The influence of socioeconomic status on presentation and outcome of acute kidney injury.

Dafydd Phillips[1], Jennifer Holmes MSc[2], Richard Davies[2], John Geen PhD[3/4], John D Williams MD[1], and Aled O Phillips MD[1]

On behalf of the Welsh AKI steering group.

[1] Institute of Nephrology, Cardiff University School of Medicine, Cardiff, U.K.
[2] Welsh Renal Clinical Network, Cwm Taf University Health Board.
[3]Department of Clinical Biochemistry, Cwm Taf University Health Board, Merthyr, U.K.
[4] Faculty of Life Sciences and Education, University of South Wales, U.K.

Corresponding Author;
Professor Aled Phillips
Institute of Nephrology
Cardiff University School of Medicine
University Hospital
Heath Park
Cardiff, CF14 4XN
Tel: +44 2920 748467
E-mail: Phillipsao@cf.ac.uk

Abstract

Aims. Although socioeconomic background is known to impact on the incidence and progression of chronic kidney disease, its influence of on the presentation and outcome for acute kidney injury is not known, and is the subject of this study

Design. The Welsh National electronic AKI reporting system was used to identify all cases of AKI in patients >18yrs of age between March 2015 and November 2017.

Methods: Socioeconomic classification of patients was derived from the Welsh Index Multiple Deprivation score (WIMD). Patients were grouped according to the WIMD score by their postcode, and the ranked data were categorised into percentiles and correlated with incidence, and measures of AKI severity and outcome.

Results. Date was collected on a total of 57 654 patients. Increased deprivation was associated with higher AKI incidence rates, more episodes of AKI per patient and more severe AKI at presentation. In contrast 90-day mortality was highest in the most affluent areas. Mortality in affluent areas was driven by increased patient age. Corrected for age 90-day mortality was higher in areas of increased deprivation.

Conclusions. This study highlights that AKI incidence presentation and outcomes are adversely affected by social deprivation. Further studies are required to understand the extent to which these differences reflect patient related factors or regional differences in provision and access to care.

Introduction

Acute Kidney Injury (AKI) is characterized by a sudden decline in renal function which is associated with increased patient morbidity and mortality (1). In patients surviving an acute episode, AKI is also associated with longer term effect on patient's health as there is an increase in incidence of subsequent Chronic Kidney disease and a higher mortality than in patients who have not experienced AKI (2). The increasing incidence of AKI is well documented. Furthermore, a recent study of AKI in Wales suggest that there is an association between the incidence of AKI and measures of social deprivation. with a higher incidence of AKI in those from socially deprived areas (3).

The relationship between Socioeconomic deprivation and higher mortality and reduced life expectancy in the UK are well established (4). A higher incidence and worse clinical outcomes related to social deprivation have been described for a number of medical conditions including coronary heart disease (5, 6) and the most common forms of cancer (7-10).

In Renal Medicine the relationship between socioeconomic deprivation, severity of chronic kidney disease (CKD) and poor clinical outcomes is well documented (11-16), as are the effects of social deprivation in renal transplantation (17-19). Whilst some aspects of the impact of social deprivation on renal disease have therefore been described, its impact on the incidence and severity of AKI at presentation and outcome following AKI has not been previously reported. This study aims to describe the relationship between social deprivation and the severity of AKI at presentation and clinical measures of outcome.

Methods

Setting

Data was collected from the seven health boards in the National Health Service in wales, representing a population of 3.06 million people. The Medical Record Number (MRN) was used as the patient identifier. This unique reference number is allocated to patients registered in the National Laboratory Information Management System (LIMS) which therefore allows for multiple visits/blood test requests to be linked. The study has been approved under the conditions of 'Service Evaluation Project Registration'.

The Electronic AKI reporting system

The Welsh electronic reporting system generates an AKI alert by comparing a current creatinine value to historic creatinine measurements for the same patient in real time. It defines AKI according to KDGIO increase in creatinine parameters (3). Patients who have an AKI episode but no previous recorded creatinine values will not be alerted by this system.

Data Collection

Data was collected on all individuals over the age of 18 years old for which an AKI alert was generated in any location across Wales between March 2015 and November 2017. Patients receiving renal replacement therapy and patients with a known renal transplant, and AKI alerts generated on the renal tertiary center base ward were excluded from the analysis to avoid spurious labelling of AKI resulting from fluctuations in serum creatinine related to renal replacement therapy as previously described (3). An incident AKI episode was defined as 30 days, and the first AKI alert was defined as the incident alert (i.e., any AKI e-alert for the same patient within 30 days of the incident alert was not considered a new episode).

In addition to measurements of renal function data was collected on patient age, gender, stage of AKI, pre-existing CKD (eGFR calculated by the Chronic Kidney Disease Epidemiology Collaboration eGFR equation (20)) <60ml/min per 1.73 m2 derived from the baseline SCr) and the clinical location at which the alert was generated.

All patients for which the first alert was issued during a hospital admission who also had a normal SCr value generated in a hospital setting within the preceding seven days were defined as Hospital acquired (HA)-AKI. Conversely patients who had an alert in a setting outside of hospital were defined as having Community acquired AKI (CA-AKI). For the CA-AKI when the follow up measurement (first or second measurement) of renal function was in a hospital setting the patient was defined as hospitalised CA-AKI.

Progression of AKI (defined as a peak AKI stage higher that the incident AKI stage or for stage 3 alerts an increase≥50% from the SCr generating the alert), renal function at 90 days and patient mortality at 90 days were collected as measures of clinical course and impact of AKI. Non recovery of renal function was defined as a serum creatinine level at 90 days, which remained above the serum creatinine baseline which remained consistent with a definition of AKI.

The day on which the incident AKI alert was generated was also recorded in order to generate two patient groups: those generating an AKI at the weekend and those generating an alert on a weekday.

Contact with medical services prior to the AKI episode was determined by recent measurement of renal function defined as a measurement of renal function within the preceding 30 days of the incident AKI alert.

Incidence rate was calculated using Mid-2013 Office for National Statistics (ONS) Population Estimates and patient level post code analyses (21). Data on patient mortality were collected from the Welsh Demographic Service (22). Socioeconomic classification of patients was derived from the Welsh Index Multiple Deprivation score (WIMD). This is the Welsh Government's official measure of relative deprivation in which the population of Wales is divided into 1909 geographical units called lower super output areas (LSOAs) each with an average population of 1600 people (23). The WIMD score is constructed from a weighted sum of the deprivation score for each of the following domains: Income (23.5%), Employment (23.5%), Health (14.0%), Education (14.0%), Access to Services (10.0%), Community Safety (5.0%), Physical Environment (5.0%), Housing (5.0%). Patients were grouped according to the WIMD score by their postcode and corresponding LSOA of residence, and the ranked data were categorised into percentiles, with percentile 1 being the most socio-economically deprived and percentile 100 being the least deprived.

Statistical analysis was carried out using SPSS software, version 20 (IBM SPSS, Chicago, I); Pearsons Coefficient was calculated to determine correlation between measures of social deprivation of AKI readouts. Multivariate Cox proportional hazard modeling was used to analyze patient survival. P values <0.05 were considered statistically significant.

Results

Incidence and Demographics.

A total of 57 654 patients triggered and electronic AKI alert between March 2015 and 2017. In total there were incident alerts equating to an average of 1.45 AKI episodes per patient. The incidence of AKI during this time period was 4.1 patients per 1000 population per year. The average age of the patient was 71.05±17.0 yrs. Overall 90-day mortality for the whole cohort was 25.8%. The majority (78.47%) of episodes were classified as AKI stage 1 at presentation, with 14.5% classified as AKI stage 2 and 7.03% classified as AKI stage 3; 30.4% of patients had pre-existing CKD. 49.8% and 38.5% of patients first presented with CA-AKI and HA-AKI respectively. 11.7% patients whilst alerting in an in-patient setting had no results for the previous 7 days, and therefore could not be confidently designated as either CA- or HA-AKI definitions, and excluded from the subgroup analysis.

Relationship between socioeconomic status and presentation.

The relationship between incidence of AKI and patient socioeconomic status is shown in Figure 1. There was a strong negative correlation between ranking by WIMD score and the incidence of AKI (r=-0.805; 95% CI, -0.924 to -0.687; P<0.001). There was also a negative association between the number of AKI episodes per patient and socioeconomic measures (r=-0.301; 95% CI, -0.492 to -0.109; p=0.002; Figure 1D). The negative correlation between ranking by WIMD and AKI incidence also seen in subgroup analysis of CA- (R=-0.759; 95% CI, -0.889 to -0.628; P<0.001) and HA-AKI (R=-0.730; 95% CI, -0.867 to -0.593; P<0.001). Although weekend presentation to hospital has previously been reported to be associated with social deprivation, whilst there was no relationship between the day of diagnosis of AKI and socio-economic measures in the whole cohort (R= 0.116; 95% CI, -0.083 to 0.315; p=n/s: Figure 2A), there was a negative correlation between weekend detection and socioeconomic deprivation in the CA-AKI subgroup (R= -0.266; 95% CI, -0.459 to -0.073; p=0.008; Figure 2B).

Mortality and socioeconomic status.

The relationship between socioeconomic measures and 90-day mortality following AKI is shown in Figure 3. In contrast to the relationship between incidence of socio-economic deprivation, there was a strong positive correlation between ranking by WIMD score and the 90-day mortality with a higher proportion of AKI patients dying within 90 days of presentation in the most socially affluent areas (R= 0.312; 95% CI, 0.122 to 0.503; P=0.002). This positive relationship between mortality and socio-economic measures was seen in both CA-AKI and HA-AKI (Figure 3B and 3C).

Kaplan-Meier survival curves by WIMD quartile are shown in Figure 4, with Quartile 1 representing the most socially deprived and Quartile 4 the most affluent geographical areas. Mean survival was longest in the most deprived WIMD quartile (475.5 days, 95% CI 471.1-479.8) and fell progressively in each WIMD quartile representing increasing affluence (2nd quartile 467.1 days, 95%CI 463.0-471.3, 3rd

quartile 462.9 days, 95% CI 458.5-467.2, 4th quartile 459.3 days, 95% CI 454.4-463.9, Chi^2 31.64, p<0.0001).

AKI severity and socioeconomic status.

Severity of AKI at presentation was determined by the % of patients with AKI stage 2 or 3 at presentation and also by the proportion of patients who progressed to a higher AKI stage following initial diagnosis (Figure 5). There was a weak negative correlation between ranking by WIMD score and the severity at presentation. This was true when assessing severity as either the percentage of patients presenting with AKI stage 3 (R= -0.201; 95% CI, -0.398 to -0.005; P=0.045) or the combined percentage presenting with AKI2 and 3 (R= -0.217; 95% CI, -0.413 to -0.022; p=0.03). This relationship held true for CA-AKI (Figure 5B) but not for HA-AKI (Figure 5C). In contrast severity of disease as assessed by progression of AKI to a higher stage was not significantly related to measures of social deprivation (Figure 5D).

Patient demographics

The relationship between age at presentation of AKI and patient socioeconomic status is shown in Figure 6. There was a strong positive correlation between ranking by WIMD score and the age of patients presenting with AKI (R= 0.876; 95% CI, 0.780 to 0.973; P<0.001: Figure 6A). This strong positive relationship was also seen in both the CA-AKI (R= 0.855; 95% CI, 0.751 to 0.959; P<0.001; Figure 6B) and HA-AKI (R= 0.807; 95% CI, 0.689 to 0.926; P<0.001: Figure 6C).

Cox regression proportional hazard modeling analysis was used to assess corrected patient mortality. For the whole cohort higher hazard of death was associated with older age (HR, 1.037; 95% CI, 1.036-1.38; p<0.001) and a higher WIMD ranking (i.e. less social deprivation) (HR, 1.001;95% CI, 1.001–1.002; p<0.001). Adjusted for age however the HR of death was lower in patients with higher WIMD ranking (adjusted HR, 0.999; 95% CI, 0.998–0.999; p<0.001).

Kaplan-Meier survival curves for patients aged <65 years of age and ≥65 years of age by WIMD quartile are shown in Figure 7, with Quartile 1 representing the most socially deprived and Quartile 4 the most affluent geographical. For the patients aged <65 years there was no effect of social deprivation and mean survival. Mean survival was no different between the highest and lowest WIMD quartiles (WIMD Quartile: 1 577.9 days 95%CI 574.4-585.6, Quartile 4: 579.5 95%CI 575.2-581.8, Chi^2 5.03, p=0.169). For older patients, aged ≥65year at the time of the AKI episode, mean survival was significantly shorter in the most deprived WIMD quartiles (Mean survival; Quartile 1: 419.0 days, 95%CI 413.8-424.2; Quartile 2: 412.3 days, 95%CI 416.3-426.4, Quartile 3: 428.9 days, 95%CI 423.8-434.1, Quartile 4: 426.7 days 95%CI 421.3-432.1, Chi^2 9.05, p=0.029)

Pre-existing CKD was used as a surrogate marker of co-existing co-morbidities (Figure 8A). There was a positive correlation seen between the proportion of AKI patients with pre-existing CKD and WIMD ranking. (R= 0.546; 95% CI, 0.378 to 0.714; P<0.001). A previous measure of renal function in the month prior to presentation of CA-AKI was used as a surrogate marker of recent medical contact again reflecting likely co-existing co-morbidity (Figure 8B). There was also a significant positive association between prior measurement of renal function and WIMD ranking (R= 0.403; 95% CI, 0.222 to 0.591; P<0.001).

Discussion

The striking finding of this study is that despite the incidence of AKI being lower in the more affluent areas, mortality is higher. This excess in mortality is not explained by the severity at presentation as AKI at presentation is more severe in the socially deprived areas and tend to be milder in the more affluent cohort. The data however suggest that excess AKI related mortality in affluent areas is related to the older age of the patients in the affluent areas presenting with AKI.

It is well recognized that we have an ageing population, which reflects the benefit of efforts to improve population health. Despite this, an aging population does bring additional challenges, a key one of which is frailty. Frailty is a distinctive health state related to the ageing process in which multiple body systems gradually lose their in-built reserves. Around 10% of people aged over 65 years have frailty, rising to between a quarter and a half of those aged over 85 years. Our data suggest that the mortality in AKI in affluent areas may provide another measure of frailty in the aging population. Previous data defining the epidemiology of AKI in Wales demonstrated increased higher hazards of death associated with older age (3). The current data reflects this in that the AKI associated mortality in the affluent areas is a reflection of increased life expectancy and an aging population. In order to reduce AKI associated mortality in this patient group, clinicians need to understand the significance of small changes in serum creatinine particularly in an elderly population. Clinicians responding to an electronic AKI alert, should be encouraged to undertake early clinical assessment of acute illness and volume status, prompt review of medications with temporary cessation of nephrotoxic medications where appropriate.

Our **linear regression analysis** also demonstrates that once corrected for age, there is a higher likelihood of death in the areas of social deprivation, most pronounced in the older patient group **as shown in the Kaplan Meier survival data in the older patient group**. **This needs to be quailed by the finding that the effect of age on survival was not liners for each WIMD quartile as survival in the second quartile was shorter that the first and most deprived quartile.** The association between social deprivation and increase mortality is well described. Data from Wales which includes some of the poorer areas in Europe, demonstrate fundamental inequalities between the poorest and wealthiest (24). Men from poorer areas of Wales die 8.8 years earlier and women 7.2 years earlier than their wealthier neighbors. This is associated with a higher incidence of smoking, obesity, poor diet, inactivity and alcohol consumption (25-27). These are risk factors are aetiologically linked to the four diseases that account for 64% of early deaths; cancer, heart disease, stroke and diabetes. As a result, the difference the “healthy life expectancy” within Wales is 18.7 years for men and 18.2 years for women in the least affluent areas. This suggests that socioeconomic deprivation is associated with “premature ageing”. Previous studies based in South Wales have demonstrated that age and pre-existing CKD are the most useful variables which can be used to predict the likelihood of developing

AKI (28). Given the evidence suggesting premature aging in the socially deprived cohort what we consider to be “old” may need to be redefined and it is not simply a question of “years”. In this study correction for age in a linear regression model also demonstrates inequality of outcome. In the socially deprived areas the weight of all “early onset” of chronic conditions such as cardiovascular disease, diabetes and obesity leads to a poorer outcome for AKI in the poorer areas, suggesting that mortality in AKI in socially deprived areas reflects the increased burden of co-morbidity. The burden of co-morbidity and poor outcome has also been described in other aspects of nephrology, with social deprivation being associated with poor outcome in CKD, with higher rates of progression of CKD and also poor outcomes once on dialysis (11-13). Outcome following renal transplantation also follows the same pattern with a higher rate of post-operative complications and poorer outcomes associated with social deprivation (17). This is also consistent with the literature related to cardiovascular disease where it is recognized that socio-economic deprivation is a marker of poor outcome following coronary artery disease. Patients undergoing coronary artery bypass grafting from socially deprived areas tend to be younger, have more risk factors and as a result have a worse outcome postoperatively due to increased risk of complications (5, 6). Most chronic diseases are preventable and adopting four of five “healthy behaviors” such as increasing exercise, reducing smoking and alcohol intake and modification of diet, have been shown to impact on the rates of diabetes vascular disease and cancers (29). The challenge is therefore to educate and support patients to make positive changes to lifestyles to reduce the burden of co-morbidities and improve life expectancy in socially deprived areas.

What else can we do to improve clinical outcomes related to social inequalities? In addition to the impact of co-morbidity, poor medical outcomes associated with social deprivation have been ascribed with inequality of access to specialist services. Specifically access to specialist cardiology services has also been shown to be reduced in the socioeconomically deprived cohort which contributes to poor outcome (30). Access to specialist services have also been demonstrated to influence outcome in nephrology, with patients from socially deprived less likely to receive access transplant waiting lists and be considered for living related a kidney transplantation (18, 19). Recent data generated in Wales suggest that access to medical services also affects AKI outcomes. Almost half of people that present with Community acquired AKI have a measure of renal function in the month prior to the AKI episode demonstrating that they are already known to medical services. This suggest that for some patient AKI may be predictable and potentially be avoided (31). Poor outcome for CA-AKI in primary care has also been associated with lack of early recognition, work which has led to the recommendation that a clinical review and repeat measurement of renal function should be undertaken within 7 days for all patients with an AKI electronic alert in primary care (32). Poor outcome for AKI has also been described for patients in whom AKI is detected at the weekend, and effect related to reduced admission rates and access to hospital in-patient care during weekends (33). Although there is data to support an effect of social deprivation on access to hospital services at the weekend (34, 35), no previous work has described the effect of social deprivation on AKI weekend presentation and outcome. Previous studies suggest that CA-AKI detected on the weekend is associated with a worse outcome (33). In the current study a higher proportion of CA-AKI was detected at the weekend in socially deprived areas, a factor therefore likely to influence mortality following AKI in socially deprived regions.

Although this study is to our knowledge the first national study to define the relationship between measures of social deprivation and AKI, its findings need to be qualified by its limitations. As the e-alert system is IT driven it lacks "intelligence" and therefore there is no clinical context applied. Using an IT based approach precludes inclusion of clinical information, such as patient co-morbidity and linkage to primary care data sets, and lacks the detail of the cause of AKI, the need for RRT, and does not shed light on the cause of death. Similarly, this method of identification of AKI does not allow details on the date and time of admission to hospital, meaning the diagnosis of HA-AKI is dependent on a previous test of renal function requested from an in-patient setting. The study is also limited in that any patient presenting with AKI but without a measurement of renal function in the previous 365 days will not be included. Similarly, the reliance on a definition of AKI based on serial changes in serum creatinine does not take into account urine output based AKI diagnosis which may also lead failure to include all cases of AKI. Despite these limitation, our data suggest that in addition to lifestyle and modification of co-morbidities, the availability and accessibility of resources and services may impact on AKI outcome measures. Careful consideration is therefore needed in order to optimize resource planning to address caseload for clinician to reflect significant difference in workload which reflect the clinical needs of patients in deprived and affluent. It is therefore likely that to improve outcomes there is a need for both social and medical interventions and the needs of patients may be somewhat different in different geographical areas. In order to improve AKI outcomes further research is needed to identify key modifiable targets for intervention which may address patients needs from different socio-economic backgrounds.

Acknowledgments: DP analysed the data and produced the figures and wrote the report. JH and RD collected the data and wrote the report. JDW and JG interpreted the data and wrote the report. AOP set up the program of work, designed the study, interpreted the data and wrote the report. The work was carried out under the auspices of the Welsh AKI steering group which is sponsored by the Welsh Renal Clinical Network and Welsh Government

Disclosures; There are no competing interests

Figure Legends:

Figure 1: The relationship between the incidence of AKI and social deprivations as measured by WIMD percentile. [A] Total AKI incidence rate. [B] Incidence of Community acquired AKI. [C] Incidence of Hospital acquired AKI. [D] Average number of AKI episodes per patient during the study period. WIMD, Welsh Index of Multiple Deprivation, where percentile 1 is the most deprived and percentile 100 is the least deprived.

Figure 2: Correlation of Percentage of total AKI [A] or community acquired AKI [B] generating an electronic AKI alert on a weekend (Saturday and Sunday) and patient socioeconomic status as assessed by WIMD percentile.

Figure 3: Correlation of percentage of patients who died within 90-day of all incident AKI patients [A], incident community acquired AKI patients [B] or incident hospital acquired AKI patients [C]. Community acquired AKI includes a total of 41 731 patients, Hospital acquired AKI includes a total of 32 692 patients.

Figure 4: Kaplan-Meier survival curves for AKI patients stratified by WIMD quartile. Quartile 1 represents the most deprived and quartile 4 the most affluent ranked geographical areas. Data was censored at two years.

Figure 5: Correlation of measures of AKI severity at presentation and socioeconomic status. Severity of AKI as assessed by the percentage presenting with AKI 3 or the combined percentage presenting with AKI stage 2 and 3, of all patients [A], patients with community acquired AKI [B], hospital acquired AKI [C] and social deprivation. Severity of AKI was also determined by the percentage of patients who progressed to a higher AKI stage, defined as a peak AKI stage higher that the incident AKI stage or for stage 3 alerts an increase≥50% from the SCr generating the alert [C].

Figure 6: Correlation of age of all incident patients [A], patients with community acquired AKI [B] and hospital acquired AKI [C] at presentation and socioeconomic status measured by WIMD percentile.

Figure 7: Kaplan-Meier survival curves for for patients aged <65 years (A) of age and ≥65 years of age (B) stratified by WIMD quartile. Quartile 1 represents the most deprived and quartile 4 the most affluent ranked geographical areas. Data was censored at two years.

Figure 8: Correlation between the percentage of AKI patients with pre-existing Chronic Kidney Disease [A] and previous measure of renal function in the month prior to presentation of CA-AKI [B] and WIMD ranking.

References:

1. Lameire N, Van Biesen W, Vanholder R. Acute renal failure. Lancet. 2005;365(9457):417-30.
2. Lafrance JP, Miller DR. Acute kidney injury associates with increased long-term mortality. J Am Soc Nephrol. 2010;21(2):345-52.
3. Holmes J, Rainer T, Geen J, Roberts G, May K, Wilson N, et al. Acute Kidney Injury in the Era of the AKI E-Alert. Clin J Am Soc Nephrol. 2016;11(12):2123-31.
4. Shaw M, Gordon D, Dorling D, Mitchell R, Smith GD. Increasing mortality differentials by residential area level of poverty: Britain 1981-1997. Soc Sci Med. 2000;51(1):151-3.
5. Taylor FC, Ascione R, Rees K, Narayan P, Angelini GD. Socioeconomic deprivation is a predictor of poor postoperative cardiovascular outcomes in patients undergoing coronary artery bypass grafting. Heart. 2003;89(9):1062-6.
6. Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, et al. Neighborhood of residence and incidence of coronary heart disease. N Engl J Med. 2001;345(2):99-106.
7. Hole DJ, McArdle CS. Impact of socioeconomic deprivation on outcome after surgery for colorectal cancer. Br J Surg. 2002;89(5):586-90.
8. Singh GK, Miller BA, Hankey BF, Edwards BK. Persistent area socioeconomic disparities in U.S. incidence of cervical cancer, mortality, stage, and survival, 1975-2000. Cancer. 2004;101(5):1051-7.
9. Schrijvers CT, Mackenbach JP, Lutz JM, Quinn MJ, Coleman MP. Deprivation and survival from breast cancer. Br J Cancer. 1995;72(3):738-43.
10. Schrijvers CT, Mackenbach JP, Lutz JM, Quinn MJ, Coleman MP. Deprivation, stage at diagnosis and cancer survival. Int J Cancer. 1995;63(3):324-9.
11. Caskey FJ, Roderick P, Steenkamp R, Nitsch D, Thomas K, Ansell D, et al. Social deprivation and survival on renal replacement therapy in England and Wales. Kidney Int. 2006;70(12):2134-40.
12. Drey N, Roderick P, Mullee M, Rogerson M. A population-based study of the incidence and outcomes of diagnosed chronic kidney disease. Am J Kidney Dis. 2003;42(4):677-84.
13. Merkin SS, Coresh J, Diez Roux AV, Taylor HA, Powe NR. Area socioeconomic status and progressive CKD: the Atherosclerosis Risk in Communities (ARIC) Study. Am J Kidney Dis. 2005;46(2):203-13.
14. Vart P, Gansevoort RT, Crews DC, Reijneveld SA, Bultmann U. Mediators of the association between low socioeconomic status and chronic kidney disease in the United States. Am J Epidemiol. 2015;181(6):385-96.
15. Vart P, Reijneveld SA, Bultmann U, Gansevoort RT. Added value of screening for CKD among the elderly or persons with low socioeconomic status. Clin J Am Soc Nephrol. 2015;10(4):562-70.
16. Vart P, Gansevoort RT, Joosten MM, Bultmann U, Reijneveld SA. Socioeconomic disparities in chronic kidney disease: a systematic review and meta-analysis. Am J Prev Med. 2015;48(5):580-92.
17. Stephens MR, Evans M, Ilham MA, Marsden A, Asderakis A. The influence of socioeconomic deprivation on outcomes following renal transplantation in the United kingdom. Am J Transplant. 2010;10(7):1605-12.

18. Udayaraj U, Ben-Shlomo Y, Roderick P, Casula A, Dudley C, Collett D, et al. Social deprivation, ethnicity, and uptake of living kidney donor transplantation in the United Kingdom. Transplantation. 2012;93(6):610-6.
19. Udayaraj U, Ben-Shlomo Y, Roderick P, Casula A, Dudley C, Johnson R, et al. Social deprivation, ethnicity, and access to the deceased donor kidney transplant waiting list in England and Wales. Transplantation. 2010;90(3):279-85.
20. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, 3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009;150(9):604-12.
21. Welsh Government; Office for National Statistics. National level population estimates by year, age and UK country 2016 [Available from: https://statswales.gov.wales/Catalogue/Population-and-Migration/Population/Estimates/nationallevelpopulationestimates-by-year-age-ukcountry.
22. NHS Wales Informatics Service. Welsh Demographic Services 2016 [Available from: http://www.wales.nhs.uk/nwis/page/52552
23. Welsh Index of Multiple Deprivation. 2014 [Available from: http://gov.wales/statistics-and-research/welsh-index-multiple-deprivation/?lang=en.
24. Allen J, H. C, Duncan-Jones A, Gartner A, May L, Patterson B. Measuring inequalities in 2016: Trends in mortality and life expectancy in Wales 2016 [Available from: http://www.publichealthwalesobservatory.wales.nhs.uk/measuring-inequalities-2016-files.
25. Diez-Roux AV, Nieto FJ, Caulfield L, Tyroler HA, Watson RL, Szklo M. Neighbourhood differences in diet: the Atherosclerosis Risk in Communities (ARIC) Study. J Epidemiol Community Health. 1999;53(1):55-63.
26. Diez-Roux AV, Nieto FJ, Muntaner C, Tyroler HA, Comstock GW, Shahar E, et al. Neighborhood environments and coronary heart disease: a multilevel analysis. Am J Epidemiol. 1997;146(1):48-63.
27. Duncan C, Jones K, Moon G. Smoking and deprivation: are there neighbourhood effects? Soc Sci Med. 1999;48(4):497-505.
28. Roberts G, Phillips D, McCarthy R, Bolusani H, Mizen P, Hassan M, et al. Acute kidney injury risk assessment at the hospital front door: what is the best measure of risk? Clinical Kidney Journal. 2015;8(6):673-80.
29. Caerphilly Study Research Team. Better than any Pill...and no side effects. The Benefit of a Healthy Lifestyel-an account of 30 years of research in Caerphilly. 2014 [Available from: healthylivingwales.co.uk/documents/Better%20Than%20Any%20Pill.pdf.
30. Ben-Shlomo Y, Chaturvedi N. Assessing equity in access to health care provision in the UK: does where you live affect your chances of getting a coronary artery bypass graft? J Epidemiol Community Health. 1995;49(2):200-4.
31. Holmes J, Geen J, Phillips B, Williams JD, Phillips AO, Welsh AKISG. Community acquired acute kidney injury: findings from a large population cohort. QJM. 2017;110(11):741-6.
32. Holmes J, Allen N, Roberts G, Geen J, Williams JD, Phillips AO, et al. Acute kidney injury electronic alerts in primary care - findings from a large population cohort. QJM. 2017;110(9):577-82.

33. Holmes J, Rainer T, Geen J, Williams JD, Phillips AO. Adding a new dimension to the weekend effect: an analysis of a national data set of electronic AKI alerts. QJM. 2018:249-55.
34. Conway R, Cournane S, Byrne D, O'Riordan D, Silke B. Time patterns in mortality after an emergency medical admission; relationship to weekday or weekend admission. Eur J Intern Med. 2016;36:44-9.
35. Conway R, Cournane S, Byrne D, O'Riordan D, Coveney S, Silke B. The Relationship Between Social Deprivation and a Weekend Emergency Medical Admission. Acute Med. 2016;15(3):124-9.

Figure 1

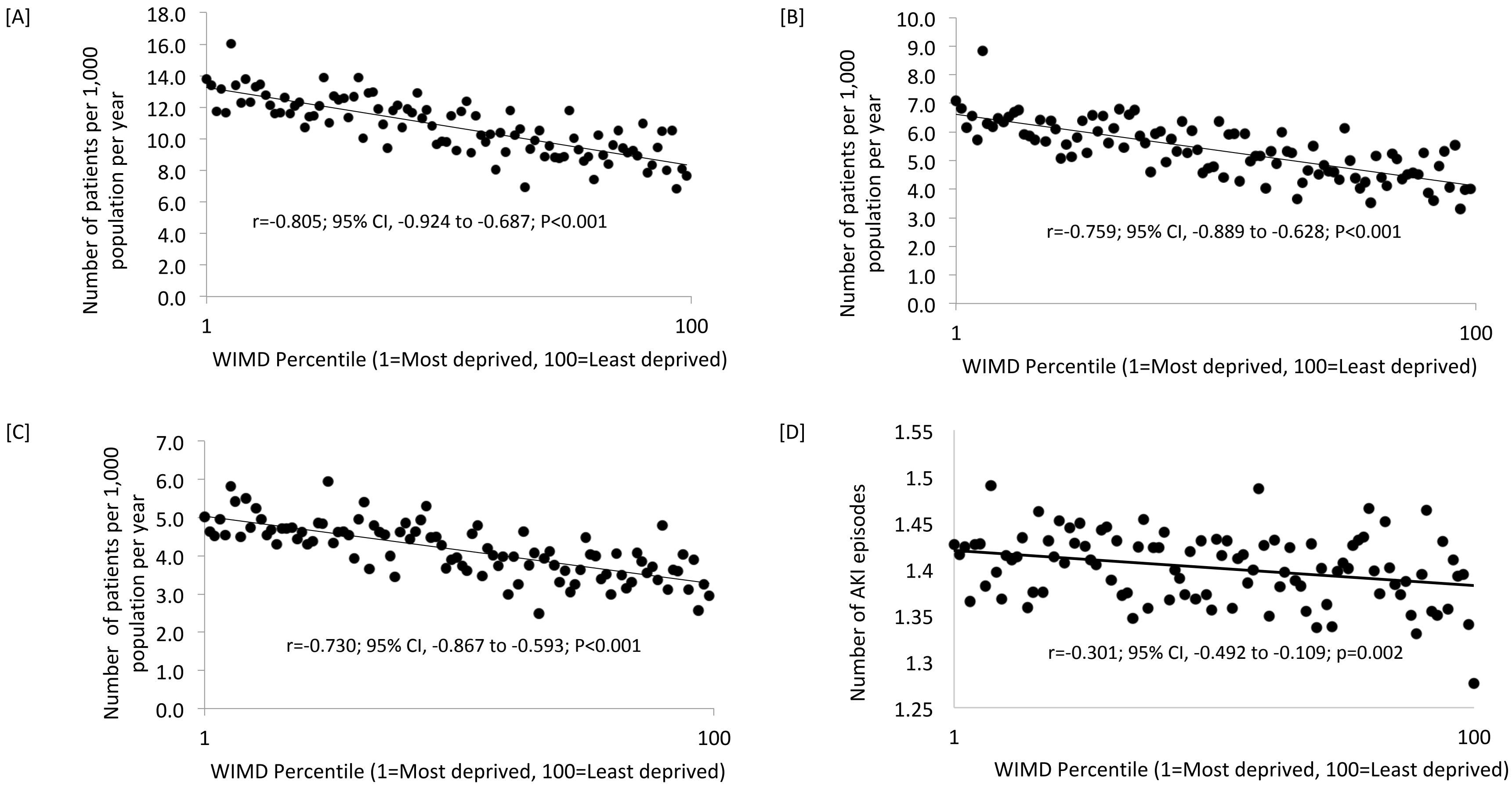
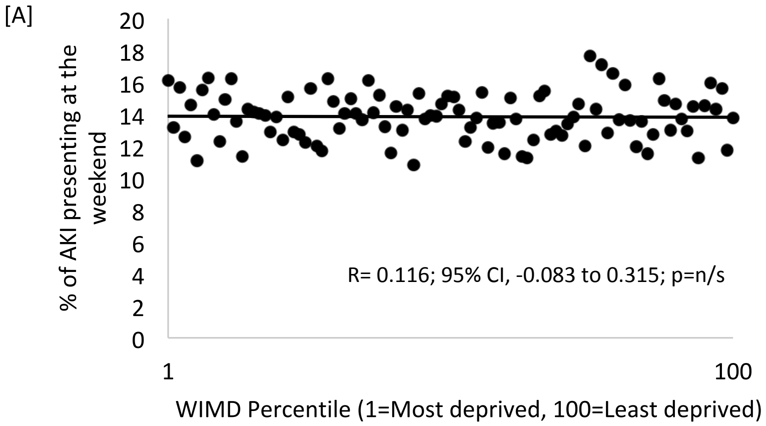

[A]
Number of patients per 1,000 population per year
r=-0.805; 95% CI, -0.924 to -0.687; P<0.001
WIMD Percentile (1=Most deprived, 100=Least deprived)
[B]
Number of patients per 1,000 population per year
r=-0.759; 95% CI, -0.889 to -0.628; P<0.001
WIMD Percentile (1=Most deprived, 100=Least deprived)
[C]
Number of patients per 1,000 population per year
r=-0.730; 95% CI, -0.867 to -0.593; P<0.001
WIMD Percentile (1=Most deprived, 100=Least deprived)
[D]
Number of AKI episodes
r=-0.301; 95% CI, -0.492 to -0.109; p=0.002
WIMD Percentile (1=Most deprived, 100=Least deprived)

Figure 2


[A]
20
18
16
14
12
10
8
6
4
2
0
% of AKI presenting at the weekend
R= 0.116; 95% CI, -0.083 to 0.315; p=n/s
1
100
WIMD Percentile (1=Most deprived, 100=Least deprived)

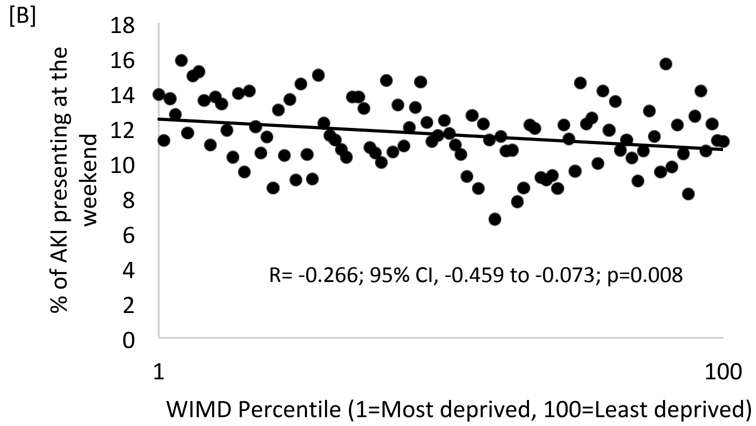

[B]
18
16
14
12
10
8
6
4
2
0
% of AKI presenting at the weekend
R= -0.266; 95% CI, -0.459 to -0.073; p=0.008
1
100
WIMD Percentile (1=Most deprived, 100=Least deprived)

Figure 3

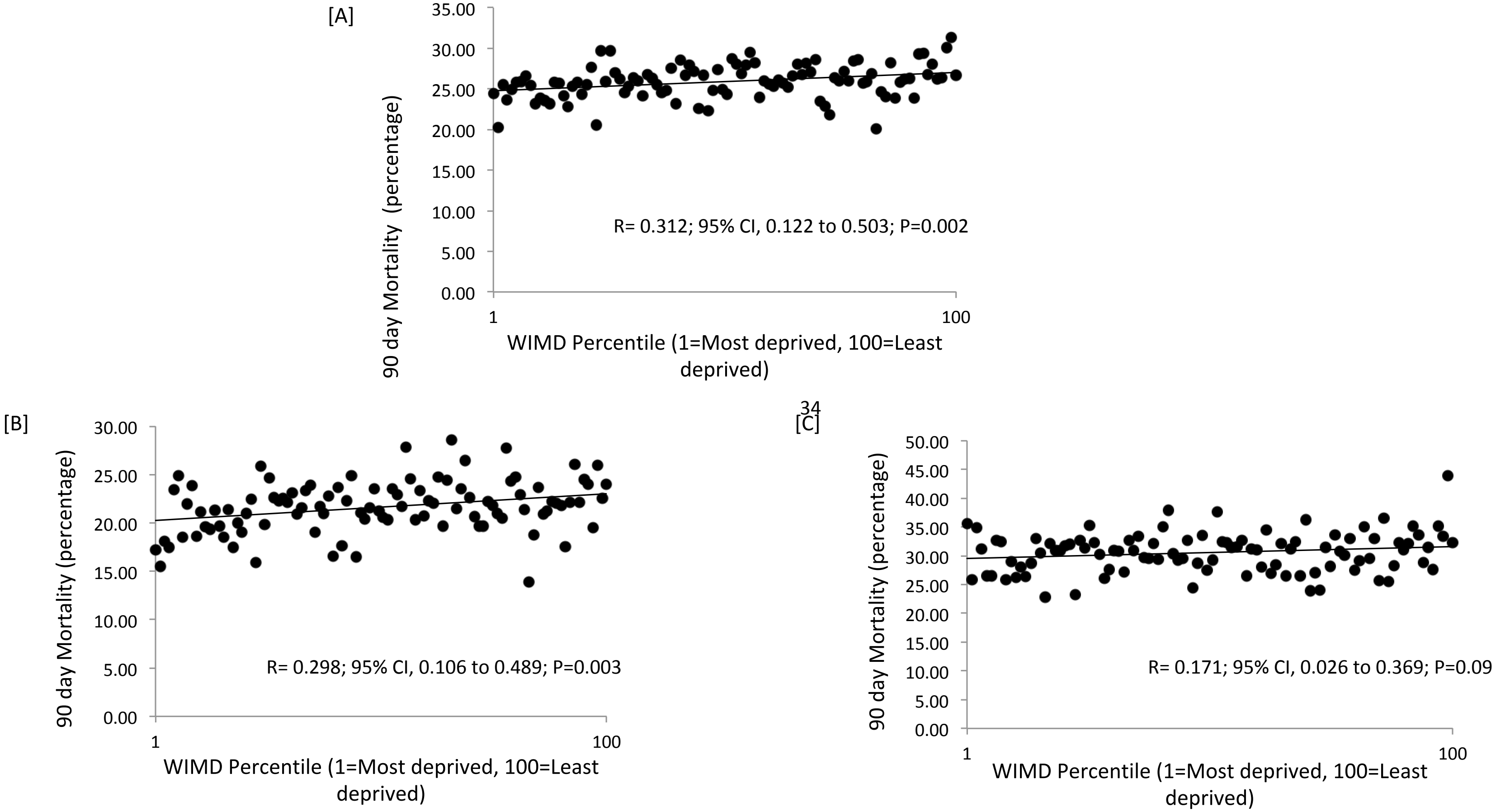

[A]
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
100
90 day Mortality (percentage)
WIMD Percentile (1=Most deprived, 100=Least deprived)
R= 0.312; 95% CI, 0.122 to 0.503; P=0.002
[B]
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
100
90 day Mortality (percentage)
WIMD Percentile (1=Most deprived, 100=Least deprived)
R= 0.298; 95% CI, 0.106 to 0.489; P=0.003
[C]
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
100
90 day Mortality (percentage)
WIMD Percentile (1=Most deprived, 100=Least deprived)
R= 0.171; 95% CI, 0.026 to 0.369; P=0.09

Figure 4

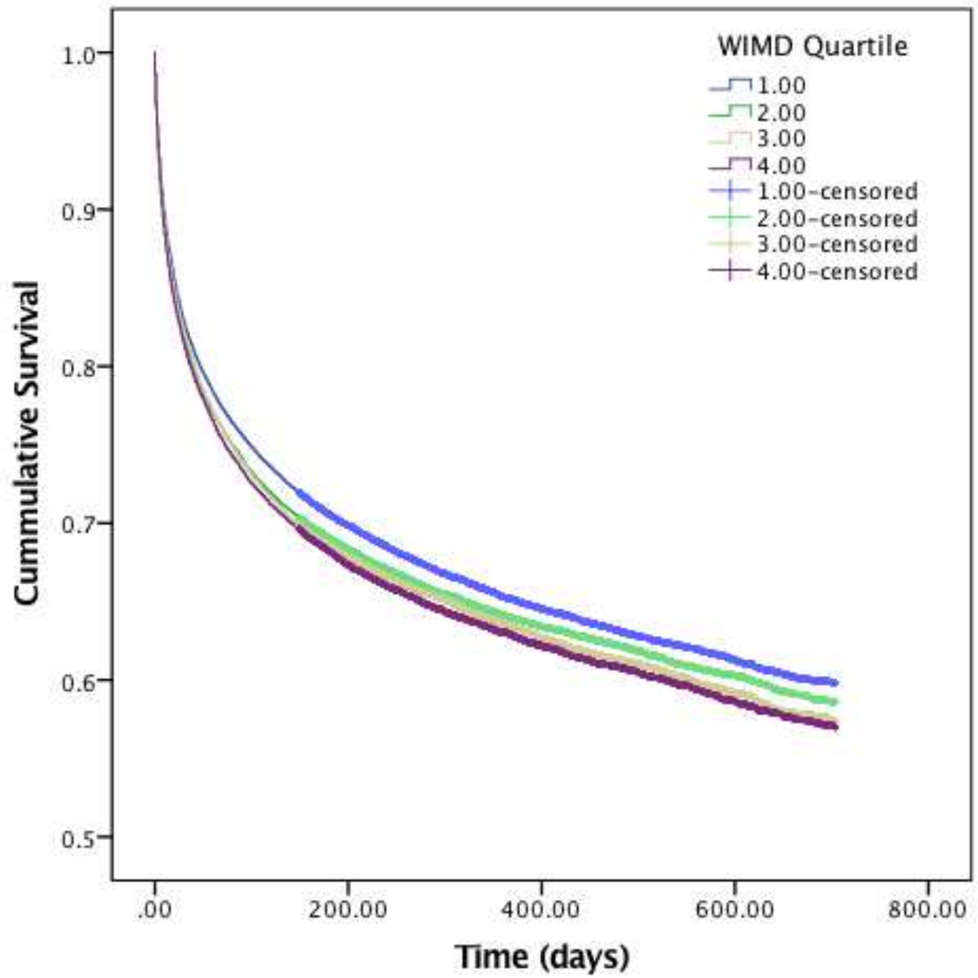
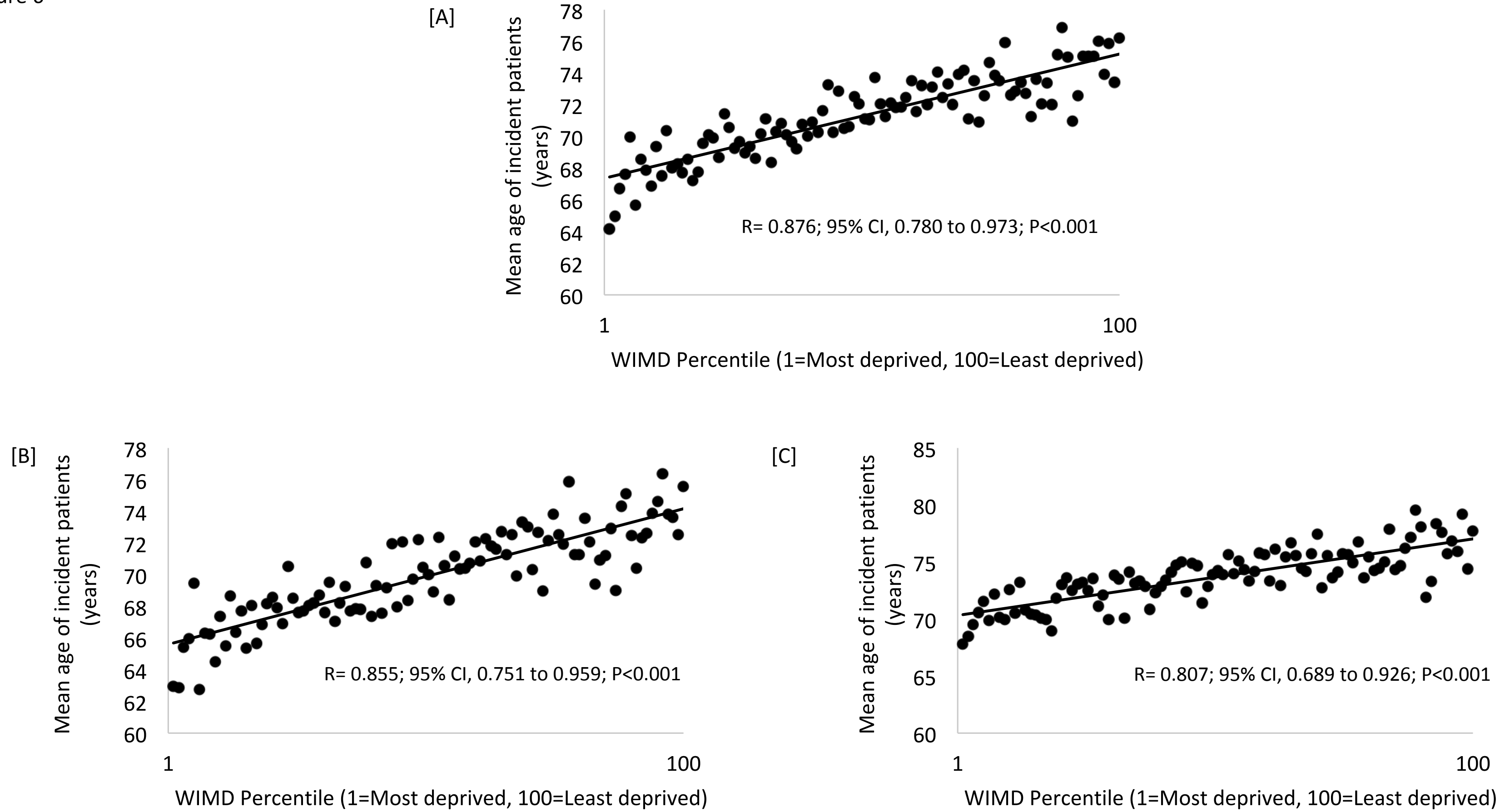

WIMD Quartile
1.00
2.00
3.00
4.00
1.00-censored
2.00-censored
3.00-censored
4.00-censored
1.0
0.9
0.8
0.7
0.6
0.5
Cummulative Survival
.00
200.00
400.00
600.00
800.00
Time (days)

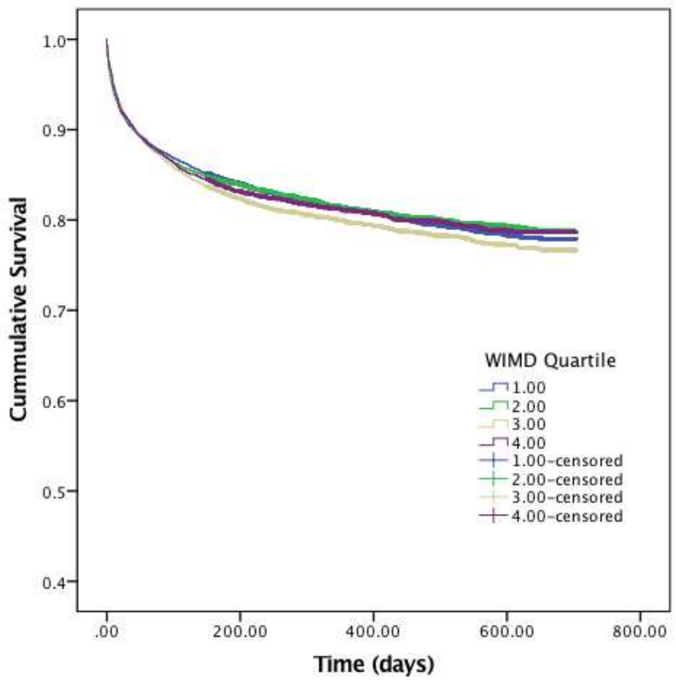
Figure 6



[A]
78
76
74
72
70
68
66
64
62
60
Mean age of incident patients (years)
R= 0.876; 95% CI, 0.780 to 0.973; P<0.001
1
100
WIMD Percentile (1=Most deprived, 100=Least deprived)
[B]
78
76
74
72
70
68
66
64
62
60
Mean age of incident patients (years)
R= 0.855; 95% CI, 0.751 to 0.959; P<0.001
1
100
WIMD Percentile (1=Most deprived, 100=Least deprived)
[C]
85
80
75
70
65
60
Mean age of incident patients (years)
R= 0.807; 95% CI, 0.689 to 0.926; P<0.001
1
100
WIMD Percentile (1=Most deprived, 100=Least deprived)

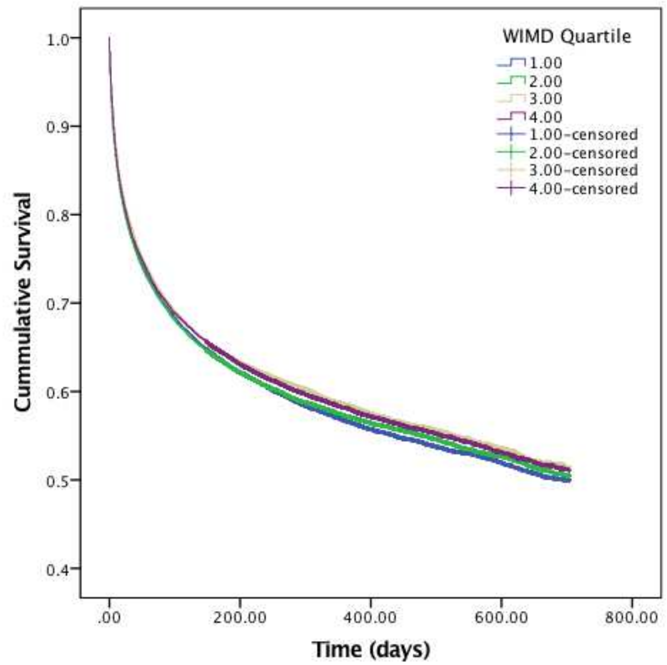
Figure 7

[A]



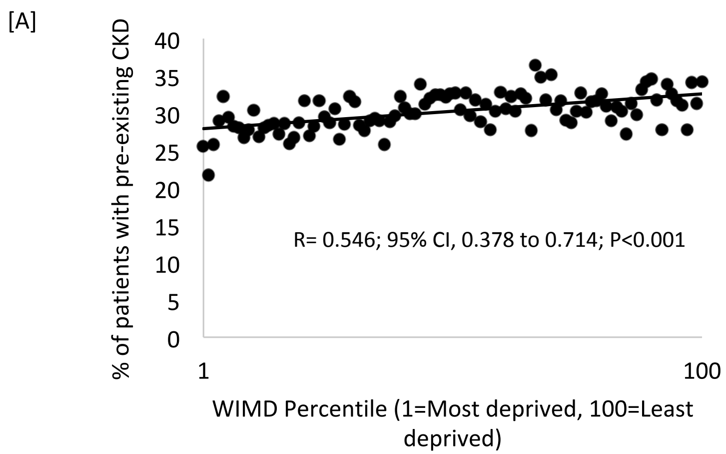
1.0
0.9
0.8
0.7
0.6
0.5
0.4
Cummulative Survival
.00
200.00
400.00
600.00
800.00
Time (days)
WIMD Quartile
1.00
2.00
3.00
4.00
1.00-censored
2.00-censored
3.00-censored
4.00-censored

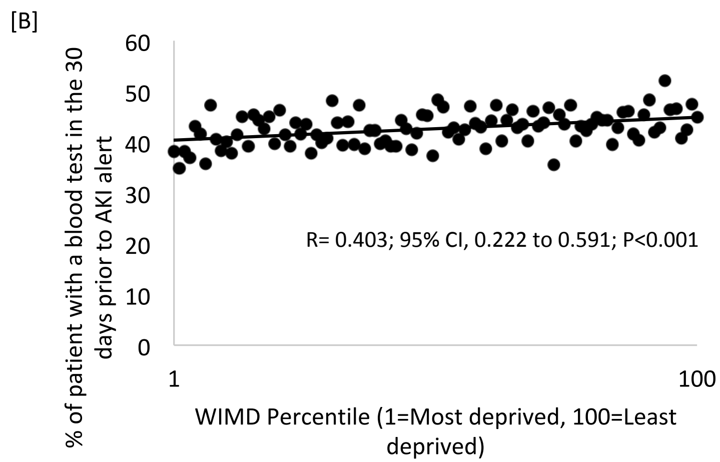
[B]



1.0
0.9
0.8
0.7
0.6
0.5
0.4
Cummulative Survival
.00
200.00
400.00
600.00
800.00
Time (days)
WIMD Quartile
1.00
2.00
3.00
4.00
1.00-censored
2.00-censored
3.00-censored
4.00-censored

Figure 8


[A]
% of patients with pre-existing CKD
40
35
30
25
20
15
10
5
0
1
100
R= 0.546; 95% CI, 0.378 to 0.714; P<0.001
WIMD Percentile (1=Most deprived, 100=Least deprived)


[B]
% of patient with a blood test in the 30 days prior to AKI alert
60
50
40
30
20
10
0
1
100
R= 0.403; 95% CI, 0.222 to 0.591; P<0.001
WIMD Percentile (1=Most deprived, 100=Least deprived)