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Opportunities for primary care to reduce hospital admissions:

a cross-sectional study of geographical variation

Abstract

Background
Reducing unplanned hospital admissions is a key priority within the UK. Substantial interpractice variation in admission rates for ambulatory care sensitive conditions (ACSC) suggests that decreases might be possible.

Aim
To identify the clinical areas and patient subgroups where the greatest opportunities exist for GPs to improve ACSC care.

Design and setting
Cross-sectional study using routine hospital data from patients registered at 8123 English GP practices during 2011 and 2012.

Method
The authors used random effects Poisson models to estimate interpractice variation after adjusting for several drivers of healthcare need and availability of local hospital services. Interpractice variation was contrasted across patient subgroups based on age.

Results
There were 1.8 million hospital admissions. Overall, high-utilisation practices had ACSC admission rates that were 55% (95% CI = 53 to 56) greater than low-utilisation practices. Differences of 67% (95% CI = 65 to 69) were found for chronic ACSCs, which was much larger than the 51% (95% CI = 49 to 52) difference exhibited by acute presentations. At least two-fold differences were found for 15 (54%) ACSCs, although large interpractice variations were not ubiquitous. Admission rates were consistently more variable among younger-than-average patients. The most variable conditions tended to disproportionately affect deprived patients.

Conclusion
Substantial interpractice variation suggests that current efforts to standardise primary care have had a limited effect on unplanned hospital admissions. GPs and healthcare commissioners should ensure they are offering best practice care for the most variable clinical areas and patient subgroups identified in the study, particularly in adults aged <70 years with chronic conditions.

Keywords
ambulatory care; general practice; geographical distribution; patient admission; primary health care.

INTRODUCTION

Unplanned admissions place a tremendous strain on UK healthcare resources, accounting for 67% of hospital bed days, costing £12.5 billion annually,[1] and disrupting elective care.[2] In England, they have increased by 47% over the last 15 years,[1] with some arguing that their continued rise threatens to bankrupt the NHS.[3] Reducing the number of unplanned admissions is a key priority within the UK.[4] Ambulatory care sensitive conditions (ACSCs) account for one in five unplanned admissions.[5] ACSCs are conditions where GPs can potentially reduce admissions by ensuring that patients receive high-quality disease management, timely treatment, and appropriate referral.[6]

Concerns that some ACSC admissions are avoidable have been fuelled by wide interpractice variations.[7,8] Part of this variation will be driven by factors beyond the control of GPs, such as patient characteristics (for example, age, deprivation, comorbidities), availability of community support (such as social services), and local hospital services (for example, A&E department proximity and bed availability).[9,10] However, an unknown proportion is likely to result from interpractice differences in primary care quality.[9,11,12] Improved understanding of the clinical areas where ACSC admission rates are most variable, and primary care might be most inconsistent, could lead to more targeted admission avoidance interventions and improved patient outcomes.

The authors used routine data from English hospitals to examine interpractice variation in unplanned ACSC admission rates that is not explained by markers of healthcare need or availability of hospital services. The study explored whether interpractice variation in admission rates is consistent across conditions, and whether it affects some patient age groups more than others.

METHOD

Data source and preparation

The authors used the Hospital Episode Statistics (HES) admitted patient care dataset to identify admissions between 1 April 2011 and 31 March 2012.[13] HES includes demographic, clinical, and geographical information. The study included all unplanned admissions for 28 common ACSCs (more than 3000 admissions annually), which were identified using International Classification of Diseases (ICD)-10 diagnosis codes (Appendix 1).[6] The authors classified ACSCs that generally require long-term management by GPs as chronic and the remainder as acute, and investigated differences in ACSC admission rates between 8123 primary care practices submitting data to the Quality and Outcomes Framework (QOF) in 2011–2012 (almost all English practices).[14] The authors converted episodes into continuous inpatient spells (CIPS), meaning that care spanning multiple hospitals was counted only once.[15] The authors included CIPS when the primary diagnoses from the admission episode

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How this fits in

Unplanned hospital admissions place a large and growing burden on healthcare resources. GPs play an important role in reducing these by ensuring that patients receive high-quality disease management, timely treatment or advice, and appropriate referral. This study used interpractice variation in unplanned admission rates to identify the clinical areas where primary care might be inconsistent. Targeted admission avoidance interventions could lead to improved patient outcomes. GPs and healthcare commissioners should ensure they are offering best-practice care for the most variable clinical areas and patient subgroups identified in this study.

indicated an ACSC. Patients with an invalid data entry for age or sex (<0.1%) were excluded.

Descriptive analysis and estimating interpractice variation

The authors described patient demographics, and calculated the number of admissions and bed days for each condition. They summed across conditions to calculate totals for acute, chronic, and all ACSCs combined. Before estimating interpractice variation a two-step process to adjust for differences in practice populations was used. The authors first calculated expected admission counts using indirect standardisation (utilising quinary age groups and sex) and national data[16] to account for differences in the size and age–sex composition of practice populations (Appendix 2). The authors then used Poisson regression to further adjust for other key determinants of healthcare need. A proxy for the deprivation of the practice population was estimated based on the practice postcode.[17] Data from QOF disease registers were used to adjust for the prevalence of atrial fibrillation, asthma, cancer, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD), dementia, epilepsy, heart failure, hypertension, learning disability, mental health problems, obesity, and stroke. The authors calculated the straight-line distance between the practice and the closest A&E department, and used this as a measure of emergency care accessibility. Other local non-primary-care factors (such as community healthcare supply and hospital admission policies) were adjusted for by including 151 dummy variables representing the primary care trust (PCT) in which the practice was located.

The authors used random effects Poisson models to quantify interpractice variation in admissions (Appendix 2). These models estimate the interpractice standard deviation (SD) in admission rates for each ACSC. A high SD indicates substantial unexplained variability. To improve interpretability, the authors calculated decile differences, defined as the percentage difference in admission rates between a high utilisation practice (at the 90th centile of the random effects distribution) and a low utilisation practice (at the 10th centile).

Contrasting interpractice variation across age subgroups

The authors calculated decile differences separately for five age subgroups (0–4, 5–19, 20–39, 40–69, and ≥70 years) using the methods described above. Subgroups containing fewer than 3000 admissions were excluded to ensure precise estimates, as were those containing less than 10% of admissions, as these represented atypical patients (for example, hypertension patients <20 years old). Four (14%) ACSCs had only one group remaining after these deletions and were excluded. The percentage difference between the decile difference in the youngest age group and those in older groups was calculated. The analyses were conducted in WinBUGS (version 1.4.3).

RESULTS

Descriptive statistics

There were 1.77 million admissions for ACSCs, accounting for 10.9 million bed days during 2011–2012 (Table 1). Many patients were older (mean age 56 years), from deprived communities (27% resided in the most deprived quintile of areas), had at least one comorbidity (58%), and were admitted through A&E (75%). These overall results concealed substantial variation between conditions (Table 2). Younger patients were more frequently admitted for a few ACSCs (for example, ENT infections) whereas others almost universally involved older patients (such as dementia). Some ACSCs exhibited a very steep socioeconomic gradient (for example, alcohol-related diseases and schizophrenia). There were wide disparities in the proportion of hospital admissions originating from primary care; 34% of ear, nose, and throat (ENT) infection admissions were GP referrals, compared with only 1% for fractured proximal femur.

Interpractice variation

Substantial differences in unplanned admission rates existed between English general practices (Table 3). For all ACSCs combined, high-utilisation practices

Table 1. Admission details for all Ambulatory Care Sensitive Conditions (ACSCs)

Characteristics	Count (%)
Number of admissions	1 767 550
Bed days	10 903 662
Mean age, years	55.6
0–19	264 541 (15.0)
20–39	207 032 (11.7)
40–59	338 316 (19.1)
60–79	512 017 (29.0)
≥80	445 644 (25.2)
Male	844 537 (47.8)
Ethnicity	
White	1 495 974 (84.6)
Asian	100 486 (5.7)
Black	41 879 (2.4)
Mixed	14 623 (0.8)
Missing	114 588 (6.5)
Deprivation	
1 (most deprived)	477 437 (27.0)
2	387 099 (21.9)
3	339 554 (19.2)
4	302 310 (17.1)
5 (least deprived)	261 150 (14.8)
Comorbidities	
Any	1 032 628 (58.4)
COPD	465 731 (26.4)
Diabetes	288 168 (16.3)
Congestive heart failure	194 692 (11.0)
Cerebrovascular disease	185 824 (10.5)
Renal disease	133 975 (7.6)
Admission source	
The usual place of residence	1 671 614 (94.6)
Other	95 936 (5.4)
Admission method	
Emergency: via A&E	1 326 882 (75.1)
Emergency: via GP	290 218 (16.4)
Other	150 450 (8.5)
Discharge destination	
The usual place of residence	1 597 060 (90.4)
Patient died	80 371 (4.6)
Nursing home	35 425 (2.0)
Other	54 694 (3.1)

ACSC = ambulatory care sensitive condition. COPD = chronic obstructive pulmonary disease.

(at the 90th centile) had admission rates 55% (95% CI = 53 to 56) higher than low-utilisation practices, after adjustment for age, sex, other markers of healthcare need, distance from A&E, and PCT-level effects. Differences of 67% (95% CI = 65 to 69) were found for chronic ACSCs, which was much larger than the corresponding figure of 51% (95% CI = 49 to 52) for acute presentations. Furthermore, the eight most variable conditions were chronic while the eight least variable were acute.

The most variable condition was alcohol-related disease, where high-utilisation practices had admission rates 237% (95% CI = 224 to 252) greater than low-utilisation practices. However, large interpractice variations were commonplace. For example, differences in excess of 150% were found for diabetes complications, iron deficiency anaemia, hypertension, and COPD. In contrast, the differences for fractured proximal femur and stroke were only 33% (95% CI = 28 to 39) and 35% (95% CI = 30 to 39) respectively. The highest interpractice variations were found among conditions that disproportionately affect deprived patients. For example, 40%, 31%, and 45% of patients admitted for alcohol-related diseases, diabetes complications, and schizophrenia, the three highest variation conditions, resided in the most deprived quintile of areas (Tables 2 and 3).

Interpractice variation across age groups

There was a clear trend for higher interpractice variation in admissions among younger-than-average age groups (Table 4). When combining all ACSCs, decile differences for patients aged 40 to 69 years and ≥70 were 18% (95% CI = 14 to 22) and 32% (95% CI = 29 to 35) lower than those aged 20 to 39 years. This trend was even more stark for chronic conditions alone. Admission rates were 45% (95% CI = 42 to 48) less variable for patients aged >70 years compared with those aged 20 to 39 years. The youngest age group was also the most variable for 20 (83%) individual conditions, including dyspepsia/other stomach function, where interpractice variation for patients aged >40 years was at least 67% lower than those aged <5 years, and for congestive heart failure where admission rates for patients >70 years were 61% (95% CI = 55 to 66) less variable than for those aged 40 to 69 years.

DISCUSSION

Summary

ACSCs accounted for 1.77 million admissions and 10.9 million bed days during 2011–2012. Overall, ACSC admission rates were 55% greater in high-utilisation practices than low-utilisation practices after adjustment for age, sex, other markers of healthcare need, accessibility of emergency hospital care, and PCT-level effects. Although the largest differences were observed in chronic conditions, substantial interpractice variation was found across a wide range of conditions. Large interpractice variation was not ubiquitous — differences of less than 35% were found for stroke and fractured proximal femur. Admission rates were consistently more variable

Table 2. Characteristics of admitted patients by condition

Condition	Mean age, years	Male, %	Resident in most deprived quintile, %	Admitted from GP, %
Alcohol-related diseases	43.8	68.0	40.1	4.3
Angina	60.5	54.6	27.0	9.1
Asthma	31.2	42.9	32.9	16.1
Atrial fibrillation/flutter	56.3	40.7	21.4	12.6
Cellulitis	51.6	52.1	27.4	26.6
Congestive heart failure	78.5	51.6	22.9	19.8
Constipation	51.4	42.6	27.6	27.0
Convulsions and epilepsy	37.6	53.5	29.8	4.2
COPD	71.2	48.3	33.5	15.6
Dehydration and gastroenteritis	40.8	44.8	27.5	26.0
Dental condition	35.1	51.8	31.8	11.8
Diabetes complications	44.9	54.6	30.6	15.6
Dyspepsia/other stomach function	40.5	50.2	27.6	21.7
ENT infection	10.2	52.9	30.8	34.2
Fractured proximal femur	80.8	26.9	18.1	1.0
Hypertension	60.9	41.3	25.7	26.3
Influenza and pneumonia	67.5	51.2	24.7	17.0
Iron deficiency anaemia	65.0	38.8	25.8	37.0
Migraine/acute headache	42.2	35.6	26.6	23.3
Neuroses	47.6	44.0	31.2	7.4
Pelvic inflammatory disease	32.6	0.0	30.7	24.5
Perforated/bleeding ulcer	56.5	54.1	26.7	19.3
Peripheral vascular disease	69.1	53.3	26.0	31.7
Pyelonephritis	63.2	34.7	24.4	19.9
Ruptured appendix	36.2	58.1	18.9	28.0
Schizophrenia	42.5	63.0	45.3	2.6
Senility/dementia	83.6	38.5	22.0	11.4
Stroke	74.7	49.3	20.0	6.7

COPD = chronic obstructive pulmonary disease. ENT = ear, nose, and throat.

among younger-than-average patients, while the most variable conditions tended to disproportionately affect deprived patients.

Strengths and limitations

This study was based on a large nationally representative dataset containing almost all unplanned admissions in England. Including a broad range of ACSCs provided a fuller description of interpractice variation than previous studies, which have focused on only a few conditions.[18] This model-based approach to quantifying interpractice variation appropriately accounted for random chance, while the transformation to the decile difference aided interpretation.

The study was based on observational evidence and hence open to confounding. The authors undertook extensive case-mix adjustment. However, it is possible that other unmeasured factors, which cannot be modified by GPs and vary within PCTs (for example, community care provision), could have affected the results. The moderate interpractice variation between practices for fractured proximal femur, where GPs probably have a relatively minor impact on the risk of admission (for example, osteoporosis detection and fall clinics), suggests that residual confounding could be responsible for some of the observed variation. Using the practice postcode to estimate deprivation could have impaired the authors' ability to adjust for this factor, as practices may be located in areas that are unrepresentative of the population they serve. This may have introduced spurious variation into the analysis, particularly for younger and middle-aged patients where deprivation could be a particularly strong determinant of healthcare need.

Comparison with existing literature

A previous international systematic review reported that interpractice and geographical variation in unplanned ACSC admission rates was almost ubiquitous across practices and other geographical units.[18] Other studies have found substantial variation in admission rates for respiratory and cardiovascular ACSCs, even between English practices from similarly deprived areas.[7,8] To the best of the authors' knowledge, this is the first study to contrast interpractice variation in admission rates across age groups.

Implications for research and practice

Substantial interpractice variation in unplanned ACSC admission rates could be a symptom of inefficient care within the English primary care system. The results suggest that the current mechanisms to standardise primary care, such as the QOF and National Institute for Health and Care Excellence (NICE) guidelines, have had a limited effect on standardising hospital admission rates and that new strategies might be required. Contrasting interpractice variation across ACSCs helps to identify the clinical areas and patient subgroups (for example, childhood diabetes) where primary care might be most inconsistent, and further exploration is urgently required. National funders, such as the National Institute for Health Research, are well placed to commission new research to reduce key treatment uncertainties (such as optimal management strategies). GPs and healthcare commissioners should ensure they are currently offering best-practice care for the most variable clinical conditions and patient subgroups identified in the study.

Table 3. Magnitude of interpractice admission rate variation

Condition	Admissions	Bed days	Decile difference (95% CI)
All chronic ACSCs combined	**735 388**	**3889**	**67 (65 to 69)**
Alcohol-related diseases	36 535	131	237 (224 to 252)
Diabetes complications	22 965	169	235 (219 to 251)
Schizophrenia	10 012	291	234 (210 to 261)
Peripheral vascular disease	3409	36	160 (123 to 193)
Iron deficiency anaemia	14 886	69	155 (139 to 171)
Hypertension	6475	14	154 (131 to 178)
COPD	114 111	727	153 (147 to 160)
Asthma	53 522	131	150 (142 to 158)
Neuroses	20 567	216	109 (98 to 121)
Senility/dementia	55 998	788	108 (102 to 115)
Atrial fibrillation/flutter	26 428	54	108 (99 to 117)
Congestive heart failure	54 917	568	92 (86 to 99)
Angina	315 563	694	80 (78 to 83)
All acute ACSCs combined	**1 032 162**	**7015**	**51 (49 to 52)**
Pelvic inflammatory disease	4659	17	124 (91 to 155)
Convulsions and epilepsy	75 788	229	123 (117 to 130)
Dyspepsia/other stomach function	18 878	24	108 (95 to 121)
ENT infections	82 292	71	106 (100 to 112)
Migraine/acute headache	66 563	127	91 (85 to 96)
Constipation	41 906	143	91 (83 to 98)
Cellulitis	88 035	441	86 (81 to 91)
Dental condition	9838	20	77 (56 to 98)
Pyelonephritis	151 979	1167	72 (69 to 75)
Perforated/bleeding ulcer	74 329	339	66 (62 to 71)
Influenza and pneumonia	151 468	1351	59 (56 to 63)
Dehydration and gastroenteritis	126 387	566	59 (56 to 62)
Ruptured appendix	10 143	54	59 (43 to 80)
Stroke	73 497	1215	35 (30 to 39)
Fractured proximal femur	56 400	1251	33 (28 to 39)
All ACSCs combined	**1 767 550**	**10 904**	**55 (53 to 56)**

ACSC = ambulatory care sensitive condition. COPD = chronic obstructive pulmonary disease. ENT = ear, nose, and throat.

These results suggest that the substantial variability in the way primary care is delivered across England could have important implications for patient outcomes. Interpractice differences have been reported in the quality of disease management,[19] treatment of exacerbations,[20] prescribing quality,[21] and referral quality.[11] Primary care access and continuity of care differ markedly, meaning that some patients might choose to directly access A&E and be admitted due to risk-averse hospital admission thresholds.[12] Heterogeneity in decile differences across conditions suggests that these factors are particularly important for some ACSCs. Chronic conditions are actively managed by GPs and hence are more likely to be sensitive to the vagaries that exist in the availability and quality of primary care. For example, wide disparities have been identified in the quality of diabetes care (such as foot surveillance) and severe mental illness management (such as care planning),[14,19] and some GPs have reported low levels of knowledge or motivation to deal with alcohol problems.[22] Conditions where a high proportion of admissions originate from primary care (for example, iron deficiency anaemia) are likely to be more sensitive to variation in GP referral thresholds than those where patients typically go directly to A&E (for example, fractured proximal femur). Availability of clear referral guidelines and alternative treatment pathways could reduce admissions originating from primary care.

Initial investigations into the causes and implications of interpractice variation should focus on pathways for younger-than-average patients for several ACSCs. Consistently high variation among children could be explained by the challenges of minimising risk and making diagnoses (such as childhood diabetes[23] and dyspepsia[24]), or pressure from anxious parents that acts to magnify the effect of variable GP referral thresholds. The strong gradient between age and prevalence for many ACSCs (such as coronary heart disease [CHD][25] and stroke[26]) — meaning that most middle-aged patients present as atypical or low risk — could amplify the effect of variable diagnostic quality among GPs. Furthermore, poorer patient compliance and delivery of disease management interventions among younger patients could lead to faster progression and earlier complications. For example, only 29% of patients with type 1 diabetes aged <40 years received eight of the nine recommended care processes, compared with 60% of those aged >80 years.[19]

The finding that conditions with the largest interpractice variations tended to be those most prevalent in deprived populations suggests that delivery of primary and community care might be most inconsistent for these ACSCs. In addition to the factors highlighted previously, avoiding admission for these conditions is likely to require substantial effort by GPs to case-find (for example, problem drinking), provide lifestyle interventions (such as smoking cessation), and engage with difficult-to-reach patients, such as the homeless and those with acute mental illness. These results could suggest this varies between practices, and efforts are required to standardise and improve care. This might be achieved through additional services or incentives — a UK-based study demonstrated that financial incentives can increase alcohol screening and intervention.[27]

A detailed understanding of the causes of

Table 4. Magnitude of interpractice admission rate variation across age subgroups[a]

	Age subgroup (95% CI)				
Condition	**0–4 years**	**5–19 years**	**20–39 years**	**40–69 years**	**≥70 years**
Asthma	297 (267 to 327)	302 (279 to 326)	366 (337 to 399)	260 (239 to 283)	263 (231 to 298)
Constipation	239 (204 to 280)	236 (206 to 271)	197 (164 to 231)	126 (106 to 145)	112 (98 to 125)
Convulsions and epilepsy	299 (276 to 324)	376 (347 to 407)	333 (307 to 362)	228 (213 to 244)	205 (186 to 225)
Dehydration and gastroenteritis	98 (91 to 106)		107 (93 to 123)	81 (72 to 92)	68 (60 to 76)
Dyspepsia/other stomach function	268 (235 to 302)			80 (51 to 107)	89 (62 to 114)
ENT infection	135 (127 to 142)	117 (100 to 132)	96 (75 to 116)		
Perforated/bleeding ulcer	228 (201 to 259)		173 (155 to 194)	93 (83 to 104)	62 (55 to 70)
Diabetes complications		646 (583 to 714)	544 (494 to 599)	320 (290 to 350)	240 (206 to 280)
Migraine/acute headache		163 (142 to 187)	127 (115 to 139)	104 (95 to 115)	103 (72 to 125)
Alcohol-related diseases			388 (353 to 422)	331 (309 to 355)	
Angina			140 (131 to 151)	98 (94 to 102)	87 (82 to 91)
Atrial fibrillation/flutter			217 (184 to 255)	122 (106 to 144)	136 (115 to 158)
Cellulitis			155 (141 to 169)	117 (107 to 125)	115 (106 to 125)
Dental condition			101 (68 to 154)	93 (54 to 123)	
Neuroses			167 (142 to 199)	128 (107 to 147)	168 (133 to 206)
Pyelonephritis			129 (116 to 142)	117 (107 to 127)	91 (85 to 96)
Ruptured appendix			81 (50 to 124)	57 (34 to 95)	
Schizophrenia			316 (271 to 361)	258 (225 to 291)	
COPD				285 (270 to 301)	173 (165 to 182)
Congestive heart failure				235 (210 to 264)	92 (85 to 99)
Fractured proximal femur				38 (22 to 70)	34 (27 to 41)
Influenza and pneumonia				80 (72 to 88)	72 (68 to 77)
Iron deficiency anaemia				185 (152 to 220)	135 (115 to 157)
Stroke				65 (54 to 77)	35 (28 to 41)
All chronic ACSCs combined			**131 (125 to 137)**	**89 (86 to 92)**	**72 (69 to 74)**
All acute ACSCs combined	**113 (108 to 117)**		**84 (80 to 88)**	**64 (62 to 67)**	**56 (54 to 58)**
All ACSCs combined			**88 (85 to 92)**	**72 (70 to 74)**	**60 (58 to 62)**

[a]Blank cells indicate a small number of admissions (<3000), or those containing less than 10% of all admissions. ACSC = ambulatory care sensitive condition. COPD = chronic obstructive pulmonary disease. ENT = ear, nose, and throat.

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the interpractice variation is crucial to guide the design of interventions to standardise care.[28] Previous research suggests that strategies to improve the continuity of primary care could reduce secondary care demand for ACSCs.[9] One English study found that unplanned ACSC admissions reduced by 0.5% for each percentage point increase in the proportion of patients able to book with a specific GP.[29] There is little evidence to suggest that larger practices, or those with better appointment availability, have fewer unplanned ACSC admissions.[9] Similarly, studies investigating the association between primary quality (measured by QOF scores) and unplanned admission rates have found little or no association except for a few diseases (such as COPD and CHD).[30] Previous research suggests that the 10% of patients with the highest multimorbidity (four or more conditions) account for over half of all potentially preventable admissions. Interventions targeted at this patient group might prove most cost-effective.[10]

Further work is required to understand the causes for the widespread interpractice variations outlined in this study, and to design interventions to improve and standardise care. Qualitative methods could provide an in-depth understanding of why patients are admitted to hospital and the role GPs could play in averting this. Work should initially focus on the most variable ACSCs and patient subgroups as these are likely to offer the greatest gains.

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Appendix 1. Included Ambulatory Care Sensitive Conditions (ACSCs) and the ICD-10 codes used to define them

Condition	ICD-10 codes
Chronic conditions	
Alcohol-related diseases	F10
Angina	I20,I240,I248,I249,I25,R072,R073,R074,Z034,Z035
Asthma	J45,J46
Atrial fibrillation/flutter	I471,I479,I495,I498,I499,R000,R002,R008
Congestive heart failure	I110,I130,I255,I50,J81
COPD	J20,J40,J41,J42,J43,J44,J47
Diabetes complications	E100,E101,E102,E103,E104,E105,E106,E107,E108,E110,E111,E112,E113,E114,E115,E116,E117,E118,E120,E121,E122,E123, E124,E125,E126,E127,E128,E130,E131,E132,E133,E134,E135,E136,E137,E138,E139,E140,E141,E142,E143,E144,E145,E146, E147,E148,E149
Hypertension	I10,I119
Iron deficiency anaemia	D460,D461,D463,D464,D501,D508,D509,D510,D511,D512,D513,D518,D520,D521,D528,D529,D531,D571,D580,D581, D590,D591,D592,D599,D601,D608,D609,D610,D611,D640,D641,D642,D643,D644,D648
Neuroses	F32,F40,F41,F42,F43,F44,F45,F46,F47,F48
Peripheral vascular disease	I73,I738,I739
Schizophrenia	F20,F21,F232,F25
Senility/dementia	F00,F01,F02,F03,R54
Acute conditions	
Cellulitis	I891,L010,L011,L020,L021,L022,L023,L024,L028,L029,L03,L04,L080,L088,L089,L88,L980
Constipation	K590
Convulsions and epilepsy	G253,G40,G41,O15,R56,R568
Dehydration and gastroenteritis	A020,A04,A059,A072,A080,A081,A083,A084,A085,A09,E86,K520,K521,K522,K528,K529
Dental condition	A690,K02,K03,K04,K05,K06,K08,K098,K099,K12,K13
Dyspepsia/other stomach function	K21,K30
ENT infections	H66,H67,J02,J03,J040,J06,J312
Fractured proximal femur	S720,S721,S722
Influenza and pneumonia	A481,A70,J10,J11,J120,J121,J122,J128,J129,J13,J14,J153,J154,J157,J159,J160,J168,J18,J181,J189
Migraine/acute headache	G43,G440,G441,G443,G444,G448,R51
Pelvic inflammatory disease	N70,N73,N74
Perforated/bleeding ulcer	K20,K210,K219,K221,K226,K250,K251,K252,K254,K255,K256,K260,K261,K262,K264,K265,K266,K270,K271,K272,K274,K275, K276,K280,K281,K282,K284,K285,K286,K920,K921,K922
Pyelonephritis	N10,N11,N12,N136,N159,N300,N308,N309,N390
Ruptured appendix	K350,K351
Stroke	I61,I62,I63,I64,I66,I672,I698,R470

ACSC = ambulatory care sensitive condition. COPD = chronic obstructive pulmonary disease. ENT = ear, nose, and throat. ICD = International Classification of Diseases.

Appendix 2. Further details on estimating interpractice variation

Calculation of age–sex specific GP population

As age–sex specific practice populations were not available for 2011–2012, these were estimated using data from 2013–2014. The authors calculated the proportion of the practice population in each of 18 age groups (grouped by 5 years up to the age of 85, with all patients over 85 joined together) and two sex groups. These proportions were multiplied by the 2011–2012 practice list size. Due to practice closures and mergers, data were not available for a small number of practices (n = 183, 2.3%). For these practices, the authors estimated the age–sex composition using the populations of the five geographically closest practices where data were available.

Estimation of interpractice variation

It was assumed that the number of admissions within each practice i, for condition j (Observed_{ij}), was drawn from a Poisson distribution with mean μ_{ij}. The authors calculated the number of admissions that would be expected given the size and age–sex composition of the practice (Expected_{ij}), using indirect standardisation. Other differences in practice populations (for example, the prevalence of chronic disease) were accounted for by including k regression coefficients, β_{jk}, which estimate the effect of each covariate, X, on the admission rate. Crucially, the linear predictor includes a normally distributed random effect, termed the practice effect (P_{ij}), which allows for differences in the linear predictor for each practice. The main parameter of interest is σ_j (the standard deviation of the practice effects), which the authors transformed to a decile difference (DD_j) for ease of interpretation. The full model is:

$$\text{Observed}_{ij} \sim \text{Poisson}\left(\mu_{ij}\right)$$

$$\log\left(\mu_{ij}\right) = \text{Expected\_Age\_Sex}_{ij} + \beta_{jk}X_{jk} + P_{ij}$$

$$P_{ij} \sim \text{Normal}\left(\theta_j, \sigma_j^2\right)$$

$$DD_j = 100 \times \left(\frac{\exp\left(1.282\left(\sigma_j\right)\right)}{\exp\left(-1.282\left(\sigma_j\right)\right)} - 1 \right) = 100 \times \left(\exp\left(2.564 \times \sigma_j\right) - 1\right)$$