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Emergent cranial computed tomography in the evaluation of adult non-trauma patients in the emergency department

緊急頭顱電腦掃描對急症室非創傷性成年病者之評估

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Objectives: To study the utilisation pattern of head computed tomography (CT) for non-trauma adult cases in an urban emergency department (ED) and the rate of clinically significant CT abnormalities. We also tried to identify any useful clinical indicators that could be used to predict abnormal scans. *Methodology:* A one-year case series of adult non-trauma cranial CT scans ordered in an urban ED was studied. Patients less than 16 years old, with CT head done prior to presentation and/or attendance precipitated by trauma were excluded. Logistic regression was used to identify significant predictors for abnormal scans. Clinical indicators that were studied included age, altered mental status (AMS), headache and vomiting, elevated blood pressure, previous history of hypertension, Glasgow Coma Scale (GCS) and presence of focal neurological sign (FNS). *Results:* 183 adult non-trauma cranial CT scans were included in the study, and 109 (59.6%) CT scans revealed clinically significant abnormalities. Only AMS and FNS were found to be statistically significant in predicting abnormal scans. Patients with AMS had a 2.5 times (95% CI: 1.1 to 5.8) higher odds for an abnormal scan compared to those without AMS, adjusting for FNS. Patients with FNS had adjusted odds of 8.9 (95% CI: 4.2 to 18.8). *Conclusion:* This study reports a high (59.6%) rate of abnormal adult non-trauma cranial CT compared with previous studies. Altered mental status and the presence of focal neurological sign are significant predictors for an abnormal scan. They should serve as useful criteria when devising utilisation strategies for emergency non-trauma cranial CT in future studies. (*Hong Kong j.emerg.med.* 2004;11:197-204)

目的：研究在一所市區的急症室中，非創傷性成年病者頭部電腦掃描的使用模式及其臨床上重要的異常率。還嘗試去識別可用於預測異常掃描影像的臨床指標。**方法：**研究一所市區的急症室一年來非創傷性成年病者進行頭顱電腦掃描的個案系列，並不包括 16 歲以下，到診前已進行了頭部電腦掃描及因創傷求診的病者。採用邏輯斯諦回歸法去識別可預測異常掃描影像的重要因子。研究的臨床指標包括年齡、精神狀態變異、頭痛及嘔吐、高血壓、高血壓的病歷、格拉斯哥昏迷指數及局部神經病徵。**結果：**研究共包括 183 名非創傷成人頭顱的電腦掃描影像。其中 109 影像（59.6%）顯示出臨床上重要的異常，並發覺只有精神狀態變異及局部神經病徵在統計學上顯著地預測異常的掃描影像。當校正局部神經病徵因素後，精神狀態變異的病者有異常掃描影像的可能性比精神狀態正常的病者高 2.5 倍（95% 置信區間：1.1 至 5.8）。有局部神經病徵的病者經校正後的異常影像可能性高 8.9 倍（95% 置信區間：4.2 至 18.8）。

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總結：這研究報告的非創傷性成人頭顱電腦掃描異常率（59.6%）比過往的為高。精神狀態變異及局部神經病徵為異常掃描影像的重要預報因子，在將來研究設計緊急非創傷性頭顱電腦掃描的使用策略時，它們應是有用的準則。

Keywords: Emergencies, radiography

關鍵詞：急症、放射照相術

Introduction

Cranial computed tomography (CT) is an important diagnostic tool in the emergency department (ED) evaluation of patients with suspected intracranial pathology. Emergent cranial CT in the event of trauma has been widely studied.[1-4] For the non-trauma ED population, several neuroimaging guidelines and recommendations are available for separate clinical presentations such as stroke, acute headache and first seizure.[5-7] These guidelines are evolving as new evidence emerges. Under different clinical circumstances (e.g. acute vs chronic headache, first vs recurrent seizure), recommendations of different strengths for conducting an emergent CT scan in the ED have been put forward.

An alternative approach is to consider all non-trauma cases and identify clinical indicators commonly associated with abnormal CT scans, to increase the yield of clinically significant abnormal findings. Studies that investigated clinical criteria useful for separating patients into high- and low-risk categories for clinically significant cranial CT abnormalities have yet to be validated in prospective studies.[8,9]

The value of a CT scan will be increased if confirmation or exclusion of the suspected intracranial pathology guides the management pathway, such as treatment and patient disposal. The less tangible value is that of reassurance from a normal scan result.

Missing a life-threatening condition (e.g. subarachnoid haemorrhage) and incorrect disposal of patients from the ED may result in adverse patient outcomes and may also result in medicolegal consequences. Thus, appropriate utilisation and understanding of the cost-effectiveness of the CT as an investigation is required for the ED physician.

This is the first local study performed to examine the utilisation pattern of adult non-trauma cranial CT in an urban ED and the rate of clinically significant abnormal findings. We were also interested in clinical features which were significantly associated with and/or predictive of abnormal scans.

Subjects and methods

Subjects

The ED in Changi General Hospital has an annual attendance of about 120,000. A one-year retrospective study was conducted on all 183 adult non-trauma CT scans ordered between 1st January 2002 to 31st December 2002 in our ED. During the study period, the ED did not have set criteria for the ordering of cranial CT in non-trauma cases. Decision to scan the patient in the ED was based on clinical assessment by the attending physician. Patients less than 16 years old, with CT head done prior to presentation and/or attendance precipitated by trauma were excluded. Patients with clinical evidence of head injuries such as haematoma or abrasion were excluded.

Altered mental status (AMS) was defined as a change in level of awareness that can occur without becoming unconscious, or before becoming unconscious. It included patients with sudden confusion, disorientation, or stupor. Elevated blood pressure was defined as systolic blood pressure ≥180 with diastolic ≥110 on first reading in the ED. A focal neurological deficit was considered present when a change in nerve function in a specific location (as opposed to general

loss of consciousness) was noted. The type, location, and severity of the neurologic change can indicate the area of the brain or nervous system involved. Clinically significant abnormal CT scans were broadly defined as: (1) acute stroke (non-haemorrhagic); (2) intracranial bleeding; (3) acute hydrocephalus; (4) intracranial malignancy; (5) intracranial infection or a combination of these findings. All other CT findings (e.g. cerebral atrophy, periventricular white matter ischaemia) were considered not clinically significant.

Statistical analysis

Multiple logistic regression was performed to identify significant predictors for abnormal CT scans. The seven clinical indicators investigated were: age, altered mental status (AMS), headache and vomiting, history of hypertension, Glasgow Coma Scale (GCS), presence of focal neurological sign (FNS) and elevated blood pressure. Variables with p-values <0.05 were considered significant. All calculations were performed using SPSS version 10.0 (SPSS Inc, Chicago, IL).

Results

The demographics and clinical characteristics of the 183 non-trauma patients are shown in Table 1. The ratio of males to females was approximately 1:1. The

Table 1. Demographic and clinical characteristics of the 183 patients

	CT Head Scan		
Variable*	Abnormal (n=109)	Normal (n=74)	Total (N=183)
A) Demographics			
Gender			
Male	57 (52.3)	37 (50.0)	94 (51.4)
Female	52 (47.7)	37 (50.0)	89 (48.6)
Race			
Chinese	66 (60.6)	43 (58.1)	109 (59.6)
Malays	30 (27.5)	14 (18.9)	44 (24.0)
Indians	5 (4.6)	7 (9.5)	12 (6.6)
Others	8 (7.3)	10 (13.5)	18 (9.8)
Median age (IQR)	64.0 (23.0)	57.0 (37.8)	58.4 (28.0)
Range	(23, 93)	(17, 90)	(17, 93)
B) Blood Pressure in ED			
Median Systolic BP (IQR)	160.5 (59.5)	134.0 (46.5)	151.0 (59.5)
Median Diastolic BP (IQR)	89.0 (38.75)	80.0 (36.0)	86.0 (35.0)
Elevated BP†	48 (44.4)	17 (23.3)	65 (35.9)
C) ED History			
Altered mental status	90 (82.6)	53 (71.6)	143 (78.1)
Headache and vomiting	17 (15.6)	9 (12.2)	26 (14.2)
Focal weakness	25 (22.9)	11 (14.9)	36 (19.7)
Focal numbness	7 (6.4)	3 (4.1)	10 (5.5)
Giddiness	17 (15.6)	9 (12.2)	26 (14.2)
Vertigo	1 (0.9)	1 (1.4)	2 (1.1)
Fever	11 (10.1)	8 (10.8)	19 (10.4)
Neck stiffness	1 (0.9)	1 (1.4)	2 (1.1)
Seizures (prehospital or in ED)	21 (19.3)	22 (29.7)	43 (23.5)
History of hypertension	47 (43.1)	25 (33.8)	72 (39.3)
History of alcohol ingestion or intoxication	2 (1.8)	4 (5.4)	6 (3.3)
History of known underlying neoplasm	3 (2.8)	3 (4.1)	6 (3.3)
D) ED Clinical Finding			
Seizures witnessed in ED	16 (14.7)	13 (17.6)	29 (15.8)
Focal neurological sign‡	82 (82.8)	25 (37.9)	107 (64.8)
Median GCS (IQR)	10.0 (9.0)	11.0 (7.25)	10.0 (7.0)

*Figures shown in the above table are counts, with percentages expressed in brackets unless otherwise indicated; †Missing data: Abnormal (n=108), Normal (n=73), Total (N=181); ‡Missing data: Abnormal (n=99), Normal (n=66), Total (N=165).
IQR=interquartile range

majority of patients were Chinese followed by Malays. The median age was 58.4 years. One hundred and forty-three patients (78.1%) had AMS and 65 out of 165 records (39.4%) had GCS 8 or less. The median GCS for scanned patients was 10. Forty-five (24.6%) patients had headache while 26 (14.2%) had both headache and vomiting. Forty-three (23.5%) patients who underwent scanning had seizures, either pre-hospital and/or witnessed in the ED. FNS were noted in 107 out of 165 (64.8%) patients, as neurological examination was either cursory or inadequately documented in 18 cases.

One hundred and nine (59.6%, 95% CI: 52.5% to 66.7%) of the 183 CT scans revealed clinically significant abnormalities. Table 2 shows the diagnoses of patients with clinically significant abnormal CT. Sixty-two (56.9%) patients had intracranial bleeding, and 34 (31.2%) had acute non-haemorrhagic stroke. Of these 109 patients with abnormal scans, 55 (50.5%) were admitted to the general ward, 40 (36.7%) to intensive care/high dependency unit, 12 (11.0%) were transferred to another hospital, 1 went for urgent surgery in the operating theatre and 1 self-discharged against advice. In comparison, of the 74 patients who did not have clinically significant scan findings, 58 (78.4%) were admitted to the general ward and 16 (21.6%) to intensive care/high dependency. These 16 patients included one patient with impaired consciousness. He had a repeat cranial CT within 24 hours which revealed intracranial bleeding. Of the remaining 15 patients, 4 had septic shock, 3 were hypertensive emergencies, 2 suspected drug overdose, 2 diabetic ketoacidosis, 2 presented with seizures, 1 was acute myocardial infarction and 1 near-drowning case.

Table 2. Diagnoses of patients with clinically significant abnormal CT

Diagnoses	Number
Intracranial bleeding	62
Parenchymal haemorrhage	44
Subarachnoid haemorrhage	15
Subdural haemorrhage	3
Acute non-haemorrhagic stroke	34
Intracranial malignancy	11
Tumour-related haemorrhage	3
Intracranial infection	1
Acute hydrocephalus	1
Total	109

The gender and ethnic distributions were similar among patients with and without abnormal CT scans. Patients with abnormal scans had a higher median age of 64.0 years compared to 57.0 years in patients with normal scans. Higher proportions of patients with elevated blood pressure, altered mental status, focal weakness, history of hypertension and focal neurological sign were observed in patients with CT abnormalities, while patients with normal CT scans tend to have a higher rate of prehospital seizures (Table 1). The proportions of patients with headache and vomiting, focal numbness, giddiness, vertigo, fever, neck stiffness, history of alcohol ingestion/ intoxication or history of known underlying neoplasm were similar in both groups. Median GCS were also similar.

Individual (univariate) logistic regression analysis of abnormal scans on the clinical parameters AMS, elevated blood pressure, presence of FNS, GCS, headache and vomiting, history of hypertension and age (≥60) showed elevated blood pressure, presence of FNS and possibly AMS to be major variables associated with abnormal scans (Table 3).

When all seven variables listed in Table 3 were entered simultaneously into a logistic regression model, treating age and GCS as continuous, only altered mental status and the presence of focal neurological deficit were found to be statistically significant with p-values <0.05. These two variables were then entered simultaneously into the final logistic regression model (Table 4). The odds of an abnormal scan for a patient with AMS was 2.5 times that of the odds of an abnormal scan for a patient without AMS, adjusting for FNS status while patients with FNS had an increased odds of 8.9 times compared to those without FNS.

Table 3. Univariate logistic regression analysis of the clinical parameters of interest

	CT Head Scan			
Variable*	Abnormal (n=109)	Normal (n=74)	Odds ratio	95% Confidence Interval
Focal neurological sign†				
No	17 (17.2)	41 (62.1)	1	
Yes	82 (82.8)	25 (37.9)	7.91	3.85 to 16.27
Elevated BP‡				
No	60 (55.6)	56 (76.7)	1	
Yes	48 (44.4)	17 (23.3)	2.64	1.36 to 5.11
Altered mental status				
No	19 (17.4)	21 (28.4)	1	
Yes	90 (82.6)	53 (71.6)	1.88	0.93 to 3.81
Age ≥60				
No	43 (39.4)	38 (51.4)	1	
Yes	66 (60.6)	36 (48.6)	1.62	0.89 to 2.94
GCS ≤8†				
No	56 (56.6)	44 (66.7)	1	
Yes	43 (43.4)	22 (33.3)	1.54	0.80 to 2.94
History of hypertension				
No	62 (56.9)	49 (66.2)	1	
Yes	47 (43.1)	25 (33.8)	1.49	0.81 to 2.74
Headache and vomiting				
No	92 (84.4)	65 (87.8)	1	
Yes	17 (15.6)	9 (12.2)	1.34	0.56 to 3.18

*Figures shown in the above table are counts, with percentages expressed in brackets unless otherwise indicated; †Missing data: Abnormal (n=99), Normal (n=66), Total (N=165); ‡Missing data: Abnormal (n=108), Normal (n=73), Total (N=181).

Table 4. Multiple logistic regression

Variable*	Regression coefficient	Standard error	Odds ratio	95% Confidence Interval	p-value
Focal neurological sign	2.18	0.38	8.87	4.19 to 18.77	<0.001
Altered mental status	0.92	0.42	2.52	1.10 to 5.78	0.030
Constant	-1.64	0.47	-	-	<0.001

*165 patients were included in this analysis. The 18 cases excluded had missing FNS data.

Discussion

Conducting an emergency cranial CT evaluation in the ED consumes resources such as time and manpower from the department. Often, the question arises as to whether the number of non-trauma cranial CT could be judiciously reduced.[10] Emergent CT conducted in the ED should aim at immediate patient management basing on its results. The clinical impact may be upon treatment, prognosis and disposal. It could expedite patients who need urgent operative intervention or influence decision to admit patients to a higher level of care (e.g. intensive care unit). The ED physician needs to understand the cost-effective usage of this diagnostic tool under different clinical circumstances in order to improve patient outcome and minimise cost.

This is the first local study on the utilisation pattern and rate of clinically significant abnormal CT for non-

trauma patients in an emergency department in Singapore. Significant abnormal scans were divided into five broad categories similar to previous studies on emergency cranial CT evaluation. We report a high rate (59.6%) of abnormal CT findings compared with these previous studies (8%, 35%).[8,9] This could possibly be explained by different selection methods for scanning and patient disease factors.

A prospective, observational study conducted by Rothrock et al on 806 non-traumatic adult cranial CT performed in the EDs of two hospitals revealed only 61 (8%) cases with clinically significant abnormalities.[8] The most frequent chief complaints in their study were headache (36%), altered mental status (22%), and focal weakness (18%); and 71 (9%) had chief complaint as seizure.

In our study, the most common presentation was altered mental status (78.1%). Out of the 183 CTs conducted, 165 had GCS documented. The median GCS was 10, and 65 (39.4%) patients had GCS ≤8. We were unable to establish the GCS in 18 patients. The second most common finding was the presence of focal neurological signs (64.8% of documented cases). Headache was noted in only 24.6% of our patients. It appears that our scanned population was clinically more ill with a substantial number incapable of giving complete history due to altered mental status and decreased level of consciousness.

Rothrock et al found the presence of any of the following: age ≥60 years, focal neurological deficit, headache with vomiting, or altered mental status, was 100% sensitive and 31% specific in detecting clinically significant CT scans. A subsequent study by Harris et al in a four month period on 62 patients similarly found the presence of any of these criteria (with alteration of "headache with vomiting" to "headache with nausea or vomiting") 100% sensitive for significant scan findings.[9] The application of Rothrock's criteria to our scanned cohort would have missed three cases with clinically significant abnormal scans. They included two cases with intracranial malignancy and one subarachnoid haemorrhage (SAH). This is not unexpected as the identification of highly sensitive criteria for ordering CT for all non-trauma cases is a very difficult task considering the wide range of disorders that can cause intracranial pathology. Failure of repeatability of criteria may also be contributed by epidemiological differences in disease. When multivariate logistic regression was applied to our data, altered mental status (AMS) and focal neurological sign (FNS) were statistically significant predictors of abnormal scans. This concurred with Rothrock's findings. We believe that they should serve as useful criteria when devising utilisation strategies for non-trauma cranial CT in future studies.

In the setting of an acute stroke, emergency CT scans help to define the nature of the stroke. Clinical practice guidelines recommend brain scanning (CT or MRI) as soon as possible, preferably within 24 hours for all patients with acute stroke.[11] Our current in-hospital stroke pathway suggests cranial CT scan in the ED if patients are "drowsy" or when intracranial haemorrhage is suspected.[12] The diagnosis of a haemorrhagic stroke in the ED from historical and clinical features alone is often difficult. Stroke scoring systems have been found to be unreliable in distinguishing ischaemic from haemorrhagic strokes.[13] More objective indications for scanning should be made available. Possible interventions should haemorrhage be detected on head scan would include withholding administration of aspirin, reversal of anti-coagulation and urgent neurosurgical consultation. Currently, thrombolysis is not considered as routine therapy in acute ischaemic stroke in Singapore.[11] Thus, the impetus to rapidly rule out intracranial haemorrhage within a short time is not present locally.

A local CT-based study of hospitalised stroke population showed that 74.0% were due to infarct, 24.2% intracranial haemorrhage and 1.8% SAH.[14] The high prevalence of intracranial bleeding (56.9%) compared to acute cerebral infarct (31.2%) detected in this study is in contrast with these statistics. This may suggest that our ED physicians were already selecting for cases with a higher likelihood of bleeding in acute stroke cases.

Headache in the ED patient without trauma may be a symptom of primary [benign] (e.g. migraine, tension headache) or secondary [sinister] (e.g. SAH, meningitis) causes. The ED physician needs to determine who needs an emergent CT scan. This decision cannot be achieved without a carefully taken history and physical examination. In primary headaches, headache is the dominant complaint and there are no signs of intracranial pathology. In these patients with recurrent headache of a defined pattern, no seizures and no focal signs/symptoms, the yield from imaging is extremely low.[15] According to local practice guidelines, neuroimaging is generally not needed in primary headaches.[16]

The American College of Emergency Physicians (ACEP) recommends with "moderate clinical certainty" emergent noncontrast head CT scan for patients presenting to the ED with headache and abnormal findings in a neurologic examination (i.e. focal deficit, altered mental status, altered cognitive function). Patients with acute sudden-onset headache should also be considered for emergent head CT scan.[6] The US Headache Consortium has reviewed studies on chronic headache.[17] They found the presence of an abnormality on the neurologic examination increased the likelihood of positive results in a neuroimaging study threefold (95% CI 2.3 to 4.0). Normal findings in neurologic examination reduced the odds of positive findings by 30%.

Our study was unable to make meaningful conclusions with regard to headache subtypes and scan abnormalities. Descriptions of headache characteristics were often poorly defined and documented. Forty-five (24.6%) of our scanned patients complained of headaches, and 29 out of the 45 (64.4%) had abnormal scan results. Keeping in mind that headache might not have been the chief complaint, and that many had combinations of other clinical findings (e.g. abnormal neurological examination), 20 of these scans showed intracranial bleeding.

Emergent neuroimaging should be performed for patients with first-time seizure or epileptics with recurrent seizure(s) when the provider suspects a serious structural lesion. Clinical studies have shown a higher frequency of life-threatening lesions in patients with new focal deficits, persistent altered mental status (with or without intoxication), fever, recent trauma, persistent headache, history of cancer, history of anticoagulation, or suspicion of AIDS. This guideline was established by a panel represented by ACEP, the American Academy of Neurology (AAN), the American Association of Neurological Surgeons (AANS), and the American Society of Neuroradiology (ASN).[7] Using a similar approach, our department has scanned 43 non-trauma adult patients with either pre-hospital or ED-witnessed seizures within the study period. Half of these scans had clinically significant abnormalities.

Limitations

It is not the objective of this paper to identify criteria for CT utilisation. The retrospective nature of this study makes that impossible. However, we see value in presenting two factors (altered mental status and presence of focal neurological sign) which were predictive of abnormal scan findings in our series.

We faced problems with data collection that are inherent to studies of a retrospective nature. Some case-sheets had poor documentation of neurological examination. Description of seizure characteristics or nature of headaches was often inadequate. GCS was routinely documented even though the cases did not involve trauma. Nevertheless, we failed to establish it in 18 (~10%) patients.

Lastly, the study was limited to a single urban ED in Singapore.

Conclusion

The ED physician needs to recognise the indications for emergent neuroimaging with CT in different clinical circumstances outside trauma. Improvement on the cost-effective utilisation of this diagnostic tool can then be made. This study reports a high (59.6%) rate of abnormal CT findings compared with previous

studies. Altered mental status and the presence of focal neurological sign are significant predictors for an abnormal scan. They should serve as useful criteria when devising utilisation strategies for emergency non-trauma cranial CT in future studies.

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