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Can continuity of primary care decrease emergency hospital admission? A patient level longitudinal analysis among older patients

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Abstract

Purpose

Secondary health care services have been under considerable pressure in England as attendance rates increase, resulting in longer waiting times and demands on staff. This study's aim was to examine the association between continuity of care and risk of emergency hospital admission (EHA).

Methods

Records from 10,000 patients aged 65+ in 2012 within 297 English general practices from the Clinical Practice Research Datalink linked with Hospital Episode Statistics. The Bice-Boxerman (BB) index and the appointed GP (last GP consulted before hospitalisation) index were used to quantify patient-doctor continuity. The BB index was used in a prospective cohort design to test continuity and risk of admission. A separate nested case-control approach used BB and appointed GP index measures to test the effect of changing clinician on odds of a hospital admission in the following 30 days.

Results

Prospective cohort approach: The BB index showed a graded non-significant inverse relationship of continuity of care with risk of EHA; though the hazard ratio for patients experiencing least continuity was 2.27 (95%CI 1.37-3.76) compared with those who had complete continuity. Retrospective nested case-control approach: a graded inverse relationship between continuity of care and EHA was shown for both BB and appointed GP indices: for the latter, the odds ratio for those experiencing least continuity was 2.32 (95%CI 1.48-3.63) compared with those with most continuity.

Conclusions

Marked discontinuity of care might contribute to increased unplanned hospital admissions in patients aged 65+. Schemes to enhance continuity of care have potential to reduce hospital admissions.

Key words: continuity of care, primary care, emergency hospital admission, longitudinal data, family practice

Abbreviations: Clinical Practice Research Datalink (CPRD), lower layer output area (LSOA), Hospital Episode Statistics (HES), Office for National Statistics (ONS), Bice and Boxerman (BB), Index of Multiple Deprivation (IMD)

Introduction

Acute hospital services in England have been under increasing pressure. Evidence suggests that many patients presenting for unscheduled secondary care could be managed in primary care.(1, 2) Therefore, aspects of general practice might be associated with Emergency Department attendance and unplanned hospital admission.

Two systematic reviews have concluded that better provider continuity of care (seeing the same clinician) reduces hospitalization.(3, 4), with similar recent findings from analyses of the Taiwanese Longitudinal health Insurance Database.(5-7)

However, studies investigating the impact of continuity of care using individual UK data for acute presentations are scarce. Salisbury et al. focused on multimorbidity and continuity of care, while Ridd et al. focused on continuity and diagnosis of cancer, but neither included acute care.(8, 9) Barker et al. found an association between higher continuity of care and fewer admissions for ambulatory care sensitive conditions.(10) Other UK based studies have used information from the General Practitioner (GP) patient survey, providing information at the practice level such as the proportion of patients able to consult their preferred GP.(11-15) These ecological studies, however, differ in their findings on the impact of continuity of care on (unplanned) hospital admission.

In the UK patients are registered at one general practice but might see different doctors within the practice. Based on the assumption that the GP regularly seen by the patient knows that patient well we hypothesized that better continuity of care was associated with a lower risk of emergency hospital admission at the individual patient level. We focussed on elderly patients as they are seen more frequently in primary care than younger adult patients(16), and are at greater risk of acute hospital admission.(17)

Methods

Study design and setting

We obtained data from the Clinical Practice Research Datalink (CPRD), which contains current data on 4.4 million anonymised patient records (6.9% of the UK population) and nationally representative in terms of age, sex and ethnicity.(18) A practice-level deprivation score, IMD2010 quintiles, was calculated after practice postcodes were mapped to geographical regions termed lower layer output areas (LSOA) and practices were categorised as conurbation, urban or rural.. Staff roles of the clinician at each consultation is recorded and data are available on each patient's date of

consultations, gender and year of birth.(18). The CPRD can be linked with Hospital Episode Statistics (HES) and Office for National Statistics (ONS) mortality data in England(19), and we investigated patients in CPRD who could be linked by their NHS number to HES data which would show emergency hospital admissions in the financial years 2012-14. We drew a random sample of 10,000 patients over 65 in 2012 within 297 English practices from all patients in the CPRD source population were sampled, stratified by GP practice, and also sampled such that the proportions of patients at each practice in the sample matched the proportions in eligible patients. Previous evidence for the effect of continuity of care(4) consisted of four relevant studies: the only one comprising individual data among older people reported an odds ratio of 0.67 for ambulatory care-sensitive hospitalizations.(20) We had anticipated emergency admission incidence of 125/1000: when dividing patients divided equally into "high continuity" and "low continuity" groupings, an odds ratio of 0.67 would be detectable with 90% power at p=0.05 with only 3,000 patients. Since other evidence(4) suggested this effect size was optimistic, we selected 10,000 patients (the maximum possible with the limited project budget) which allowed 90% power to detect a risk ratio of 0.83 (approximately half the effect size initially estimated).

We tested our hypothesis using two methods: a prospective cohort approach to assess the general impact of continuity of care on emergency admission and a nested case-control approach to test if seeing a different GP from usual increases the risk or odds of emergency admission during the following 30 days.

Prospective cohort approach

The observation period of patients' GP consultation history ran from 1 April 2010 to 30 March 2014, or earlier if transferred out of their current practice, e.g. moved or died (censored observation), or when admitted to hospital between April 2012 and March 2014. Patients were selected if they made at least two GP consultations after March 2012; in total 8248 patients of our sample were included in the prospective cohort analysis. The observation period of those patients' being at risk of an emergency hospital admission started at the date of the second GP consultation following March 2012 and ended on 30 March 2014 or earlier if transferred out (Supplementary Figure 1). In total 1828 of the 8248 patients had an emergency hospital admission within the time period.

Nested case-control approach

We identified patients with an emergency hospital admission between 1 April 2012 and 30 March 2014. Patients were included as a case only if they had at least two GP consultations in the two years prior to hospital admission, of which the last was within 30 days before that admission

(Supplementary Figure 2). A period of 30 days was chosen to capture a time span over which the GP's care might affect the chance of an emergency admission. In total 1215 patients were selected as potential cases. Control patients were defined as not experiencing an emergency hospital admission, were matched to cases on the following characteristics: GP practice, age group, and the last GP consultation was 30 days prior to hospitalisation of the matched case while at least one other consultation was made in the previous two years. We did not limit the number of controls per case. 769 (63.3%) of the cases could be matched, and in total 2123 patients qualified to be controls (Supplementary Figure 3).

Outcome measure

The first emergency hospital admission between April 2012 and March 2014. No distinction was made between admissions by specific routes i.e. admission through the emergency department or admission via direct GP referral to a hospital specialty.

Measures of continuity of care

We measured longitudinal continuity of care (consultations over time with as few doctors as possible).(21) Staff identified as senior partner, partner, or salaried partner were classified as a GP. Labels such as associate and assistant, which might or might not indicate a GP, made up very few consultations (each less than 0.4%), and were excluded. Locum consultations were also excluded as numbers were small (approximately 2%). Consultation locations included clinic, home visits, out of hours' visits, telephone consultations, and third party consultations; multiple consultations occurring the same day for an individual patient were counted as separate consultations.

We used two indices to measure longitudinal continuity of care; one that does and one that does not require an assigned provider.(22)

1. The Bice and Boxerman (BB)(23) index, which does not need an assigned GP provider, known as the Continuity of Care (COC) index. We divided it into six categories; patients with a BB index of 0 (complete absence of continuity of care) and of 1 (complete continuity of care), and four quartiles of those with an index-score between 0 and 1. In a sensitivity analysis, the COC index was divided into tertiles, not separating patients with a BB index of 0 and of 1.(24)

2. The provider identification index(25) (see Supplementary Textbox 1). The assigned provider index score is the percent of visits during the study period to the GP most recently visited before the index event of hospitalization for the cases; the appointed GP index scores were divided into quartiles.

Measures of confounding variables

Our choice was guided by the QAdmissions score(26), previously developed on a similar routine GP database to predict hospital admissions. We included age, gender, number of GP consultations, having had a previous emergency hospital admission in 2010-12, and the following morbidities measured before April 2012, the presence or absence of each of the diagnoses, using published clinical code lists as collected in the Manchester Clinical Codes repository (27): epilepsy(28), chronic renal disease(29), cancer(30), asthma(29), stroke(31), coronary heart disease(31), diabetes(31), COPD(28), depression(32), and schizophrenia(32). Furthermore, we took into account clustering at the practice level (33): we included practice level information including deprivation, location (conurbation/urban/rural), and estimated the number of GPs in a practice using consultations and staff role information.

Statistical methods

In the prospective cohort analysis, we applied mixed-effects Weibull regression to model the relative hazard of the first emergency admission in relation to the level of continuity of care a patient experienced over the period of follow up, adjusting for the clustering due to the different practices where patients were registered. In the nested case-control analysis, we applied conditional logistic regression to obtain odds ratios for having had an emergency hospital admission in relation to the level of continuity of care a patient experienced.

Results

Prospective cohort analysis: Bice and Boxerman index

Figure 1 shows that the distribution of BB index scores varied widely among the 8248 patients in the analysis. 95(1.1%) and 575 (6.9%) patients never/always saw the same GP when visiting the GP practice, resulting in a continuity of care score of 0 and 1 respectively. As these patients consulted a GP less frequently (Supplementary Table 1), we adjusted for the number of GP consultations.

Figure 1 here

Table 1 here

Table 1 shows the results of mixed-effects Weibull regression model for unadjusted and adjusted associations between BB index score and emergency hospital admission. In the unadjusted model, patients with less than perfect continuity of care (BB score<1) experienced a higher incidence of emergency hospital admission. A similar pattern was seen after adjustment though the higher incidence was only statistically significant for those with a COC index score of 0. When examining trend across the six categories (1=highest BB index score, 6=lowest) as a discrete score, the associated hazard ratio per increasing category was 1.042 (95% 0.997-1.090; p=0.068). The practice average continuity of care index was not associated with a patient's risk of having experienced an emergency hospital admission in either the unadjusted or adjusted models.

A sensitivity analysis with BB index divided into tertiles showed no significant association (Supplementary Table 3).

Nested case-control analyses

The Bice and Boxerman index

BB index scores varied widely among 2892 patients in the nested case-control analysis (Supplementary Figure 4). Almost 300 (9.8%) patients always saw the same GP when visiting the practice, resulting in an index score of 1. Again, patients with a BB index score of 0 or 1 consulted a GP less frequently (Supplementary Table 4).

Table 2 here

Table 2 shows the results of the conditional regression model for unadjusted and adjusted associations between BB index score and emergency hospital admission. In the unadjusted model there was an association between less than perfect continuity of care and higher odds of emergency hospital admission. A similar result was seen in the adjusted model, particularly showing a higher odds among those with an index score below 0.4. When regarding the six categories as a discrete score (1= highest BB index, 6=lowest), the associated odds ratio per increasing category was 1.162 (95% 1.067-1.265; p=0.001).

A sensitivity analysis with BB index scores divided into tertiles showed that patients whose index scores were in the lowest and middle tertiles had odds ratios of 1.589 (95% CI 1.212-2.084; p=0.001) and 1.304 (95% CI 1.013-1.678; p=0.039) respectively when compared to patients whose index scores were in the highest tertile (highest continuity), showing a gradient increase of risk of emergency hospital admission (Supplementary Table 6).

The appointed GP index

Figure 2 shows the distribution of the appointed GP index also varied widely among patients included in the nested case-control analysis. Again, almost 300 patients always saw the appointed index GP (prior to admission or at the corresponding time point for controls) when visiting the practice, resulting in an index score of 1. Patients with a low index score (the first quartile), had consulted a GP more often (Table 3). In the analysis we therefore adjusted for a patient's number of GP consultations.

Figure 2 here

Table 3 here

Table 4 shows the results of conditional regression model for unadjusted and adjusted associations between the appointed GP index score and emergency hospital admission. The odds ratios of emergency hospital admission were raised for patients who did not see the appointed GP every time they consulted. This is especially marked for patients who saw the appointed GP fewer than four out of ten times in the adjusted model. When regarding the five categories as a discrete score (1=highest appointed GP index score, 5=lowest), the associated odds ratio per increasing category was 1.626 (95% 1.161-1.372; p<0.001).

Table 4 here

Discussion

Statement of principal findings

Older patients who experienced more discontinuity of care in general practice had a higher risk of an emergency hospital admission. Within the nested case-control approach, both the BB index score and the appointed GP index measure showed patients who had lower continuity of care in general practice had a significant higher odds of an emergency hospital admission. The finding based on using the appointed GP index suggests that the encounter with a GP other than the appointed index GP was associated with increased risk of admission within 30 days. In the prospective cohort approach and using the BB index score, the trend was in the same direction, although only patients with a continuity of care of 0 showed a significant higher risk of an emergency hospital admission.

Strengths and limitations

Within the UK patients are registered at one general practice, but may see different doctors within that practice, and therefore this setting is ideal for studying the impact of continuity of care at individual patient level. This study used longitudinal individual level data of older patients from the CPRD to assess continuity of care and its relationship with incidence of unplanned admission, filling a methodological gap.(34) We constructed two different commonly used types of longitudinal continuity of care measurements for patients who had consulted a GP at least twice: the BB index score and the appointed GP index (in this study taken to be the last GP seen before admission). Both indices showed high frequencies of 0 (worst possible continuity) and 1 (best possible), partly attributable to low numbers of consultations by these patients, so we accordingly defined them as separate categories. We repeated analysis which divided the whole distribution by tertiles (Supplementary Tables 3 and 6), but saw essentially similar trends. By selecting the most recent GP seen before hospitalization within the nested case-control approach, we could have introduced the potential for confounding by indication as seeing a different GP than usual may be indicative of the need for an urgent review due to clinical deterioration rather than being causal. Furthermore, a longer observation-period might have increased the number of patients with sufficient consultations to estimate continuity of care, and might have reduced the number of patients with perfect continuity of care.

However, this database allowed us to apply two study designs: a nested case-control approach and a prospective cohort approach. For this study, the nested case-control approach might be more appropriate for testing the impact of continuity of care on emergency hospitalisation as the last consultation with the GP was within 30 days of hospital admission. Furthermore, within the nested case-control we matched for both individual factors, including age and last time-period of last GP visit, and system-level factors (as we matched on GP practice), thus controlling for GP staff

composition, deprivation level, and alternative service availability such as out-of-hours. By controlling for system-level factors, we eliminated the effect of local alternative primary care facilities.

Comparison with existing literature

Most previous UK studies have been ecological in nature, involving aggregated data at practice level (11-15), meaning that associations cannot necessarily be applied to individual patients. Barker's study was one of the first in the UK to link continuity of care and number of hospital admissions using individual-level data.(10) This study used individual-level longitudinal data, allowing a stronger basis for inferring a causal relationship between continuity of care and first emergency hospital admission between April 2012 and March 2014. Other recent individual-based studies investigating the relation between continuity of care and hospitalization are from Taiwan[5-7] which showed similar findings although the health care system in Taiwan is not completely comparable: Taiwan implemented a compulsory health insurance in 1995 and has a health care system with less focus on gatekeeper role of GPs.(35) These studies used similar measures of continuity of care to the present study but excluded patients with only a few GP consultations, which could introduce bias and two studies focused on diabetes patients alone. Furthermore, the outcomes in those studies included emergency department visits, avoidable hospitalization and hospital admission in general. Those differences might limit comparability of the findings, though it shows the value of our work for the UK and considerations for future research.

Implications for general practices and future research

We have assumed that avoiding hospitalisation is beneficial, consistent with results from the Dutch cohort study.(36) As this study shows, patients who experienced marked discontinuity of care had an increased risk of emergency hospital admission. This finding might be highly relevant for policymakers because of increasing elderly populations.(37) Discontinuity of care reduces the opportunity for building trust and mutual responsibility between patients and doctors which might underly the increased risk of emergency hospital admission.(37) Therefore, more qualitative and quantitative research is needed to understand the relationship between continuity of care and reasons for admission, and to understand patients' values and experiences of continuity of care.(38) Distinguishing between GP referred emergency hospital admissions and admissions through an ED requires a larger data set. Qualitative research might help us understand how, when and why

continuity of care influences health care use, such as consultation skills of the GP, doctor knowledge of patients, a patient's trust in the doctor and his/her abilities, and the patient's feelings of loyalty towards the doctor.(39-41) The introduction in 2014 of a 'named GP' who is responsible for their health care for each patient 75 and over offers the opportunity to investigate whether this intervention indeed resulted in better longitudinal continuity of care and in reduced hospital admission.(42)

Conflicts of interests

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TABLES & FIGURES

Table 1: Estimates of hazard ratios from mixed-effects Weibull regression for the association between continuity of care (Bice and Boxerman index) and emergency hospital admission in a prospective cohort approach, patients aged 65 or older (N=8248).

	N	Unadjusted			Adjusted*		
		Hazard ratio	*95% CI*	*P-value*	*Hazard ratio*	*95% CI*	*P-value*
Continuity of Care (BB index)							
COC is 0	95	1.589	0.970, 2.604	0.066	2.272	1.371, 3.764	0.001
Q1 COC>0 & <0.247	1892	1.188	0.953, 1.482	0.126	1.123	0.882, 1.431	0.346
Q2 COC>=0.247 & <0.383	1891	1.091	0.875, 1.358	0.441	1.050	0.830, 1.329	0.685
Q3 COC>=0.383 & <0.567	1901	1.101	0.885, 1.369	0.390	1.053	0.837, 1.323	0.661
Q4 COC>=0.567 & <1	1894	1.031	0.829, 1.281	0.784	0.963	0.768, 1.206	0.741
COC is 1 (ref.)	575						
Practice average COC (BB index)							
Q1 COC<0.336	2085	1.083	0.915, 1.282	0.352	0.968	0.809, 1.158	0.702
Q2 COC>0.366 & <0.436	2017	0.916	0.771, 1.089	0.321	0.853	0.718, 1.014	0.072
Q3 COC >0.436 & <0.535	2068	0.871	0.735, 1.031	0.110	0.878	0.744, 1.037	0.122
Q4 COC>0.535 (ref.)	2078						

BB= Bice and Boxerman index, CI=confidence interval, COC=continuity of care, ref.=reference category.

*Adjusted for age, gender, number of GP consultations, having had a previous emergency hospital admission in 2010-12, deprivation level, GP practice location (urban/rural), number of GPs in a practice, and the following morbidities: diabetes, COPD, asthma, epilepsy, cancer, stroke, coronary heart disease, chronic renal disease, depression and schizophrenia. See supplementary Table 2 for the complete table.

Table 2: Estimates of odds ratios from a conditional (fixed-effects) logistic regression for the association between continuity of care (Bice and Boxerman index) and emergency hospital admission in a nested case-control approach, patients aged 65 or older (N=2892).

	N		Unadjusted			Adjusted*		
	Cases	*Contr.*	*Odds ratio*	*95% CI*	*P-value*	*Odds ratio*	*95% CI*	*P-value*
Continuity of Care (BB index)								
COC is 0	14	60	1.525	0.752; 3.094	0.242	2.148	1.009, 4.572	0.047
Q1 COC>0 & <0.257	188	446	2.674	1.762; 4.059	0.000	1.832	1.157, 2.901	0.010
Q2 COC>=0.257 & <0.395	171	437	2.137	1.422; 3.212	0.000	1.569	1.002, 2.427	0.049
Q3 COC>=0.395 & <0.576	176	486	1.989	1.331; 2.973	0.001	1.370	0.881, 2.130	0.162
Q4 COC>=0.576 & <1	171	459	1.935	1.307; 2.866	0.001	1.170	0.758, 1.807	0.479
COC is 1 (ref.)	49	235						

COC=continuity of care; BB= Bice and Boxerman index, Q=quartile

*Adjusted for: gender, number of GP consultations, previous hospital admission, and morbidities. See supplementary Table 5 for the complete table.

Table 3: Cross tabulation of a patient's appointed GP index score and the number of GP consultations of 2892 patients in the nested case-control analysis.

	Number of GP consultations (%)				
Continuity of Care	2-7	8-12	13-19	20+	Total
Q1 (0.01 - <0.18)	77 (12.1)	157 (24.7)	167 (26.3)	234 (36.9)	635 (100.0)
Q2 (0.18 - <0.4)	188 (28.1)	174 (26.0)	150 (22.4)	157 (24.5)	669 (100.0)
Q3 (0.4 - <0.71)	175 (27.1)	153 (23.7)	159 (24.7)	158 (24.5)	645 (100.0)
Q4 (>0.71 - <1)	96 (14.6)	170 (25.8)	168 (25.5)	225 (34.1)	659 (100.0)
GP index score=1	151 (53.7)	61 (21.5)	51 (18.0)	21 (7.4)	284 (100.0)
Total	687 (23.8)	715 (24.7)	695 (24.0)	795 (27.5)	2892 (100.0)

COC=continuity of care, Q=quartile

Table 4: Estimates of odds ratios from a conditional (fixed-effects) logistic regression for the association between continuity of care (appointed GP index score) and emergency hospital admission in a nested-case approach, patients aged 65 or older (N=2892).

	N		**Unadjusted**			**Adjusted***		
	Cases	*Controls*	*Odds Ratio*	*95% CI*	*P-value*	*Odds Ratio*	*95% CI*	*P-value*
Index GP								
Q1 (0.01 - <0.18)	232	403	3.591	2.393; 5.387	<0.001	2.318	1.481; 3.627	<0.001
Q2 (0.18 - <0.4)	177	492	2.096	1.391; 3.157	<0.001	1.614	1.033; 2.522	0.036
Q3 (0.4 - <0.71)	160	485	1.932	1.288; 2.898	0.001	1.496	0.963; 2.325	0.073
Q4 (>0.71 - <1)	151	508	1.585	1.066; 2.359	0.023	1.031	0.666; 1.596	0.890
GP index score=1 (ref.)	49	235						

Q=quartile.

*Adjusted for: gender, number of GP consultations, previous hospital admission, and morbidities. See supplementary Table 7 for the complete table.

Figure 1: Distribution of Bice and Boxerman's quantitative measure of continuity of care of 8248 patients in the prospective cohort analysis.

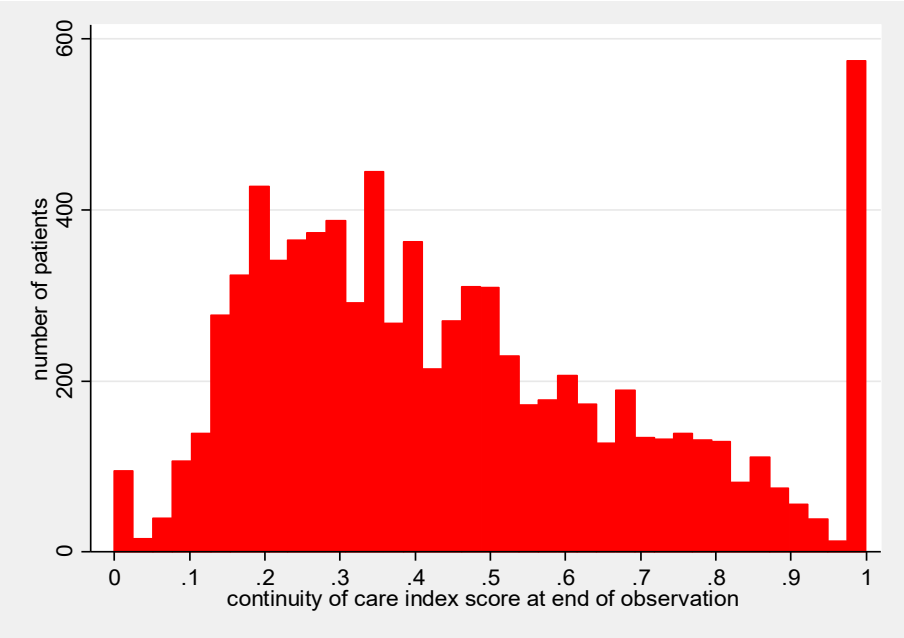
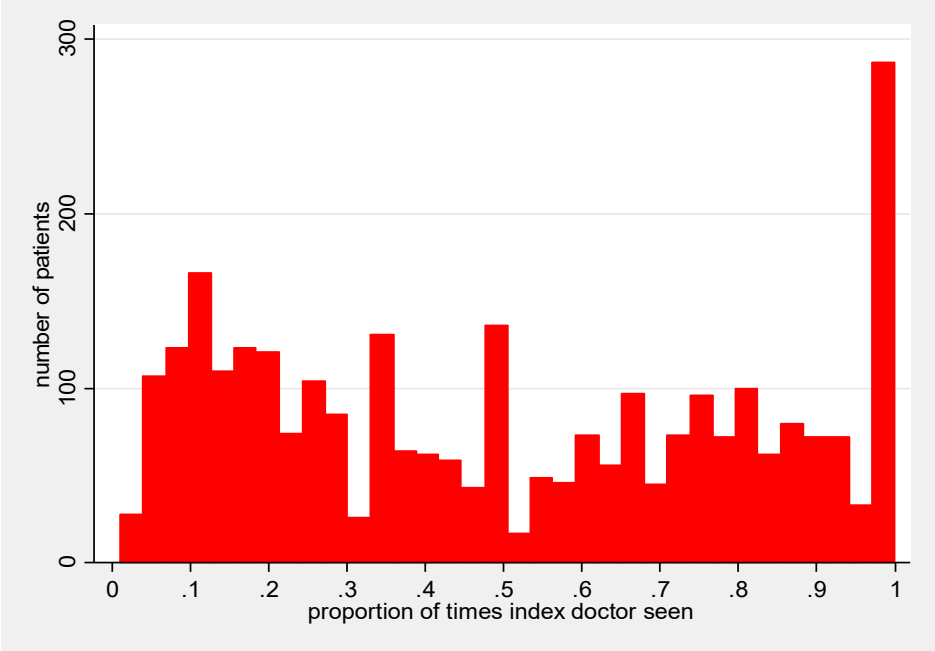


Figure 2: Distribution of appointed GP index among 2892 patients in the nested case-control analysis.



APPENDIX

Supplementary Table 1: Cross tabulation of Bice and Boxerman (BB) score and the number of GP consultations of 8248 patients in the prospective cohort analysis.

	Number of GP consultations (%)				
Continuity of Care (BB index)	2-9	10-16	17-26	27+	Total
COC = 0	95 (100.0)	0	0	0	95 (100.0)
Q1 COC>0 & <0.247	458 (24.2)	490 (25.9)	487 (25.7)	457 (24.2)	1892 (100.0)
Q2 COC>=0.247 & <0.383	397 (21.0)	444 (23.5)	471 (24.9)	579 (30.6)	1891 (100.0)
Q3 COC>=0.383 & <0.567	367 (19.3)	511 (26.9)	487 (25.6)	536 (28.2)	1901 (100.0)
Q4 COC>=0.567 & <1	257 (13.6)	500 (26.4)	547 (28.9)	590 (31.2)	1894 (100.0)
COC = 1	305 (53.0)	155 (27.0)	81 (14.1)	34 (5.9)	575 (100.0)
Total	1879 (22.8)	2100 (25.5)	2073 (25.1)	2196 (26.6)	8248 (100.0)

COC=continuity of care, BB= Bice and Boxerman index, Q=quartile

Supplementary Table 2: Estimates of hazard ratios from mixed-effects Weibull regression for the association between continuity of care (Bice and Boxerman index) and emergency hospital admission in a prospective cohort approach, patients aged 65 or older (N=8248)

	N	Hazard ratio	95% CI	P-value
Continuity of Care (BB index)				
COC is 0	95	2.272	1.371, 3.764	0.001
Q1 COC>0 & <0.247	1892	1.123	0.882, 1.431	0.346
Q2 COC>=0.247 & <0.383	1891	1.050	0.830, 1.329	0.685
Q3 COC>=0.383 & <0.567	1901	1.053	0.837, 1.323	0.661
Q4 COC>=0.567 & <1	1894	0.963	0.768, 1.206	0.741
COC is 1 (ref.)	575			
Gender				
Male (ref.)	3560			
Female	4688	0.901	0.819, 0.992	0.034
Age				
85+	1225	3.515	3.106, 3.978	<0.001
75-84	2651	1.897	1.696, 2.123	<0.001
65-74 (ref.)	4372			
Deprivation (IMD)				
Q1 – least deprived (ref.)	1455			
Q2	2055	1.057	0.888, 1.257	0.533
Q3	1823	1.085	0.911, 1.292	0.359
Q4	1435	1.298	1.078, 1.562	0.006
Q5 – most deprived	1480	1.169	0.973, 1.403	0.095
Location				
Cities & towns	4579	1.029	0.913, 1.161	0.635
Rural	1104	0.824	0.681, 0.999	0.048
Urban conurbation (ref.)	2565			
Hospital admission in 2010-12				
No (ref.)	6675			
Yes	1573	2.379	2.145, 2.639	<0.001
Number of consultations				
Q1 2-9 (ref.)	1879			
Q2 10-16	2100	0.836	0.714, 0.980	0.027
Q3 17-26	2073	0.857	0.734, 1.001	0.052
Q4 >26	2196	0.689	0.588, 0.809	<0.001
Number of GPs in practice				
Q1 <4 GPs (ref.)	882			
Q2 4-6 GPs	2213	0.944	0.776, 1.151	0.573
Q3 7-8 GPs	2263	0.927	0.758, 1.133	0.458
Q4 9+ GPs	2890	0.927	0.756, 1.136	0.465
Practice average COC (BB index)				
Q1 COC<0.336	2085	0.968	0.809, 1.158	0.702
Q2 COC>0.366 & <0.436	2017	0.853	0.718, 1.014	0.072
Q3 COC >0.436 & <0.535	2068	0.878	0.744, 1.037	0.122
Q4 COC>0.535 (ref.)	2078			
Morbidities				
Epilepsy	132	1.615	1.193, 2.189	0.002
Chronic renal disease	133	2.220	1.736, 2.838	<0.001
Cancer	864	1.124	0.976, 1.295	0.104
Asthma	887	1.157	1.004, 1.334	0.044
Stroke	671	1.103	0.955, 1.273	0.184
Coronary heart disease	1114	1.392	1.239, 1.564	<0.001
Diabetes	1001	1.242	1.092, 1.412	0.001
COPD	398	1.583	1.335, 1.878	<0.001
Schizophrenia	67	1.717	1.163, 2.535	0.007
Depression	1629	1.196	1.067, 1.340	0.002
Constant		0.001	0.001, 0.002	<0.001
/Ln_p		-0.302	-0.344, -0.259	<0.001
Practice-level var(constant)		0.031	0.012, 0.086	

BB= Bice and Boxerman, CI=confidence interval, COC=continuity of care, ref.=reference category

Supplementary Table 3: Estimates of hazard ratios from mixed-effects Weibull regression for the association between continuity of care (Bice and Boxerman index, tertiles) and emergency hospital admission in a prospective cohort approach, patients aged 65 or older (N=8248)

	N	Hazard ratio	95% CI	P-value
Continuity of Care (BB index, tertiles)				
T1: COC >=0 & <0.3003	2796	1.121	0.980, 1.280	0.095
T2: COC >=0.3003 & <0.5312	2703	1.076	0.953, 1.214	0.236
T3: COC>=0.5312 & =<1 (ref.)	2749			
Gender				
Male (ref.)	3560			
Female	4688	0.901	0.818, 0.992	0.035
Age				
85+	1225	3.486	3.081, 3.944	<0.001
75-84	2651	1.888	1.688, 2.112	<0.001
65-74 (ref.)	4372			
Deprivation (IMD)				
Q1 – least deprived (ref.)	1455			
Q2	2055	1.043	0.876, 1.243	0.634
Q3	1823	1.071	0.898, 1.277	0.444
Q4	1435	1.288	1.070 1.552	0.008
Q5 – most deprived	1480	1.161	0.966, 1.394	0.112
Location				
Cities & towns	4579	1.016	0.901, 1.145	0.799
Rural	1104	0.814	0.671, 0.986	0.036
Urban conurbation (ref.)	2565			
Hospital admission in 2010-12				
No (ref.)	6675			
Yes	1573	2.378	2.144, 2.638	<0.001
Number of consultations				
Q1 2-9 (ref.)	1879			
Q2 10-16	2100	0.810	0.694, 0.945	0.007
Q3 17-26	2073	0.830	0.714, 0.963	0.014
Q4 >26	2196	0.667	0.571, 0.778	<0.001
Number of GPs in practice				
Q1 <4 GPs (ref.)	882			
Q2 4-6 GPs	2213	0.939	0.778, 1.135	0.517
Q3 7-8 GPs	2263	0.934	0.767, 1.137	0.495
Q4 9+ GPs	2890	0.942	0.769, 1.154	0.561
Practice average CoC (BB index, tertiles)				
T1: COC >=0.2210 & <0.3746	2790	0.949	0.810, 1.113	0.522
T2: COC >=0.3746 & <0.4934	2710	0.836	0.724, 0.966	0.015
T3: COC >=0.4934 & =<1 (ref.)	2748			
Morbidities				
Epilepsy	132	1.607	1.186, 2.178	0.002
Chronic renal disease	133	2.222	1.738, 2.840	<0.001
Cancer	864	1.122	0.974, 1.292	0.111
Asthma	887	1.158	1.004, 1.334	0.044
Stroke	671	1.105	0.957, 1.276	0.172
Coronary heart disease	1114	1.394	1.241, 1.567	<0.001
Diabetes	1001	1.243	1.093, 1.414	0.001
COPD	398	1.570	1.324, 1.861	<0.001
Schizophrenia	67	1.727	1.170, 2.549	0.006
Depression	1629	1.191	1.062, 1.334	0.003
Constant		0.001	0.001, 0.002	<0.001
/Ln_p		-0.303	-0.350, -0.260	<0.001
Practice-level var(constant)		0.034	0.013, 0.087	

BB= Bice and Boxerman, CI=confidence interval, COC=continuity of care, ref.=reference category

Supplementary Table 4: Cross tabulation of a patient's Bice and Boxerman (BB) score and the number of GP consultations of 2892 patients in the nested case-control analysis.

	Number of GP consultations (%)				
Continuity of Care (BB index)	2-7	8-12	13-19	20+	Total
COC is 0	74 (100.0)	0	0	0	74 (100.0)
Q1 COC>0 & <0.257	135 (21.3)	187 (29.5)	159 (25.1)	153 (24.1)	634 (100.0)
Q2 COC>=0.257 & <0.395	145 (23.9)	126 (20.7)	150 (24.7)	187 (30.8)	608 (100.0)
Q3 COC>=0.395 & <0.576	109 (16.5)	177 (26.7)	173 (26.1)	203 (30.7)	662 (100.0)
Q4 COC>=0.576 & <1	73 (11.6)	164 (26.0)	162 (25.7)	231 (36.7)	630 (100.0)
COC is 1	151 (53.2)	61 (21.5)	51 (18.0)	21 (7.4)	284 (100.0)
Total	687 (23.8)	715 (24.7)	695 (24.0)	795 (27.5)	2892 (100.0)

COC=continuity of care, BB= Bice and Boxerman, Q=quartile

Supplementary Table 5: Estimates of odds ratios from a conditional (fixed-effects) logistic regression for the association between continuity of care (Bice and Boxerman index) and emergency hospital admission in a nested case-control approach, patients aged 65 or older (N=2892).

	N	**Odds ratio**	**95% CI**	**P-value**
Continuity of Care (BB index)				
COC is 0	74	2.148	1.009, 4.572	0.047
Q1 COC>0 & <0.257	634	1.832	1.157, 2.901	0.010
Q2 COC>=0.257 & <0.395	608	1.569	1.002, 2.427	0.049
Q3 COC>=0.395 & <0.576	662	1.370	0.881, 2.130	0.162
Q4 COC>=0.576 & <1	630	1.170	0.758, 1.807	0.479
COC is 1 (ref.)	284			
Gender				
Male (ref.)	1256			
Female	1636	0.824	0.675, 1.005	0.056
Hospital admission in 2010-12				
No (ref.)	2264			
Yes	628	2.330	1.858, 2.922	<0.001
Number of consultations				
Q1 2-7 (ref.)	687			
Q2 8-12	715	1.116	0.810, 1.538	0.502
Q3 13-19	695	1.647	1.209, 2.243	0.002
Q4 >19	795	2.753	1.995, 3.799	<0.001
Morbidities				
Epilepsy	50	0.612	0.283, 1.325	0.213
Chronic renal disease	61	2.706	1.494; 4.901	0.001
Cancer	347	1.107	0.831, 1.475	0.487
Asthma	358	0.895	0.669, 1.197	0.456
Stroke	247	0.945	0.679, 1.315	0.738
Coronary heart disease	428	1.256	0.975, 1.617	0.077
Diabetes	393	1.347	1.022, 1.775	0.035
COPD	158	1.774	1.194, 2.636	0.005
Schizophrenia	27	1.861	0.782, 4.428	0.160
Depression	623	0.979	0.773, 1.239	0.859

BB= Bice and Boxerman, CI=confidence interval, COC=continuity of care, ref.=reference category

Supplementary Table 6: Estimates of odds ratios from a conditional (fixed-effects) logistic regression for the association between continuity of care (Bice and Boxerman index, tertiles) and emergency hospital admission in a nested case-control approach, patients aged 65 or older (N=2892).

	N	Odds ratio	95% CI	P-value
Continuity of Care (BB index, tertiles)				
T1: COC >=0 & <0.3182	964	1.589	1.212, 2.084	0.001
T2: CoC >=0.3182 & <0.5632	964	1.304	1.013, 1.678	0.039
T3: COC >=0.5632 & =<1 (ref.)	964			
Gender				
Male (ref.)	1256			
Female	1636	0.823	0.675, 1.004	0.054
Hospital admission in 2010-12				
No (ref.)	2264			
Yes	628	2.333	1.862, 2.924	<0.001
Number of consultations				
Q1 2-7 (ref.)	687			
Q2 8-12	715	1.118	0.822, 1.523	0.478
Q3 13-19	695	1.637	1.216, 2.204	0.001
Q4 >19	795	2.758	2.025, 3.758	<0.001
Morbidities				
Epilepsy	50	0.631	0.291, 1.366	0.243
Chronic renal disease	61	2.740	1.517; 4.948	0.001
Cancer	347	1.108	0.832, 1.476	0.482
Asthma	358	0.907	0.679, 1.213	0.512
Stroke	247	0.937	0.674, 1.302	0.798
Coronary heart disease	428	1.256	0.975, 1.617	0.077
Diabetes	393	1.343	1.012, 1.771	0.036
COPD	158	1.799	1.211, 2.672	0.004
Schizophrenia	27	1.916	0.803, 4.571	0.143
Depression	623	0.977	0.773, 1.239	0.859

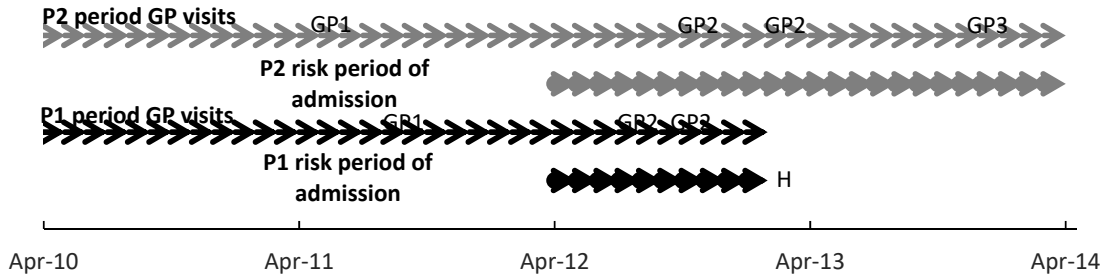
BB= Bice and Boxerman, CI=confidence interval, COC=continuity of care, ref.=reference category

Supplementary Table 7: Estimates of odds ratios from a conditional (fixed-effects) logistic regression for the association between continuity of care (appointed GP index score) and emergency hospital admission in a nested case-control approach, patients aged 65 or older (N=2892).

	N	Odds ratio	95% CI	P-value
Continuity of Care (BB index)				
Index GP				
Q1 (0.01 - <0.18)	635	2.318	1.481; 3.627	<0.001
Q2 (0.18 - <0.4)	669	1.614	1.033; 2.522	0.036
Q3 (0.4 - <0.71)	645	1.496	0.963; 2.325	0.073
Q4 (>0.71 - <1)	659	1.031	0.666; 1.596	0.890
GP index score=1 (ref.)	284			
Gender				
Male (ref.)	1256			
Female	1636	0.805	0.659, 0.984	0.034
Hospital admission in 2010-12				
No (ref.)	2264			
Yes	628	2.268	1.801, 2.846	<0.001
Number of consultations				
Q1 2-7 (ref.)	687			
Q2 8-12	715	1.035	0.757, 1.416	0.827
Q3 13-19	695	1.489	1.100, 2.014	0.010
Q4 >19	795	2.524	1.840, 3.643	<0.001
Morbidities				
Epilepsy	50	0.626	0.288, 1.359	0.236
Chronic renal disease	61	2.660	1.463; 4.832	0.001
Cancer	347	1.102	0.826, 1.470	0.509
Asthma	358	0.889	0.663, 1.194	0.435
Stroke	247	0.932	0.670, 1.300	0.676
Coronary heart disease	428	1.260	0.976; 1.627	0.077
Diabetes	393	1.362	1.032, 1.799	0.029
COPD	158	1.773	1.193, 2.636	0.005
Schizophrenia	27	1.943	0.803, 4.700	0.141
Depression	623	0.959	0.755, 1.218	0.730

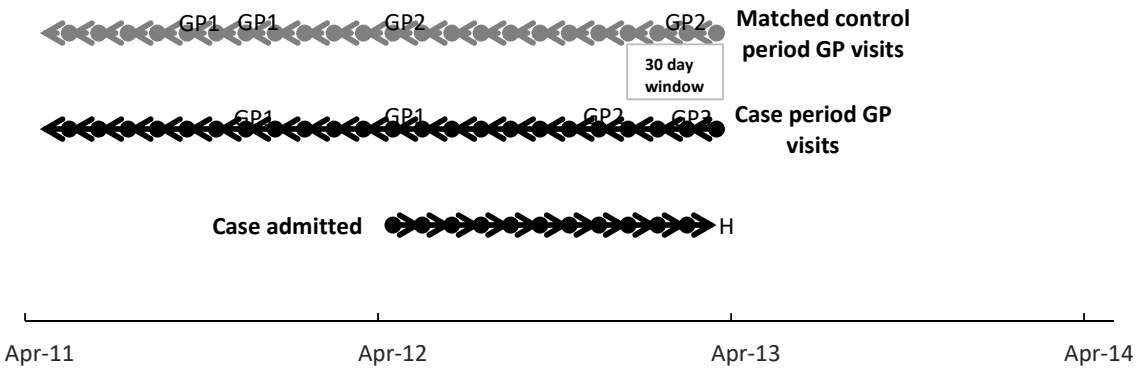
BB= Bice and Boxerman, CI=confidence interval, ref.=reference category

Supplementary Figure 1: time line prospective cohort approach



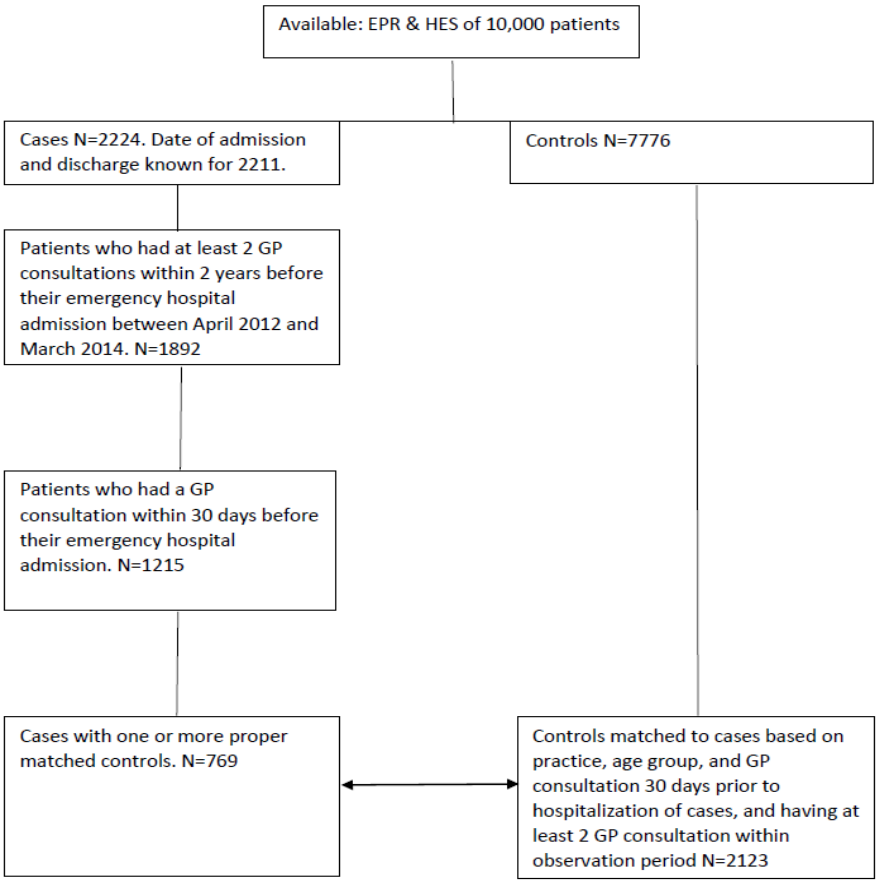
GP= consultation with a GP, H= emergency hospital admission, P= patient

Supplementary Figure 2: time line nested case-control approach

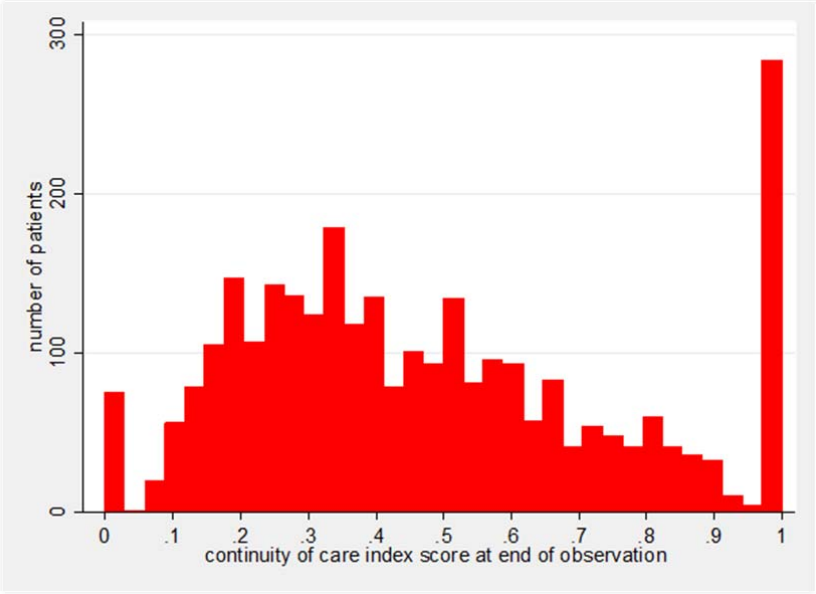


GP= consultation with a GP, H= emergency hospital admission

Supplementary Figure 3: Flow chart of the nested case-control approach.



Supplementary Figure 4: Distribution of Bice and Boxerman's quantitative measure of continuity of care of 2892 patients in the nested case-control analysis.



Supplementary Textbox 1: Bice and Boxerman (BB) and the appointed GP index

The BB measure is an individual-based measure that takes account of the proportion of consultations with the same doctor, adjusted for the number of consultations, with values between 0 and 1, where 0 indicates complete absence of continuity and 1 indicates complete provision. This measure was split into 6 categories; patient scoring 0, 1 and quartiles between 0.01 and 0.99. Besides the individual BB index score, we also calculated the general effect of continuity of care at the practice level by combining the individual BB index scores of all the patients within the same practice, allowing to distinguish between the individual and the practice level continuity of care.

The second measure used was (a variation on) the index provider identification. Usually this index defines the first provider seen as the primary provider. In our study we calculated this index concentrating on the last GP seen before hospitalisation. We refer to this measure as the appointed GP index and this was only relevant for the nested case-control approach to our analysis. This allowed us to calculate the proportion of times the last GP was seen in consultations during the previous two years. As all patients had consulted the appointed GP at least once, possible values for the proportions range from 0.01 to 1. A low proportion indicates that a patient saw another GP more often than the last GP. This measure was subdivided into 5 categories: patient scoring 1, and quartiles between 0.01 and 0.99.