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ORIGINAL RESEARCH

Role and impact of brain computed tomography in the management of drug overdoses and guideline recommendations

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Abstract

Objective: Patients presenting with overdoses commonly receive computed tomography brain (CTB) scans in their assessment. There is no current guideline or validated decision support tool for neuroimaging in overdose patients. We investigated the proportion of overdose patients who received a CTB scan and its impact on management.

Methods: A single site retrospective study was conducted to analyse drugs and alcohol overdose-related presentations over a 2 year period. Outcome measures were the proportion of patients who received a CTB scan and the proportion of those who had an associated change in management. A decision support tool to guide the indications for CTB in overdose patients was developed based on this.

Results: A total of 7521 drugs and alcohol-related presentations were screened, where 4086 were overdoses. This involved 3200 patients. CTB scans were conducted in 519 (12.7%) of presentations. The majority of patients with CTB did not have head injury (n = 325, 62.5%). Of 519 CTB scans, 25 (4.8%) were abnormal of which 20 (3.9%) were associated with a change in management. A decision support tool was devised and tested and provided a relatively high yield where a CTB could be justified.

Conclusions: A high proportion of overdose patients received CTB scans. There was only a low yield in terms of management alteration. We propose that clinicians adopt a guided approach using a decision support tool to minimise unnecessary CTB scans.

Key words: *computed tomography, intoxication, neuroimaging, overdoses, poisoning.*

Key findings

- A high proportion of patients presenting with overdose receive CTB scans which were low yield and did not change clinical management.
- A guided approach using a decision support tool could minimise unnecessary CTB scans.
- Prospective studies for the validation of the 'HEAD' decision support tool for CTB indications in overdoses are required prior to clinical adoption.

Introduction

Poisoning represented 1% of all ED presentations according to the 2016–2017 Australian hospital statistics on ED care, with 40% of these requiring admission.[1] In addition to standard care, patients presenting with poisoning commonly receive a computed tomography brain (CTB) scan. The Canadian CT Head Rule[2] for minor head injury is the recommended guideline by the Australasian College for Emergency Medicine and the Royal Australian and New Zealand College of Radiologists.[3] There is no current guideline specific to neuroimaging in overdoses and no validated tool to aid in decision making in this cohort. The decision to perform CTB is often made based on the perceived need to rule out a differential or additional diagnosis. Other groups have demonstrated that unnecessary tests can be avoided with the use of clinical decision-making tools in areas such as imaging for pulmonary embolism[3–5] and ankle injuries.[3,6,7]

Objectives

Our objective was to investigate the proportion of patients with overdose presentations who received a CTB scan and its impact on management.

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We then developed and retrospectively tested a decision support tool to guide clinicians regarding the decision to order neuroimaging in these patients.

Evidence review

A MEDLINE® search was conducted to seek existing guidelines and recommendations for CTB in overdose cases. Search terms used were 'overdose', 'poisoning', 'intoxication', 'computed tomography' and 'neuroimaging'. The database between 1996 to the date of search returned 438 articles. These were screened by titles and abstracts, with full texts read where relevant to locate guidelines for undertaking CTB in overdose cases. There were 157 overdose-relevant articles, the majority of which were case descriptions. No specific guidelines for the place of CTB in overdoses were found.

Methods

Study design

A single site retrospective cohort study was conducted to analyse the data for drugs and alcohol overdose-related presentations and admissions over a 2 year period from 1 May 2014 to 1 May 2016 inclusive. Data was obtained from electronic clinical information databases. All ED attendances with drugs and alcohol-related presentations were obtained via the DXC Emergency Department Information System (EDIS) software. Additional data was obtained from the Health Information records for patients who were admitted but may not have been identified through EDIS. Information including discharge summaries, pathology and imaging results was obtained from WebdeLacy™, a centralised electronic source for clinical information.

This study was approved by the hospital's Human Research Ethics Committee.

Screening process and inclusion criteria

Broadly, the inclusion criterion was 'overdose presentation'. Patients were identified as follows – EDIS was screened by the diagnoses registered and triage and assessment histories. Overdose-related keywords ('poisoning', 'intoxication', 'overdose', 'drug affected', 'suicide', 'suicidal attempt' and 'drug induced mental disorder') were used to help identify relevant presentations. Admission episodes were screened based on primary diagnoses via the Health Information records, these being ICD-10 diagnostic codes of intoxication or poisoning. Discharge summaries, laboratory and imaging results were also referred to. Final diagnoses entered into our database were a combination of free-hand texts and ICD-10 codes from the databases. Laboratory results used included blood alcohol concentrations, plasma drug concentrations and urine drug screens. CTB request reasons and reports were sought. Finally, disposition of patients was noted.

Outcome measurements

Outcomes were the proportion of patients with overdose having received a CTB within the same attendance and the proportion of these who had a change in their management. A change in management was defined as an admission under specialist teams other than Emergency Medicine, interventions such as neurosurgical procedures, or further neuroimaging.

Statistical analysis

For statistical analysis, sensitivity, specificity and odds ratio were employed. For continuous variables, *t* tests were applied while χ^2-tests were used for categorical variables. All tests were two-tailed, with a *P*-value of <0.05 considered statistically significant.

Tool design

Possible presentations or complications in overdoses that were considered appropriate reasons for ordering neuroimaging were explored. A decision support tool was developed by consensus between the authors and applied retrospectively to the dataset.

Results

There were 7521 drugs and alcohol-related presentations. Of these, 4086 presentations involving 3200 patients were included having met the inclusion criterion and screening processes. CTB was undertaken in 519 of 4086 presentations (12.7%). A total of 485 patients received a CTB scan. Of these, 25 patients who had repeat presentations received more than one CTB, with a median of two, to a maximum of four scans each in two patients. Of the 519 scans, 25 (4.8%) had an abnormal result reported. Overall, 3.9% (n = 20) of all presentations with CTB performed was associated with a change in management (Fig. S1).

Although not a paediatric hospital, 84 patients under age-18 fulfilled criteria of overdose-related presentation – one aged 2, and 83 aged 14–17. The 2 year old was excluded from further analysis. A small proportion had a concomitant history of head injury (n = 234, 5.7%). Types of overdose were divided into alcohol only (33.6%), and others (including co-ingestion with alcohol, 66.4%). Approximately 82.0% had overdose-related diagnoses at the time of discharge, which were 'poisoning', 'intoxication' and 'overdose', while the others had diagnoses (Table S1) not necessarily relating to the overdose presentation.

Figure 1 shows the various drugs identified in all overdose presentations, and those presentations that received a CTB scan. Alcohol was identified in 54.6% (n = 2229) of presentations, either exclusively or co-ingested with other drugs. The next most common were sedative drugs (37.4%, n = 1528), then stimulant-type drugs (26.7%, n = 1090). The sedative drugs included opioids, benzodiazepines (including the related Z-drugs), gamma hydroxybutyrate and antipsychotics. Stimulant-type drugs included amphetamines, cocaine, methylphenidate, phentermine and caffeine tablets. In 7.7% of

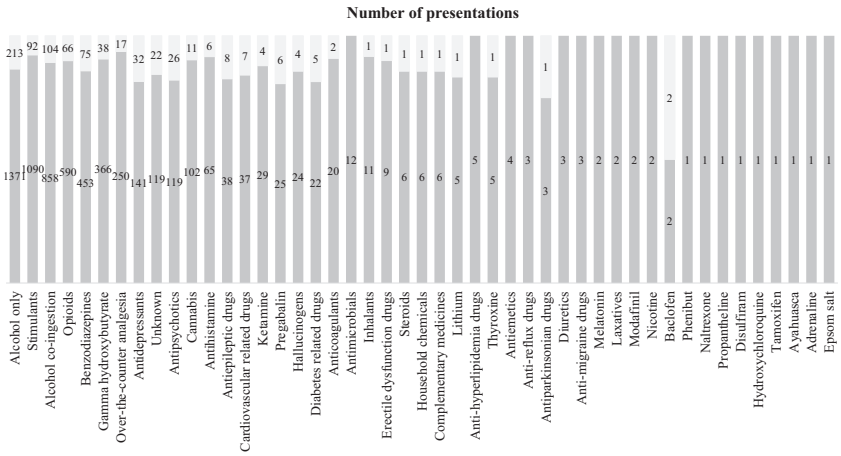

Figure 1. *Substances† involved in overdose presentations (*n = *4085) and in the presentations with CTB scans (*n = *519). Overdose presentations excluding a 2 year old patient. †Further notes on identified drugs and drug classes can be found in the Supporting Information. (■), All presentations; (□), presentations with CTB scans.*

presentations there was documented use of over-the-counter medications. Antidepressants (3.4%) were in the top five groups of drugs identified.

Table 1 compares the characteristics of patients who received a CTB with those who did not. Three patients under age-18 received a CTB (n = 1 aged 16, n = 2 aged 17); none had a history of head injury. Of 10 patients who died during their overdose admission, five received CTB scans. Of these, two had abnormal results and three with normal CTB results who had presented with overdose-related cardiorespiratory arrest. Patients who were admitted had a higher probability of receiving a CTB when compared to those not admitted (sensitivity 24.5%, specificity 91.7%, $P < 0.0001$).

Table 2 compared the characteristics of patients and presentations between the normal and abnormal CTB result groups. A large proportion of CTB were reported normal (95.2%); the majority (64.0%) of these had no concomitant head injury.

Overall, 20 (3.9%) CTB were associated with a change in management. Six were reported normal, while 14 had abnormal results (Table S2). Eleven out of all 25 (44.0%) abnormal CTB results were discharged and did not have a change in management (Table S3). Those with abnormal CTB result had a significantly higher chance of a change to management ($P < 0.00001$). Meanwhile, CTB results were not a good predictor for an admission to hospital (sensitivity 5.2%; specificity 95.6%; odds ratio 1.18; 95% CI 0.53–2.66; $P = 0.683$).

For our analysis, we considered those with a history of acute concomitant head injury as appropriate indication for CTB investigation. Other recorded reasons for a CTB scan in those without head injury are shown in Figure 2. Clinical information on the CTB request forms was written in free-text by the ordering clinicians. Most included more than one reason for requesting the test. Reduced level of consciousness (as measured by Glasgow Coma Scale) (n = 152, 46.8%), and overdose or intoxication (n = 129, 39.7%) were the top two reasons for ordering a CTB. A history of falls was commonly recorded (n = 43, 13.2%), but no specific documentation relating to head injury was included. The high proportion of CTB

TABLE 1. *Comparisons of overdose presentations between those with and without CTB‡*

Presentations	CTB n = 519 (12.7%)	No CTB n = 3566 (87.3%)	
Age (years)	Median = 40 (IQR = 29–52.5, R = 16–91)	Median = 33 (IQR = 24–43, R = 14–91)	$t = -12.130$ $P = 2.709 \times 10^{-33}$†
Sex	Male = 365 (70.3%)	Male = 2220 (62.3%)	
History of head injury	Yes = 194 (37.4%)	Yes = 40 (1.1%)	$\chi^2 = 1102.95$ $P < 0.00001$†
Types of overdose	Alcohol only = 213 (41.0%) Others§ = 306 (59.0%)	Alcohol only = 1158 (32.5%) Others§ = 2408 (67.5%)	$\chi^2 = 14.91$ $P = 0.0001$†
Disposition – hospital admission	No = 249 (48.0%) Yes = 270¶ (52.0%)	No = 2736†† (76.7%) Yes = 830‡‡ (23.3%)	$\chi^2 = 190.28$ $P < 0.00001$†

†Statistically significant. ‡Overdose presentations excluding a 2 year old patient. Disposition – hospital admission referred to whether patients required admission to hospital under specialist teams for further inpatient care. §Included overdose episodes involving co-ingestion with alcohol. ¶Five deceased. ††One deceased. ‡‡Four deceased. IQR, interquartile range; R, range.

TABLE 2. *Comparison of characteristics between normal and abnormal scans*

CTB results	Normal *n* = 494 (95.2%)	Abnormal *n* = 25 (4.8%)	
Age (years)	Median = 40 (IQR = 29–51, *R* = 16–90)	Median = 49 (IQR = 31–65, *R* = 19–91)	$t = -2.382$ $P = 0.017$†
Sex	Male = 346 (70.0%)	Male = 19 (76.0%)	
History of head injury	Yes = 178 (36.0%)	Yes = 16 (64.0%)	$\chi^2 = 7.95$ $P = 0.0048$†
Types of overdose	Alcohol only = 201 (40.7%) Others‡ = 293 (59.3%)	Alcohol only = 12 (48.0%) Others‡ = 13 (52.0%)	$\chi^2 = 0.525$ $P = 0.468$
Change in management	6 (1.2%)	14 (56.0%)	$\chi^2 = 192.76$ $P < 0.00001$†
Disposition – hospital admission	No = 238 (48.2%) Yes = 256§ (51.8%)	No = 11 (44.0%) Yes = 14¶ (56.0%)	$\chi^2 = 0.166$ $P = 0.683$

†Statistically significant. ‡Included overdose episodes involving co-ingestion with alcohol. §Three deceased. ¶Two deceased. IQR, interquartile range; R, range.

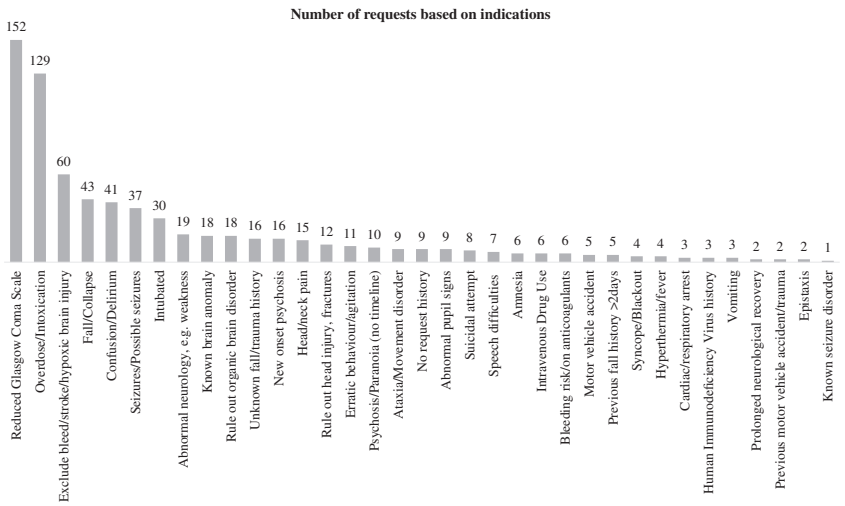

Figure 2. *Recorded indications for CTB for presentations without head injury (*n = *325 presentations).*

scan requests stating the indication as 'overdose' implied these were known overdose presentations, commonly with known overdosed substances involved. Many scans were requested to 'rule out intracranial pathology, organic disorders or head injury' (*n* = 90, 27.7%), possibly indicating a lower level of confidence in overdose alone being sufficient to explain the presentation.

In response to our study findings of the low yield from CTB scans, the 'HEAD' decision support tool (Fig. 3) was developed to assist in the decision-making process. Important clinical indications that could warrant a CTB scan were considered. These included clinical suspicion of hypoxic brain injury, poor or delayed neurological recovery, status epilepticus and clinical features of abnormal behaviour or neurological complications not explained by the known overdosed substances. Reasonableness was defined as a significant pre-test probability that an abnormality would be found that would lead to a management change. Post-hoc analysis of the reasonableness of a CTB scan request in our cohort, using the 'HEAD' tool was conducted. The 'HEAD' tool criteria when applied to our cohort, identified 223 presentations where a CTB was a reasonable investigation (sensitivity 80.0%, specificity 58.5%, negative predictive value 98.7% and positive predictive value 7.2%). This equated to less than half (43%) of the 519 scans actually conducted. All 194 presentations with a history of head injury that received a CTB were identified as having a reasonable indication for the scan. More detailed clinical history might have excluded some of these. Only 29 out of 325 scanned patients without a head injury were identified by the 'HEAD' tool as appropriate for scanning. All six patients with a normal CTB result who required a change in management (Table 2) were also identified by the 'HEAD' tool as appropriate for scanning. Of those with abnormal results, 18 (of 25) were identified as appropriate, including 10 who required a change in management. Out of this latter group, only two had no history of head injury – one died following overdose presentation complicated by cerebral infarction and another was admitted under specialist team and underwent further neuroimaging.

Of those seven with abnormal results that were not identified via the 'HEAD' tool, four were classified as having a change in management because they were admitted under specialist teams – two with CTB

'HEAD' Decision Support Tool for CTB Indications in Overdoses†

- ❑ **H**ead trauma‡ or signs of possible head injury
  - ❑ Risk assessment with the ‡Canadian CT Head Rule for minor head injury
- ❑ Status **E**pilepticus not explained by substances in overdose and other syndromes, e.g.
  - ❑ Myoclonic status epilepticus
- ❑ **A**bnormal behaviour or neurological signs and symptoms not explained by overdosed substances
- ❑ **D**elayed or poor neurological recovery, or hypoxic brain injury, e.g.
  - ❑ Poor recovery off or without sedation
  - ❑ Localising signs
  - ❑ Dilated, fixed pupils

Figure 3. *Decision support tool for CTB indications in overdose presentations. †Presence of any of these indications support investigation with CTB.*

findings that were noted as coincidental, one had CT evidence of contusion implying possible unreported head trauma and one died, whose CTB showed hypoxic ischaemic injury. These latter two were not identified by the 'HEAD' tool because of the lack of relevant reasons for a CTB being recorded and the available clinical history being quite limited. A further two had evidence of chronic changes in the CTB with no intervention required.

Discussion

We found that a high proportion of overdose presentations received CTB scans with very low yield with respect to influencing management. Presentations involving combined alcohol and sedative drugs led to more CTB scans. Patients who received CTB were older than those who did not, similar to the findings of Patel *et al*.[8] Those with abnormal CTB results were also older.

Based on the data available, the majority of patients did not require CTB scan. Decreased level of consciousness and overdose *per se* were the most common reasons recorded (86.5%) and therefore 'predictors' for undertaking CTB scans in our study. These indicators were considered inadequate for requesting this test according to our proposed guideline. Anecdotally our experience suggested that CTB was thought to be a requirement for admission acceptance by specialist teams. Alcohol use whether alone or co-ingested, was associated with a higher incidence of head injury (82.1% of all with head injury, $\chi^2 = 74.688$, $P < 0.00001$) and higher rates of CTB scans (60.9% of all scans, $\chi^2 = 9.042$, $P = 0.0026$) and at face value this might seem reasonable. However, the recent study by Granata *et al*. on alcohol intoxicated patients with possible brain injury suggested that it was safe practice to monitor clinical status for improvement and delay CTB scanning due to its low initial yield.[9]

In line with the proposal to clinically monitor and delay imaging, the use of alcohol and drug screening and considerations of the pharmacology of substances taken in overdose (when known) should be included in decision making regarding these patients. Prompt and accurate alcohol and drug measurements may assist in determining the knowledge of the drug(s) ingested or toxidrome in keeping with the clinical condition of patients. This provides clinicians more confidence in real-time clinical assessment of patients and when considering the merits of performing a CTB scan. With the current data, the 'HEAD' tool has shown potential as a guide to ensuring those with the relevant indications are screened with a CTB scan.

Radiation exposure is a risk. An effective dose for one CTB scan (average 2.0 mSv) is thought to equate to almost an additional year of natural environmental exposure in Australia or 100 chest X-ray exposures.[10] Although inter-individual variability exists with the radiation doses received, exposures are cumulative over time,[11] raising concerns for longer term health risks. Our observations also included a subgroup of patients who were recurrent presenters with overdoses. These patients are at a higher cumulative exposure risk because of repeat CTB scans.

Other patient- and systems-factors that must be considered if performing low yield CTB scans in a typical overdose presentation include prolonged length of stay to enable scan to be performed and reported, potential disruption or delay of required treatment as well as the high costs. Therefore, the use of CTB scan as a routine assessment tool in overdose presentations should be reviewed.

Limitations

This was a single site study; generalisability to other hospitals may be limited as practices may differ. The testing of the 'HEAD' tool in other health settings is needed to add to the validation of its acceptability. Given this retrospective analysis, there were limitations in our ability to delineate the timelines between decision making for an admission, and for a CTB scan request. Progress notes and other paper-based documents were not accessed although they were likely to have added information on the details of assessment and management processes. Due to the free-text option and clinician variability in registering the final diagnoses, some diagnoses did not correlate with the initial reasons for presentation. Therefore, some cases may have been missed, with some others included that were not true overdose cases. We adopted a conservative

approach in defining an abnormal CTB, which had an over-inclusive effect to our data, particularly of those with chronic changes. The efficacy and validation of the 'HEAD' tool needs to be investigated in prospective trials.

Conclusions

To minimise the number of patients referred for largely unnecessary and low-yield CTB scans following overdose presentations, we firstly propose due consideration of the pharmacokinetics and pharmacodynamics of drugs ingested. This provides an expectation of the duration of impaired consciousness and other toxidrome manifestations. Confidence regarding this aspect of overdose assessment should assist in the decision-making process regarding the need for neuroimaging. CTB scans should be utilised as a supplementary tool when the risk of intracerebral pathology is high rather than a default screening test. We have developed the 'HEAD' tool as a simple tool to assist this decision-making process, and potentially minimise patient and clinician variability, although prospective validation studies are needed.

Patients with obvious high-risk head injuries warrant neuroimaging investigations. In addition to the Canadian CT Head Rule for patients with head injury, we propose other indications for CTB scan in patients presenting with an overdose (Fig. 3). Given the lack of benefit from undertaking CTB scans in typical overdose patients, we propose that following prospective validation studies, clinicians may consider adopting a guided approach to these patients utilising the 'HEAD' CTB decision support tool.

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Competing interests

None declared.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Figure S1. Overall analysis.

Table S1. Other diagnoses.

Table S2. CTB results associated with change in management (n = 20).

Table S3. Abnormal CTB results not associated with change in management (n = 11).