

Computed tomography in patients with epileptic seizures admitted acutely to hospital: A population level analysis of routinely collected healthcare data

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ABSTRACT

Approximately 1.4% of emergency medical admissions are due to epileptic seizures. For the majority of such cases, computed tomography (CT) will not inform acute management and is unnecessary.

Pseudonymised, routinely collected data from seven hospitals within the Cheshire and Merseyside area of the UK were analysed. All patients with emergency admissions to hospital due to seizures between 2014 and 2017 were included. Use of CT of the head was identified from routine coding.

We identified 4,183 individuals with an acute seizure admission, of which over 30% received a CT of the head. There was significant variation in CT among hospital trusts.

The rate of CT for patients admitted with seizures is high and CT is not being directed to those where they may be indicated. Integrated care pathways and guidelines are required to improve the management of patients presenting acutely with seizures.

KEYWORDS: Epilepsy, seizure disorders, neurology, imaging, care systems

DOI: 10.7861/clinmed.2019-0303

Introduction

Epilepsy is common with an estimated prevalence of five per 1,000 population. While antiepileptic drug treatment can prevent seizures in most people with epilepsy, there are more than 40,000 epilepsy related admissions to NHS hospitals in England per annum, accounting for 1.4% of all emergency medical admissions.^{1–3}

The goal of emergency brain imaging in patients presenting with a seizure is to identify potentially treatable structural lesions or reversible causes that require immediate treatment such as intracranial

haemorrhage or large tumours.⁴ Alternatively, it can be used to assess brain injury in those sustaining a head injury during a seizure.

Evidence supports the use of emergency computed tomography (CT) in only a subgroup of adults who present with a first seizure, where there is history of head injury, fever, immunosuppression, malignancy, focal motor or sensory onset of seizure, or where patients present with a persistently reduced level of consciousness.^{5,6} This has been adopted into the UK Guidelines in Emergency Medicine Network (GEMNet) protocol on the management of first seizure in the emergency department (ED).⁷ For the remainder of first seizure patients, brain imaging, usually magnetic resonance imaging (MRI), can be requested at an outpatient neurology or first seizure clinic.²

In contrast, for patients with an established diagnosis of epilepsy, there is no evidence to support the routine use of emergency CT, which will only inform clinical management in those with concomitant head trauma, prolonged alteration level of consciousness or a new focal abnormality on neurological examination.⁸

Although at an individual patient level the increased risk of lifetime carcinoma attributable to CT is small, there are well documented public health concerns about the risks from CT related to the rapid increase in its use across an entire population.⁹ Furthermore, appropriate use of neuroimaging can lead to significant cost savings, with a non-contrast CT estimated to cost the NHS £78.00 including radiology reporting.¹⁰

Recent analysis of the National Audit of Seizure management in Hospitals (NASH) 2015 data indicates that of patients attending the ED with a seizure, 21.6% with known epilepsy and 31.8% without a prior epilepsy diagnosis undergo CT prior to discharge, indicating possible overuse of neuroimaging in this setting.¹¹ NASH was not a population-based study; each hospital provided information on 50 consecutive seizure attendances, the aim being to identify problems with the process of care. One such problem identified was the use of CT, and here we present a population level analysis using administrative data from the Cheshire and Merseyside region of England in which we further investigate CT rates following admission with a seizure and factors associated with it in order to inform future changes to pathways and practice. Our focus is upon admissions with seizures as they can be readily and reliably identified in episode level datasets. It is not currently possible to undertake similar analyses of ED attenders as they cannot be adequately identified in the Secondary Uses Service (SUS) emergency care dataset due to insufficient quality of diagnostic coding.^{12,13}

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Objective

We aimed to retrospectively quantify at population level the use of CT in patients admitted to hospital with seizures across the Cheshire and Merseyside region of the UK over 3 years, and to identify patient factors associated with the rate of scanning.

Methods

To identify patients admitted with a seizure, we analysed pseudonymised SUS data for seven acute NHS hospitals within the Cheshire and Merseyside region between the financial years 2014/15 to 2016/17. The SUS data used combined NHS commissioning datasets produced by hospital coders covering inpatient hospital admissions and outpatient attendances. It includes information on reason for admission and comorbidity based on the work of coders working to standard methods to create a list of up to 20 *International statistical classification of diseases and related health problems: ICD-10* (ICD-10) diagnoses.¹⁴ It also records demographic details, length of 'spell' data as well as codes for procedures undertaken during an admission. Only patients residing in or registered at general practitioner practices within the Cheshire and Merseyside region were included.

We created an algorithm based on knowledge of disease behaviour, clinical pathways and clinician feedback, using multiple diagnoses from the ICD-10 list to select those where a seizure was likely to be the prime reason for admission.³ This approach has been shared with specialists and developed using an iterative approach and has now been used widely across a broad range of conditions as well as epilepsy.^{15–17} This algorithm accesses more of the coded information and is more likely to be representative of the true clinical picture compared to previous algorithms used by clinical commissioners.

Cases included for analysis were identified using our algorithm for identifying seizure related emergency hospital admissions (for full list of ICD-10 codes used for case ascertainment see supplementary material S1).

- > All emergency admissions to the major medical specialties that were primarily related to presentation with a seizure between financial years 2014/15 to 2016/17.
- > Method of admission was:
 - > emergency (excluding day and elective cases) and
 - > under care of the major medical specialties (cardiology, respiratory, neurology etc) and
 - > a seizure admission was defined from the discharge diagnosis codes:
 - > an epilepsy code (G40, G41) in the first diagnosis position (P1) or
 - > an epilepsy code second or third in the list (and a supportive symptom or condition code in P1).

Our primary outcome was usage of CT of the head, which was identified using *OPCS classification of interventions and procedures version 4* (OPCS-4) codes for each patient spell where they had likely presented with a seizure as the prime reason for admission (for full list of OPCS-4 codes, see supplementary material S1).

The Charlson Comorbidity Index (CCI) was used to measure comorbidity burden. It is a widely used measure of comorbidity developed over 20 years ago to predict 1-year mortality in a cohort of medical inpatients.^{18,19} An overall score is calculated from a list of conditions, weighted based on adjusted relative risk of 1-year

mortality, with increased scores representing a higher burden of comorbid disease.

The Index of Multiple Deprivation (IMD) is the official measure used in the UK of relative deprivation for neighbourhoods in England.²⁰ The IMD ranks each small area in England with approximately 1,500 residents or 650 households (lower-layer super output areas) from 1 (most deprived area) to 32,844 (least deprived area). We used IMD decile (decile 1 = least deprived to decile 10 = most deprived) to account for social deprivation level in our analysis.

For each admission we also recorded the neurological (outpatient code 400) clinic attendances covering a period of at least 1 year prior to admission to determine whether the patient was known to neurology services or unknown. To be sure that we were not missing outpatient data, we confirmed with the service that all neurology clinics had been included, whether occurring locally or in the regional tertiary referral centre.

Sample size calculation was not performed since we included every possible case presenting in the region meeting the above inclusion criteria within the predefined period.

For analysis we split patients into two groups, in line with previous published work using SUS data.³

- > Those who had been seen in a neurology clinic in the preceding year (ie those who are under active follow-up).
- > Those who had not been seen in a neurology clinic in the preceding year, representing either patients with suspected first seizures or patients not in active follow-up.

We calculated descriptive statistics of demographic details for both groups. Comparisons were made using χ^2 and Wilcoxon rank-sum (Mann–Whitney *U*) tests where the distribution in at least one comparison group did not follow a normal distribution. The proportion of patients undergoing CT at their first observed spell was compared between both cohorts and analysed based on hospital trust attended using χ^2 test. We also undertook univariate followed by multivariate regression to assess the association of factors with CT of the head rates. Variables included in the model were age grouped by decade, IMD decile, CCI score, concomitant head and/or neck trauma, whether under active neurology follow-up and hospital provider. For ease of analysis and where patients had multiple admissions to hospital due to seizures over the 3-year period we analysed data from the first episode to allow for consistency in grouping based on whether the patient was under active neurology follow-up. Data were analysed using STATA version 15.0.

Results

We identified a total of 7,342 hospital admissions (spells) representing 4,183 patients who were admitted to hospital due to a seizure over 3 years (Table 1). Forty per cent of patients (1,677) were under active neurology follow-up and had been seen in a neurology outpatient clinic in the year preceding admission. While there was no significant difference in sex distribution between the two groups, patients under active neurology follow-up were significantly younger (Mann–Whitney *U* = 18.27; $p < 0.001$) and from more deprived areas as measured by IMD decile (Mann–Whitney *U* = 5.174; $p < 0.001$) compared to those not under active neurology follow-up. The median number of hospital admissions (spells) for the whole population equalled 1 (IQR 1–2) and ranged from 1 to 29 over the 3-year period. Patients under active neurology follow-up had significantly more hospital admissions

Table 1. Demographic details

	Not under active neurology follow-up, n=2,833	Under active neurology follow-up, n=1,350	Test statistic
Male, n (%)	1,467 (54.3)	758 (51.22)	$\chi^2=7.00$; $p=0.008$
Median age, years (IQR)	61 (44–76)	48 (33–61)	Wilcoxon rank-sum (Mann–Whitney U) = 16.64; $p<0.001$
CCI score = 0 (%)	1,411 (49.81)	903 (66.9)	$\chi^2=147.4$; $p<0.001$
CCI score = 1 (%)	759 (26.8)	321 (23.8)	
CCI score ≥ 2 (%)	663 (23.4)	126 (9.3)	
Index of multiple deprivation decile median (IQR)	3 (1–6)	2 (1–5)	Wilcoxon rank-sum (Mann–Whitney U) = 6.657; $p<0.001$

CCI = Charlson Comorbidity Index; IQR = interquartile range.

compared to patients not under neurology follow-up (Mann–Whitney U = -14.4 ; $p<0.001$).

Over the 3-year period, 31.2% of patients admitted with a seizure not under active neurology follow-up and 32.9% under neurology follow-up received at least one CT of the head during their hospital spell (Table 2). There was significant variability in CT of the head use among trusts: for patients under active neurology follow-up this ranged from 13.9% to 44.4% ($\chi^2=53.6$; $p<0.001$), and patients not under active neurology follow-up from 16.3% to 42.7% ($\chi^2=102.0$; $p<0.001$).

Over 3 years there was a decrease in the proportion of CT of the head performed in patients under active neurology follow-up ($p=0.045$). This compared to an increase in those not under active neurology follow-up which did not reach statistical significance ($p=0.201$), see Table 2.

Some patients with multiple admissions had multiple CT of the head (Table 3); 27 patients under active neurology follow-up received four or more scans within the 3-year period, with one patient receiving a total of eight CT of the head over this timeframe.

Patients admitted with seizures with a concomitant diagnosis of trauma for that admission were more likely to have a CT of the head compared to patients admitted with a seizure without a concomitant trauma code as a main diagnosis ($\chi^2=21.70$; $p<0.001$).

Logistic regression modelling identified older age, concomitant head and neck trauma, and hospital provider as associated with CT. No association was found with active neurology follow-up, IMD decile or CCI score (Table 4).

Discussion

This population-based analysis identifies a high rate of CT of the head in those admitted following a seizure in the Cheshire and Merseyside region of the UK. The decision to perform CT when patients present with a seizure is typically undertaken early in a patient's hospital admission, usually in the ED or under the care of acute medical specialties. While patients admitted to hospital with seizures may represent a cohort of patients with more complex presentations compared to those who attend the ED with simple seizures and are discharged straight home, this rate of scanning is difficult to justify and is likely to represent unnecessary radiation exposure and poor use of resources.

Many patients in our sample were under active neurology follow-up, but that had no impact on scanning rates and they were just

as likely to be scanned as those not under active follow-up, even though most are likely to have an established diagnosis of epilepsy, having been investigated with MRI and other investigations as appropriate. For these patients, acute CT is very unlikely to inform management. In contrast, those not under active follow-up, including those with a first seizure, may be more likely to have an unknown or acute intracranial lesion, and therefore benefit from acute neuroimaging. Our regression model found that older patients and those coded as having a head injury were more likely to be scanned indicating that some patient factors did impact on the clinical decision to proceed to a scan, but neither deprivation nor the CCI score had an impact on scanning rates.

Table 2. Proportion of patients having computed tomography of the head during first spell (hospital admission) over 3-year period by hospital trust and year

	Not under active neurology follow-up, total n=2,833, n (%)	Under active neurology follow-up, total n=1,350, n (%)
Whole population	884 (31.2)	433 (32.9)
Grouped by hospital trust		
Trust A	134 (37.0)	103 (34.6)
Trust B	60 (34.7)	25 (34.3)
Trust C	109 (21.9)	8 (28.6)
Trust D	199 (37.7)	117 (37.9)
Trust E	70 (16.3)	34 (13.9)
Trust F	134 (42.7)	67 (44.4)
Trust G	178 (33.7)	79 (32.1)
Grouped by year		
2014–2015	336 (28.9)	198 (33.8)
2015–2016	293 (31.5)	132 (32.9)
2016–2017	255 (34.3)	103 (28.4)
Test statistic	$\chi^2=6.18$; $p=0.045$	$\chi^2=3.20$; $p=0.071$

CT = computed tomography.

Table 3. Cumulative number of computed tomography of the head performed over the 3-year period by patient

Numbers of CT of the head	Not under active neurology follow-up, total n=2,703	Under active neurology follow-up, total n=1,480	Total, grand total n=4,183
0, n (%)	1,724 (63.78)	809 (54.66)	2,533
1, n (%)	863 (31.93)	501 (33.85)	1,364
2, n (%)	81 (3.00)	108 (7.30)	189
3, n (%)	22 (0.81)	35 (2.36)	57
4 or more, n (%)	13 (0.38)	27 (1.82)	40
			$\chi^2=88.3; p<0.001$

CT = computed tomography.

Importantly we also found considerable variability in scanning rates among hospitals, which ranged from 15.4% (medium-sized district general hospital) to 44.3% (large teaching hospital) and cannot be explained by differences in case mix. This variability is

most likely to represent the availability of emergency CT at each site, individual trust pathways and policies and individual clinician decision making. These are the factors that need most to be addressed if we are to ensure appropriate use of CT.

There are a few limitations which should be considered when interpreting the findings of this work. Firstly, we used pseudonymised SUS data which allowed us to search a regional dataset to identify 4,183 patients admitted to hospital with seizures over a 3-year period. While the sample size is large, we did not have access to clinical case notes, and were unable to evaluate the clinical decision-making process and assess whether this was guideline compliant. We were therefore unable to assess the appropriateness of emergency CT requests on an individual patient basis. Despite this, our results are likely to underestimate the true proportion of patients undergoing emergent CT of the head given our use of OPCS-4 data which relies on correct coding and translation from patient notes into the SUS database. Thirdly, the region studied represents a more deprived area of the UK, it is possible that engagement with medical services and relative use of inpatient and outpatient neuroimaging may differ in other areas in the UK.

Call for change

Firstly, we propose that patients with epilepsy under neurology follow-up have individualised treatment plans and are educated as to when is appropriate and necessary to present to the ED. This may limit ED attendance to only when is necessary and resultantly lead to reduced exposure to investigations which may not be required.

Secondly, previous research has demonstrated that clinicians less familiar with a patient's background are more likely to order emergency CT of the head in patients who present with seizures.²¹ It is possible that high rates of CT of the head observed in our analysis in patients already under active neurology follow-up can be, in part, explained by a lack of access to information about previous investigations and diagnoses. At present, data regarding diagnoses and clinical history are frequently not available early in a patient's admission to hospital in the UK, especially when admitted out of working hours. We propose a call for increased healthcare data sharing within and across local regions, so that clinicians can make better informed decisions regarding the initial management of patients who present acutely to hospital with seizures. This should reduce the number of unnecessary scans performed in this patient group and lead to improved patient outcomes and improved resource utilisation.

Table 4. Logistic regression model

	Odds ratio	SE	z-score	p value	95% CI
Active neurology follow-up	1.07	0.08	0.94	0.348	0.93–1.23
Age, years					
16–19	N/A	N/A	N/A	N/A	N/A
20–29	1.12	0.28	0.46	0.648	0.69–1.82
30–39	1.71	0.42	2.16	0.030	1.05–2.77
40–49	1.72	0.42	2.25	0.025	1.07–2.76
50–59	1.93	0.47	2.73	0.006	1.20–3.10
60–69	2.34	0.57	3.50	<0.001	1.45–3.77
70–79	2.48	0.62	3.68	<0.001	1.53–4.04
≥80	2.35	0.59	3.41	0.001	1.44–3.84
IMD decile (reverse)	1.01	0.01	0.44	0.661	0.98–1.03
Head/neck trauma	1.58	0.13	5.64	<0.001	1.35–1.85
CCI score = 0	N/A	N/A	N/A	N/A	N/A
CCI score = 1	1.04	0.08	0.47	0.637	0.89–1.21
CCI score ≥2	1.18	0.11	1.74	0.089	0.98–1.41
Hospital provider					
Trust E	N/A	N/A	N/A	N/A	N/A
Trust B	3.58	0.62	7.37	<0.001	2.55–5.03
Trust C	1.72	0.24	3.81	<0.001	1.39–2.27
Trust D	3.68	0.44	10.83	<0.001	2.91–4.67
Trust A	3.43	0.43	9.77	<0.001	2.68–4.40
Trust F	4.60	0.62	11.22	<0.001	3.52–6.00
Trust G	3.18	0.39	9.54	<0.001	2.51–4.04

Trust E was used as a reference category to investigate differences in providers. CCI score = Charlson Comorbidity Index score; CI = confidence interval; IMD = Index of Multiple Deprivation; N/A = not applicable; SE = standard error.

Further research

Future work should be performed in the UK in a range of areas with different levels of deprivation to validate the generalisability of the results across the entire population. The reasons for excess CT should be further explored, ideally in studies using both qualitative and quantitative approaches, the aim being to identify potential interventions and organisational changes that could be implemented. One option is to assess the utility of national cross-sectional imaging guidelines for the management of patients presenting acutely to hospital with seizures, whether known epilepsy or not. Furthermore, real-time analysis of CT use following guideline implementation may demonstrate reduced inappropriate CT and improved healthcare resource allocation with the implementation of such measures.

Conclusion

We have identified a high rate of CT of the head for patients admitted with seizures in Cheshire and Merseyside, as well as considerable variability in scanning rates among hospitals, indicating poor use of resources and unnecessary radiation exposure, particularly for patients with known epilepsy. This variability highlights the influence of institutional culture and processes, and it is important to explore reasons as well as processes, pathways, guidelines and educational packages to ensure that CT is used appropriately. ■

Supplementary material

Additional supplementary material may be found in the online version of this article at www.rcpjournals.org/content/clinmedicine/51 – Algorithm, codes, follow-up and identification.

Conflicts of interest

This project is part-funded by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care North West Coast (CLAHRC NWC). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care (DHSC).

Connected Health Cities is a Northern Health Science Alliance (NHS) led programme funded by the DHSC and delivered by a consortium of academic and NHS organisations across the north of England. The work uses data collected by the NHS as part of their care and support. The views expressed are those of the authors and not necessarily those of the NHS, NHS or the DHSC.

Acknowledgements

The authors would like to acknowledge support from the NIHR CLAHRC NWC.

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