counted just once for each patient using the first and last inpatient episode.

Based on the ARIA, there were three levels of remoteness categories relevant to the NT, which were Outer Regional, Remote and Very Remote. Numerical ARIA scores were used for measuring patient migration (rather than the three remoteness categories). Changes were compared to estimate the likelihood of moving to "less remote" (inflows) with that of moving to "more remote" (outflows). As illustrated in Table 1, the number of inflows is patients moving away from more remote areas towards less remote areas, ie. $N_{21} + N_{31} + N_{32}$; the number of outflows represents patients moving from less to more remote areas, which is $N_{12} + N_{13} + N_{23}$; the number of patients who did not change remoteness category

is $N_{11}+ N_{22}+ N_{33}$. The risk ratio (RR) between inflows and outflows is obtained dividing $N_{21}+ N_{31}+ N_{32}$ by $N_{12}+ N_{13}+ N_{23}$. The percentage of net migration is

$$\frac{\left(N_{21}+N_{31}+N_{32}\right)-\left(N_{12}+N_{13}+N_{23}\right)}{\sum_{i=1}^{3}\sum_{j=1}^{3}N_{ij}}. \quad (3)$$

Table 1. Notational Illustration of Patient Migration in ARIA Categories and Changes between the First and Last Hospitalisations.

ARIA category at first hospitalisation	ARIA category at last hospitalisation		
	Outer regional (Urban)	Remote	Very remote
Outer regional (Urban)	N_{11} (Urban stayers)	N_{12} (Urban to remote movers)	N_{13} (Urban to very remote movers)
Remote	N_{21} (Remote to urban movers)	N_{22} (Remote stayers)	N_{23} (Remote to very remote movers)
Very remote	N_{31} (Very remote to urban movers)	N_{32} (Very remote to remote movers)	N_{33} (Very remote stayers)

Note: ARIA=Accessibility/Remoteness Index of Australia; N_{ij}=number of people (i=1, 2, 3; j=1, 2, 3). Source: the Authors.

Statistical Analysis

Demographic variables included sex, age group and region at first episode. Due to the difference in geographic location and population characteristics, the analysis was also stratified into two regions: the Top End and Central Australia. Health conditions were identified by the Australian refined diagnosis related groups (Australian Department of Health and Aged Care, 1998). Due to repeated hospital admissions, a person was allowed to have more than one condition.

A linear regression model was used for multivariate analysis with the last admission ARIA score as the dependent variable, and the first admission ARIA score and the time (in years) between the first and last admission as independent variables to estimate average ARIA score changes per year.

Multivariate analysis using log-linear regression was performed to assess the association of migration from more to less remote areas with

age group, sex, region and severity measures (such as number of hospitalisations). The log-linear model is a regression model with dependent variable being the frequency of a contingency table and all explanatory factors as independent variables, including age, sex, region, hospitalisation and patient migration in this study. It is commonly used to assess association between two independent variables by setting interaction terms. The RR estimates can be derived from the log-linear model by examining the interaction terms between patient migration and associated variables. Refer to Christensen (1997) for details of log-linear modelling. Forward selection was undertaken for modelling. There was no statistically significant difference between males and females, so a term for sex was not included in the final model. A separate multivariate analysis (using the log-linear model) restricted to only patients who died in hospital was performed to assess the patient migration patterns in the last few years before death.

Straight line distance was derived from MapInfo (Professional 10.5) on the basis of the farthest distance of SLAs using distance calculator (Pitney Bowes Software, 2010). Straight lines were measured to describe distance of patient migration.

Spider Diagrams

Spider diagrams were used to illustrate inflows and outflows of migration separately. In the inflow diagram, a straight line represents migrations from a locality with a higher ARIA score to one with a lower ARIA score, whereas in the outflow diagram, migrations in the opposite direction are illustrated. To simplify the spider diagrams, one line in the spider diagram represents ten patients. Migration lines with less than ten patients were not included. To avoid overlapping, the migration lines are reassigned to different combinations of Collection Districts of the SLAs. Patients with positive $A_0 - A_m$ were regarded as inflows (see panel a in Figure 1) and those with negative $A_0 - A_m$ as outflows (panel b), in comparison with the NT map (panel c).

Impact of Migration on Mortality Rates

The patient migration patterns were then incorporated into a micro-simulation model to evaluate the impacts of patient migration on mortality estimates (Schmertmann and Sawyer, 1996). The micro-simulation model is devised to imitate migration patterns and key

demographic indicators, and to compare different scenarios with and without patient migration. In the micro-simulations, three ARIA categories of very remote, remote and outer regional were considered with distinct mortality patterns, taken from the 2006 NT Indigenous life tables by remoteness (there are no inner regional or major city categories in the NT). Over lifetimes, individuals may switch back and forth between regions via migration, in which the level, age and sex patterns of mobility were determined by the earlier patient migration results. The model assumptions broadly matched the mortality and migration patterns of the NT Indigenous population. The modelling results mirror the implication of interregional patient migration on mortality. The migration bias was assessed by comparing mortality estimates for different scenarios. This was of course a simple representation of reality, but this lead to some interesting insights of the impacts of patient migration on mortality outcomes. The micro-simulation involves the following steps:

(a) Estimate probabilities of death based on current mortality data, conditional on age, sex and region.

(b) Generate individual level population micro-data and applied Bernoulli random numbers to simulate death. The Bernoulli random numbers were generated in MS Excel using RAND() function. A macro and user-defined functions were written in Visual Basic to generate binomial and Poisson random numbers. The attributes of individuals included age, sex, Indigenous status, region, death and migration. The bottom-up approach was applied to micro-simulation.

(c) Validate the micro-simulated data in comparison with current mortality and population data. Mortality rates were calculated for comparison. Run the model multiple times to ensure the micro-simulated data were not biased. Absolute differences in mortality rate between the actual and synthetic data were used for validation.

(d) Use the micro-simulated data as baseline scenario, which is subject to patient migration. The no patient migration scenario was constructed by assuming that the RRs were applicable to the deaths (the numerator of mortality rate) and the population (denominator). The RRs were derived from equation (3).

(e) Compare the no patient migration scenario with the baseline to estimate bias introduced by patient migration.

For a more detailed discussion of micro-simulation method, see O'Donoghue et al. (O'Donoghue *et al.*, 2013).

The study was approved by the Human Research Ethics Committee of the NT DoH and Menzies School of Health Research (HREC-2010-1401).

3. RESULTS

Between July 1998 and June 2011, 46,309 Indigenous NT residents had at least two inpatient episodes (Table 2). This was almost three-quarters (72%) of the total NT Indigenous population (approximately 64,000 in 2006). Approximately 10% of patients moved over a straight line distance of longer than 100 kilometres at least once, among whom 20% made multiple movements ranging from 2 to 36 times. Ten percent of the patients moved to a less remote area after hospitalisation, 7% to a more remote area, and 82% remained in the same remoteness category. Among those who migrated, migration was 35% more likely to be to a less remote area than to a more remote area, with 2.7% net migration.

Indigenous patient migration from more remote to less remote areas increased with increasing age and number of inpatient episodes, and was higher in Central Australia than in the Top End, but was similar for males and females (Table 2). Indigenous patients with diabetes, renal disease, chronic obstructive pulmonary disease (COPD) and injury have a higher RR than those with ischaemic heart disease (IHD), hypertension, or pregnancy. This patient migration pattern was not unique to Indigenous residents, and non-Indigenous residents had a similar but stronger pattern of patient migration with a greater risk differential in males, youth and Central Australia region (Table 3). Pregnancy played a more important role in non-Indigenous patient migration.

Table 2. Remoteness Changes and Risks of Inflow by Demographic and Geographic Variables and Health Category, Indigenous Population, Northern Territory, 1998/9-2010/1.

		Migration (%)					% net
	Persons	Less remote	More remote	RR		(RR 95% CI)	migration
All patients	46,309	10.1	7.5	1.35	**	(1.30, 1.41)	2.7%
Age							
<10	16,338	7.4	6.7	1.10	*	(1.02, 1.20)	0.7%
10-19	7,117	10.3	8.1	1.28	**	(1.15, 1.42)	2.3%
20-39	14,242	12.3	8.6	1.44	**	(1.34, 1.55)	3.8%
>=40	8,612	11.6	6.7	1.72	**	(1.56, 1.91)	4.9%
Sex							
Males	20,201	10.1	7.5	1.35	**	(1.26, 1.44)	2.6%
Females	26,108	10.2	7.5	1.36	**	(1.28, 1.44)	2.7%
Region							
Top End	28,938	9.3	8.5	1.09	**	(1.04, 1.15)	0.8%
Central Australia	17,371	11.6	5.8	1.99	**	(1.85, 2.14)	5.8%
Hospitalisations							
2	10,931	4.6	4.5	1.01		(0.89, 1.14)	0.0%
3-4	13,137	7.8	7.2	1.08		(0.99, 1.18)	0.6%
5-9	12,726	12.1	9.0	1.34	**	(1.24, 1.44)	3.1%
10-19	6,382	15.0	9.4	1.60	**	(1.45, 1.77)	5.6%
>19	3,133	21.8	9.0	2.43	**	(2.13, 2.78)	12.7%
Disease category							
Pregnancy	9,535	10.7	8.6	1.24	**	(1.14, 1.36)	2.1%
Hypertension	196	16.8	12.8	1.32		(0.80, 2.17)	3.5%
IHD	2,699	13.1	8.9	1.48	**	(1.26, 1.73)	4.2%
COPD	3,080	16.1	7.8	2.07	**	(1.78, 2.40)	8.2%
Renal disease	2,325	17.8	8.3	2.14	**	(1.82, 2.52)	9.4%
Diabetes	1,170	20.2	8.9	2.27	**	(1.82, 2.83)	11.0%
Alcohol use	1,525	18.6	10.4	1.79	**	(1.49, 2.16)	8.0%
Injury	317	18.6	8.8	2.11	**	(1.37, 3.25)	9.0%
Cancer	319	11.6	6.3	1.85	*	(1.09, 3.15)	5.0%
Deaths	1,817	16.5	7.2	2.29	**	(1.88, 2.79)	9.2%
Proximity to death							
0-1	574	9.8	3.8	2.55	**	(1.56, 4.15)	5.8%
2-4	501	16.4	7.2	2.28	**	(1.56, 3.33)	8.8%
>4	742	21.8	9.8	2.22	**	(1.71, 2.89)	11.5%

Note: * 0.01<P<0.05; ** P<0.01; CI=confidence interval; COPD = chronic obstructive pulmonary disease; IHD = ischaemic heart disease; RR=risk ratio. Source: the Authors.

Table 3. Remoteness Changes and Risks of Inflow by Demographic and Geographic Variables and Health Category, Non-Indigenous Population, Northern Territory, 1998/9-2010/1.

		Remoteness					% net
	Persons	Less remote	More remote	RR		(RR 95% CI)	migration
All patients	59,010	3.9	2.7	1.44	**	(1.36, 1.54)	1.2%
Age							
<10	10,705	3.2	2.1	1.50	**	(1.27, 1.78)	1.1%
10-19	4,846	4.8	2.3	2.10	**	(1.67, 2.63)	2.5%
20-39	22,148	4.7	3.3	1.43	**	(1.3, 1.57)	1.4%
>=40	21,311	3.3	2.5	1.31	**	(1.17, 1.46)	0.8%
Sex							
Males	26,997	4.2	2.8	1.52	**	(1.39, 1.67)	1.4%
Females	32,013	3.7	2.7	1.38	**	(1.26, 1.5)	1.0%
Region							
Top End	44,229	2.9	3.2	0.93		(0.86, 1)	-0.2%
Central Australia	14,781	6.9	1.4	4.91	**	(4.22, 5.71)	5.5%
Hospitalisations							
2	24,758	2.6	1.8	1.41	**	(1.25, 1.6)	0.8%
3-4	18,948	4.3	2.9	1.48	**	(1.32, 1.65)	1.4%
5-9	10,959	5.5	3.9	1.41	**	(1.24, 1.59)	1.6%
10-19	3,191	6.0	4.1	1.48	**	(1.18, 1.84)	1.9%
>19	1,154	5.5	3.3	1.66	*	(1.11, 2.48)	2.2%
Disease category							
Pregnancy	14,426	4.5	3.1	1.45	**	(1.29, 1.64)	1.4%
Hypertension	95	3.2	5.3	0.60		(0.14, 2.52)	-1.9%
IHD	2,486	4.5	3.3	1.38	*	(1.04, 1.84)	1.2%
COPD	4,822	4.5	3.6	1.25	*	(1.02, 1.53)	0.9%
Renal disease	1,465	3.7	2.5	1.50		(0.98, 2.29)	1.2%
Diabetes	692	4.2	2.5	1.71		(0.93, 3.11)	1.7%
Alcohol use	763	9.2	5.6	1.63	*	(1.12, 2.37)	3.5%
Injury	296	5.1	4.4	1.15		(0.55, 2.42)	0.7%
Cancer	1,136	4.3	2.3	1.88	*	(1.17, 3.04)	2.0%
Deaths	2,256	3.5	2.0	1.74	**	(1.21, 2.51)	1.5%
Proximity to death (years)							
0-1	817	2.7	1.2	2.20	*	(1.03, 4.69)	1.5%
2-4	619	3.1	1.1	2.71	*	(1.13, 6.52)	1.9%
>4	820	4.8	3.5	1.34		(0.83, 2.17)	1.2%

Note: * 0.01<P<0.05; ** P<0.01; CI=confidence interval; COPD = chronic obstructive pulmonary disease; IHD = ischaemic heart disease; RR=risk ratio. Source: the Authors.

The spider diagrams in Figure 1 compare the inflows and outflows of Indigenous patient migrations in the NT maps. By comparing the density of panels (a) and (b), it is apparent that the inflows were generally more frequent than outflows. The inflows were mainly from South East Top End, Luritja-Pintupi, South East Arnhem, Maningrida and Anmatjere, to Darwin, Alice Springs, and Katherine. The outflows were mainly from Darwin, Alice Springs and Katherine. Areas to receive larger outflows were Katherine East, North East Arnhem, Eastern Arrernte-Alyawa, Pitjantjatjara and Port Keats.

The patient migration pattern was further investigated using proximity to death (in years). The movements were more pronounced for Indigenous people close to the end of their lives. The closer the proximity to death, the more likely they migrated to less remote areas (Table 2). Figure 2 shows Indigenous patient migration flows by the proximity to death. It is evident that the transits moving from the upper-left to the lower-right corner were more frequent than those in the opposite direction, suggesting that patient inflows are associated with proximity to death.

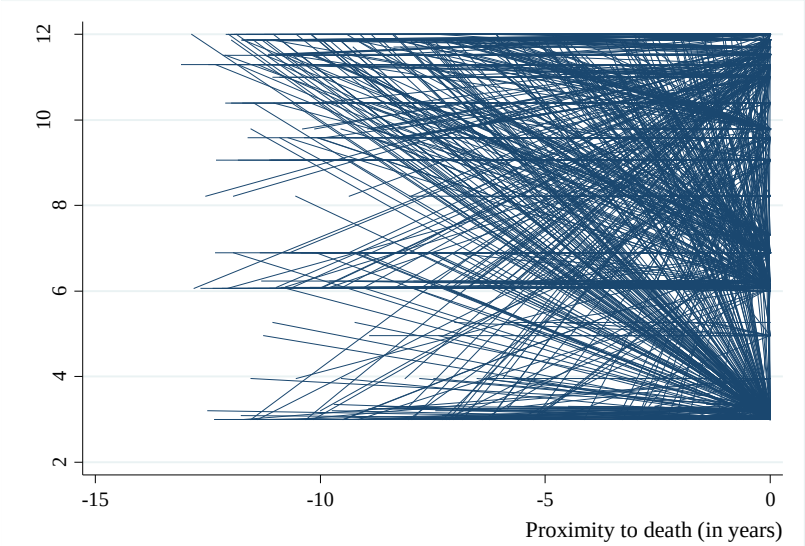
The Indigenous patient migration pattern data were then analysed by multivariate linear and log-linear models to quantify the magnitude of the effect. The linear models suggest that on average, the ARIA score of patient decreased by 0.16 of one ARIA score annually prior to death (Table 4). The log-linear models show that the risk of moving to less remote areas after hospitalisation was mainly driven by the number of hospitalisations, age and Central Australia region ($P<0.01$) (Table 5). Sex was not selected in the final model.

Micro-simulation results suggest the Indigenous patient migration prior to death leads to over-estimation of mortality rate in urban areas by 3%, and under-estimation of mortality in remote and very remote areas by 6%.

Interstate hospital transfer is relatively minor. Of all hospitalisations, 0.8% and 1.6% involved interstate hospital transfer for Indigenous and non-Indigenous NT residents, respectively.

Areas (ARIA score): A=Darwin (3); B=Alice Springs (6); C=Katherine (7); D=North East Arnhem (10); E=Anmatjere (11); F=Katherine East (11); G=Luritja-Pintupi (11); H=Maningrida (11); I=South East Arnhem (11); J=Eastern Arrernte-Alyawa (12); K=Pitjantjatjara (12); L=South East Top End (12); M=Port Keats (12); N=Tanami (12); O=Minjilang (12); P=Ngukurr (12); Tennant Creek (12) Note: ARIA= Accessibility/Remoteness Index of Australia. Source: the Authors.

Figure 1. Spider Diagrams of Inflows (from remote to urban areas) and Outflows (from urban to remote areas) of Patient Migration, Northern Territory, 1998-2011



Note: ARIA=the Accessibility/Remoteness Index for Australia
Source: the Authors.

Figure 2. Remoteness Changes by Proximity to Death for Indigenous Hospital Patients, Northern Territory, 1998-2011

Table 4. Parameters Estimated by Linear Regression Model for Indigenous Patient Migration after Hospitalisation Prior to Death

	Coefficient	Standard error	t-value*	95% confidence interval	
ARIA score of first admission					
4	4.65	0.88	5.30	2.93	6.37
5	3.69	0.81	4.54	2.10	5.28
6	6.22	0.17	36.90	5.89	6.55
7	7.40	1.35	5.47	4.75	10.05
8	7.60	0.45	16.95	6.72	8.47
9	7.82	0.23	33.79	7.36	8.27
10	7.80	0.28	28.35	7.26	8.34
11	9.22	0.15	60.10	8.92	9.52
12	9.69	0.28	34.72	9.14	10.23
Proximity to death					
Years	-0.16	0.02	-8.59	-0.19	-0.12

* All t-values are statistically significant (P<0.01). Source: the Authors.

Table 5. Risk Ratios Estimated by Log-Linear Regression Model for Indigenous Patient Migration

		RR*	95% CI	
Hospitalisations	3-9	1.33	1.16	1.52
	10-19	1.72	1.46	2.02
	20+	2.14	1.78	2.58
Age (years)	10-39	1.31	1.18	1.45
	40+	1.60	1.40	1.82
Region	Central Australia	1.82	1.66	2.00

Note: CI=confidence interval; RR=risk ratio; * All RRs are statistically significant (P<0.01). Source: the Authors.

4. DISCUSSION

Migration is a continuous, dynamic and complex social phenomenon, and an important factor for health planning and service delivery. Selective migration may affect mortality and morbidity estimates (Brimblecombe *et al.*, 2000; Boyle, 2004; Norman *et al.*, 2005), and be the result of the movement of a selective group of either healthy or unhealthy migrants (Kington *et al.*, 1998). A longitudinal case–control study on Indigenous alcohol treatment in the NT indicated that alcohol users who were treated in the program and resumed drinking at the same level were less likely to return to remote communities with alcohol restrictions (Dingwall, 2011). People in very remote areas often relocate to access health, education and other goods and services in urban areas, because there is a lack of these services in their remote communities. In this study, we documented the interregional Indigenous patient migration patterns using the HMD. The hospital Indigenous patients who migrated were 35% more likely to move to less remote areas than to more remote areas. For those who died in hospital, ARIA score decreased by an average of 0.16 of one ARIA score annually prior to death. This health-related migration is broadly in line with one element of the selective migration hypothesis (Bentham, 1988; Norman *et al*., 2005), which is that the unhealthier old people tend to move to urban areas. Unfortunately it is difficult to investigate the other element (that young and healthier population also tend to move to urban areas to access employment and social opportunities) using the HMD because it lacks relevant data.

Patient migration appears to be a component of late-life migration in the Indigenous population. It is linked to morbidity in later-life, rather than retirement, because of the low labour force participation in the Indigenous population (Australian Bureau of Statistics, 2004). However, the need for health care is not the only reason. Other life course events such as housing, employment, education, and better access to other services may all play an important part in population mobility (Cohn *et al.*, 1994). It is also evident that 82% of hospital Indigenous patients and 93% of hospital non-Indigenous patients did not change remoteness category between their first and last inpatient episode. The net effect in general is not overwhelming (2.7% and 1.2% for Indigenous and non-Indigenous patients respectively), but it is notably elevated in Central Australia, and increased with number of hospitalisations. Based on this information, the existing patient migration pattern is unlikely to play a major role in changing service planning. Indigenous patient migration increased with age (Table 2) and non-Indigenous patient migration peaked at ages 10-19 years (Table 3). Overall, the RRs were driven mainly by disease severity (hospitalisations, disease and death) for Indigenous patients and by demographic and geographic variables (age, sex and region) for non-Indigenous patients.

Patient migration may deflate the number of deaths among the long-term population of very remote areas. The masking effect for remote area mortality may lead to confusions in differences of mortality and health outcome between remote and urban Indigenous populations. By data simulations, we can demonstrate how the Indigenous patient migration affects mortality estimates. The effect is to raise mortality rates in less remote areas (by 3%) and lower them in more remote areas (6%). Patient migration can distort the true picture of regional variation in health risk. This result is consistent with international study (Rogerson and Han, 2002), and may partially explain why the Indigenous mortality rate was underestimated in very remote areas (Zhao *et al*, 2009). Based on the micro-simulation and empirical data from this study, illness-related migration may lead to under-estimation of morbidity and mortality in very remote areas and over-estimation in better serviced regional and urban areas.

The analyses by condition support the general argument that those with more protracted and progressive conditions have a greater risk of urban migration. Among the listed health conditions, the extremes were pregnancy, which is a short term event, in which a woman is likely to return to her community, versus diabetes, a progressive condition requiring ongoing management of increasing complexity. Injury and

alcohol use possibly demonstrate reverse causality: the migration may not have been associated with ill health and health care need, but rather indicated migration to urban areas to access and consume alcohol, which increased the risk of alcohol-related disease and injury that in turn lead to more inpatient care.

Several limitations require consideration in interpreting these findings. Firstly, this study assumed a stable NT Indigenous population closed to net interstate migration. In 2006, the net interstate migration of NT Indigenous people was estimated to be close to zero (Australian Bureau of Statistics, 2009). The non-Indigenous patient migration results may be less reliable than the Indigenous results, due to higher levels of interstate migration among non-Indigenous population. Admissions to private hospital and lower hospitalisation rate further limit the utility of non-Indigenous results. Secondly, this study is dependent on the reliability of the HMD. The residential locality data in the HMD have been validated in the national hospital data quality surveys and the data accuracy was assessed to be good (88%) (Foley *et al*., 2012). Thirdly, the net transition model utilised only the first and last ARIA scores as a proxy of change in remoteness. The ARIA scores in between have been ignored. This may be potentially biased. As part of the sensitivity tests, all moves were also analysed to compare with the net transition model. The results were very close, and therefore omitted for brevity. Another alternative method we tested was to calculate regression coefficients at the individual level using all moves and a Stata module "bcoeff" (Wang and Cox, 2000). The results were also broadly consistent with those presented in Section 3. Finally, the causes of patient migration are complex and vary geographically. This analysis shows that severity of disease may offer partial explanation of Indigenous patient migration in the NT. More research is needed for further investigation of this issue. Indigenous people are highly mobile, regardless of whether or not health and hospital services are provided. The extent to which our findings can be generalised to other parts of Australia is unknown, particularly in relation to inner regional and metropolitan areas which could not be included in this study. A future study designed to investigate this issue nationally seems warranted. Although general patterns apply to similar environments, individual situations do need careful consideration. Unpacking the key elements of patient migration is an important tool to understanding population health, and will benefit health care planning and service delivery.

There appears to be a patient movement from more remote to less remote areas after hospital admission in remote Indigenous and non-Indigenous populations. The patient migration pattern is an important factor to consider in interpreting health outcome measures and health planning. More research is needed to further explore why Indigenous patients migrate, and how health and other services can be better managed for health outcome improvement.

REFERENCES

Andreasyan, K. and Hoy, W. E. (2010). Patterns of mortality in Indigenous adults in the Northern Territory, 1998-2003: are people living in more remote areas worse off? *Medical Journal of Australia*, 190, pp. 307-311.

Atherly, A., Kralewski, J., Johnson, C. and Brasure, M. (2003). Developing rural primary health care service areas: an analysis of patient migration patterns. *Health Care Management Review*, 28, pp. 189-197.

Australian Bureau of Statistics (2004). *Australian Social Trends.* ABS: Canberra.

Australian Bureau of Statistics (2007). *Population Distribution, Aboriginal and Torres Strait Islander Australians.* ABS: Canberra.

Australian Bureau of Statistics (2009). *Experimental Estimates and Projections, Aboriginal and Torres Strait Islander Australians.* ABS: Canberra.

Australian Department of Health and Aged Care (1998). *Development of the Australian Refined Diagnosis Related Group (AR-DRG) Classification: Development of AR-DRG classification version 4.1 (includes appendices on computer disk).* Department of Health and Aged Care: Canberra.

Australian Institute of Health and Welfare (2010). *Australian Hospital Statistics 2008–09.* AIHW: Canberra.

Begg, S. J., Vos, T., Barker, B., Stanley, L. and Lopez, A. D. (2008). Burden of disease and injury in Australia in the new millennium: measuring health loss from diseases, injuries and risk factors. *Medical Journal of Australia*, 188, pp. 36-40.

Bentham, G. (1988). Migration and morbidity: implications for geographical studies of disease. *Social Science & Medicine*, 26, pp. 49-54.

Boyle, P. (2004). Population geography: migration and inequalities in mortality and morbidity. *Progress in Human Geography*, 28, pp. 767-776.

Brimblecombe, N., Dorling, D. and Shaw, M. (2000). Migration and geographical inequalities in health in Britain. *Social Science & Medicine*, 50, pp. 861-878.

Cass, A., Cunningham, J., Wang, Z. and Hoy, W. (2001). Regional variation in the incidence of end-stage renal disease in Indigenous Australians. *Medical Journal of Australia*, 175, pp. 24-28.

Chappell, R., Vickers, L. and Evans, H. (2000). The use of patient registers to estimate migration. *Population Trends*, pp. 19-24.

Christensen, R. (1997). *Log-Linear Models and Logistic Regression.* Springer: New York.

Cohn, S. E., Klein, J. D., Mohr, J. E., Van Der Horst, C. M. and Weber, D. J. (1994). The geography of AIDS: patterns of urban and rural migration. *Southern Medical Journal*, 87, pp. 599-606.

Commonwealth Department of Health and Aged Care (1999). *Measuring Remoteness. Accessibility/Remoteness Index of Australia (ARIA).* DOHA: Canberra.

Dingwall, K. M., Maruff, P. and Cairney, S. (2011). Similar profile of cognitive impairment and recovery for Aboriginal Australians in treatment for episodic or chronic alcohol use. *Addiction*, 106, pp. 1419-1426.

Fascioli, S., Capocaccia, R. and Mariotti, S. (1995). Cancer mortality in migrant populations within Italy. *International Journal of Epidemiology*, 24, pp. 8-18.

Foley, M., Zhao, Y. and Condon, J. (2012). *Demographic Data Quality Assessment for Northern Territory Public Hospitals 2011.* Department of Health: Darwin.

Hodgkin, D. (1996). Specialized service offerings and patients' choice of hospital: The case of cardiac catheterization. *Journal of Health Economics*, 15, pp. 305-332.

International Organization for Migration (2005). *Health and Migration: Bridging the Gap.* Migration Policy and Research Programme of the International Organization: Geneva.

Kington, R., Carlisle, D., McCaffrey, D., Myers, H. and Allen, W. (1998). Racial differences in functional status among elderly US migrants from the south. *Social Science & Medicine*, 47, pp. 831-840.

Kirch, W. (2004). *Public Health in Europe: 10 Years European Public Health Association.* Springer: New York.

Norman, P., Boyle, P. and Rees, P. (2005). Selective migration, health and deprivation: a longitudinal analysis. *Social Science & Medicine*, 60, pp. 2755-2771.

O'Donoghue, C., Ballas, D., Clarke, G. P., Hynes, S. and Morrissey, K. (2013). *Spatial Microsimulation for Rural Policy Analysis.* Springer: New York.

Pitney Bowes Software (2010). *MapInfo Professional 10.5 User Guide.* Pitney Bowes Business Insight: New York.

Rogerson, P. A. and Han, D. (2002). The effects of migration on the detection of geographic differences in disease risk. *Social Science & Medicine*, 55, pp. 1817-1828.

Rowley, K. G., O'Dea, K., Anderson, I., McDermott, R., Saraswati, K., Tilmouth, R., Roberts, I., Fitz, J., Wang, Z. and Jenkins, A. (2008). Lower than expected morbidity and mortality for an Australian Aboriginal population: 10-year follow-up in a decentralised community. *Medical Journal of Australia*, 188, pp. 283-286.

Saarela, J. and Finnäs, F. (2008). Internal Migration and Mortality: The Case of Finland. *Environmental Health Insights*, 2, pp. 1.

Schmertmann, C. P. and Sawyer, D. O. (1996). Migration bias in indirect estimates of regional childhood mortality levels. *Mathematical Population Studies*, 6, pp. 69-93.

Verheij, R. A., Van De Mheen, H. D., De Bakker, D. H., Groenewegen, P. P. and Mackenbach, J. P. (1998). Urban-rural variations in health in The Netherlands: does selective migration play a part? *Journal of Epidemiology and Community Health*, 52, pp. 487-493.

Vigotti, M. A., Cislaghi, C., Balzi, D., Giorgi, D., La Vecchia, C., Marchi, M., Decarli, A. and Zanetti, R. (1988). Cancer mortality in migrant populations within Italy. *Tumori*, 74, pp. 107.

Wakerman, J. (2008). Rural and remote public health in Australia: building on our strengths. *Australian Journal of Rural Health*, 16, pp. 52-55.

Wang, Z. and Cox, N. J. (2000). *BCOEFF: Stata Module to Save Regression Coefficients to New Variable*. Chestnut Hill IDEAS. Online version accessed 26 September 2012, http://ideas.repec.org/c/boc/bocode/s412201.html

Wilkinson, D., Hiller, J., Moss, J., Ryan, P. and Worsley, T. (2000). Mortality variation across Australia: descriptive data for States and Territories, and statistical divisions. *Australian and New Zealand Journal of Public Health*, 24, pp. 226-233.

Wismar, M., Palm, W., Figueras, J., Ernst, K. and Ginneken, E. (2011). *Cross-border Health Care in the European Union: Mapping and Analysing Practices and Policies.* European Observatory on Health Systems and Polcies: Brussels.

Zhao, Y., Guthridge, S., Li, S. and Connors, C. (2009). Patterns of mortality in Indigenous adults in the Northern Territory, 1998-2003. *Medical Journal of Australia*, 191, pp. 581-582.