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Implementation of a computerized decision support system for CT scan requests for non-traumatic headache in the emergency room

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Implementation of a computerized decision support system for CT scan requests for non-traumatic headache in the emergency department

Background: Non-traumatic headache is a frequent complaint in the emergency department (ED). Cranial computed tomography (CT) is a widely available test for the diagnostic work-up, despite the risk of exposure to ionizing radiation.

Objectives: To develop and evaluate a cranial CT request computerized decision support system (CDSS) for adults with first presentation of unusual severe non-traumatic headache in the ED.

Methods: Electronic database searches identified clinical decision and prediction rules, and studies delineating risk factors in non-traumatic headache. A long list of risk factors extracted from these articles was reduced by a 30-member multidisciplinary expert panel (radiologists, emergency physicians, methodologists), using a 90% agreement threshold. This shortlist was used to develop the algorithm for the cranial CT request CDSS, which was implemented in March 2016. Impact evaluation compared CT scan frequency and diagnostic yield of pathologic findings before (March-August 2015) and after (March-August 2016) implementation.

Results: From the 10 selected studies, 10 risk factors were shortlisted to activate a request for cranial CT. Before implementation, 377 cranial CTs were ordered (15.3% of 2,469 CT) compared to 244 after (9.5% of 2,561 CTs) (pre-post difference 5.74%; 95% confidence interval [CI] 3.92 to 7.56%; p <0.001), corresponding to a 37.6% relative reduction in test ordering rate (95% CI 25.7 to 49.5%; p<0.001). Despite the reduction

in cranial CT scans, we did not observe an increase in pathological findings after introducing the decision support system (70 cases before, 18.5%, vs 35 cases after, 14.3%; pre-post difference -4.0%; 95% CI -10.0 to 1.6%; p = 0.170).

Conclusion: In non-traumatic headache among adults seen in the ED, CDSS decreased the cranial CT request rate although the diagnostic yield did not improve.

Key words: CDSS, cranial CT, non-traumatic headache, algorithm, emergency department

INTRODUCTION

Non-traumatic headache, a frequent reason for consultation in the Emergency Department (ED), accounts for 1%-4.5% of all cases (1,2), and is differentiated into primary and secondary headaches (3). Most primary cases are benign, but secondary cases, representing 19% of all cases, can be life-threatening. While cranial CT is the diagnostic test of choice, it involves avoidable exposure to ionizing radiation, and its unnecessary use in ED can delay the diagnosis and treatment of other patients who need CT. This work focuses on the diagnostic management of secondary headaches.

The use of cranial CT has been progressively increasing in EDs (4,5). However, when the request for this test is not justified, the resultant inefficiency in the health system increases costs. The need to develop a strategy to optimize the request for CT in ED for diagnosing headache is well-recognised. International initiatives, such as the "*Choosing Wisely"* campaign (6) or the *"Do not do"* recommendations (7), offer guidelines for reducing unnecessary diagnostic procedures. In Spain, the MAPAC (Improvement of the Adequacy in the Clinical Care and Practice) initiative (8) aims to improve the adequacy of the application of X-rays and CT in the ED.

We designed a computerized decision support system (CDSS) to improve the adequacy of cranial CT requests at first presentation with unusual severe non-traumatic headache in the ED. The system was developed using existing clinical decision rules (CDR) or clinical prediction rules (CPR), as well as studies of relevant pathological risk factors (9,10). We evaluated the impact on service use and diagnostic yield before and after the implementation of the CDSS.

MATERIAL AND METHODS

In an electronic search in MEDLINE (from 1946 to 2015) and EMBASE (from 1980 to February 2015), we combined the term non-traumatic headache and its synonyms with terms for clinical suspicions that lead to the request for a CT scan. We did not include terms referring to other suspicions such as stroke or cranial trauma because in our ED we already have specific protocols in place for these events (i.e. Stroke and Cranial Trauma clinical pathways). We focused our study on the most frequent clinical suspicions for CT scan request in headache: subarachnoid haemorrhage (SAH), brain tumour and infections such as encephalitis, meningitis and cerebritis. The scope of the search was limited to the ED setting and methodological search filters for clinical prediction models were deployed (11) (Appendix table). This search was complemented by manual searches of the ACR Appropriateness Criteria (12) and computerised searches of the ACCESSSS metasearch engine (13), which conducts literature searches simultaneously in several evidence-based information services, yielding content that is hierarchically organized (14).

The selection of the studies was carried out by two methodologists, who resolved any discrepancies by consensus. The selection criteria were articles that described a CDR or CPR for secondary non-traumatic headache in any phase of development and testing (10) in the ED setting in adult patients. A CDR was defined as a decision-making tool, derived from original research that incorporated 3 or more variables from history, physical examination, or simple tests. A CPR was designed to help physicians with diagnostic or therapeutic decisions at the bedside. We excluded articles in paediatric patients or patients with a repeat presentation with primary headache.

Three investigators (2 radiologists and 1 emergency physician) extracted a long list of risk factors associated with an urgent request for a CT scan. This was reduced by a 30-member multidisciplinary expert panel (radiologists, emergency physicians, and methodologists), who gave their input anonymously. The final shortlist was drawn up using a 90% agreement threshold.

The consensus recommendations were subsequently implemented into the software for requesting diagnostic tests from the ED (HP-HIS system - HP Spain Inc.). At the time of requesting a cranial CT for non-traumatic secondary headache consultation, a pop-up window appeared with the list of selected risk factors identified in the electronic searches and shortlisted by the multidisciplinary panel. As part of implementation of the CDSS, several training sessions were held to inform emergency physicians and radiologists about the new procedure for requesting CT scans.

To assess the impact of the CDSS on the frequency and appropriateness of CT requests, the baseline number of CTs requested for unusual severe non-traumatic secondary headache during the 6 months prior to the implementation of the recommendations (March - August 2015) was recorded. After implementation in March 2016, the same measurements were repeated during the same 6 months of the following year (March - August 2016), a time period chosen to avoid seasonality bias.

A Chi-squared test was performed to statistically compare the pre-post difference in the proportion of CTs due to headache with respect to the total number of CTs

105 requested in the two periods. In order to compare the pre-post difference in diagnostic
106 yield, the findings observed in the images according to the radiologists' reports were
107 classified into four categories: 1) no pathological finding, 2) incidental finding of no
108 consequence to therapeutic patient management, 3) pathological finding
109 corresponding to the reason for headache consultation, and 4) pathological finding
110 suggestive of another diagnosis. We compared the proportion of pathological findings
111 (either related to headache or suggestive of another diagnosis) observed in the two
112 time periods using a Chi-squared test.
113
114 To assess the safety of the CDSS, we selected all patients presenting with unusual
115 severe non-traumatic secondary headache during the September 2016 - February 2017
116 period, excluding patients with other reasons for consultation that may involve
117 headache (for example: stroke or head injury). We then identified the number of
118 deaths and any hospital admission in the following 90 days for reasons related to
119 headache and compared mortality rate and hospital admission rate between patients
120 with a cranial CT scan and patients without.
121
122 The level of significance was set at 0.05 and statistical tests were two-tailed. We
123 estimated the differences in proportion between the two periods along with their
124 corresponding 95% confidence intervals (CI). The analyses were performed with the
125 statistical package, Stata v15.1 (StataCorp, 2017. Stata Statistical Software: Release 15.
126 College Station, TX: StataCorp LLC).
127
128

RESULTS

Search and selection:

The literature database searches identified 120 potentially relevant citations, of which 11 were selected after screening of titles and abstracts. The ACCESSSS search and follow-up of the references identified six more potentially relevant articles. After the two reviewers read the full text of these 17 articles, 10 were selected for the synthesis phase (Table 1). We did not find any work that evaluated the clinical impact of using a CDR or CPR. Four studies described the testing or validation phase of a CPR (15–18). The rest of the studies described the first step in the development of a CPR (19–23) or an univariate approach for exploring risk factors (24).

Synthesis of risk factors:

The multidisciplinary panel agreed upon a shortlist of 10 risk factors associated with intracranial pathology findings in the cranial CT (Table 2). To maximize the sensitivity of the decision algorithm, the presence of at least one of these factors was used to activate the request for a cranial CT (Figure 1).

Implementation:

The CDSS was implemented as follows: When an emergency physician initiated the request for a cranial CT in a patient with unusual severe non-traumatic secondary headache, the system produced a pop-up window with the risk factors. The system prompted the physician to select the patient's risk factors. If the patient did not have any of the risk factors, the system showed a message discouraging the performance of

the test. In the presence of at least one risk factor, the request for the test was processed.

Evaluation of the impact:

During the 6 months prior to implementation, 377 cranial CTs (15.3% of 2,469 CT) were performed, compared to 244 in the 6 months after implementation (9.5% of 2,561 CTs) (pre-post difference 5.74%; 95% CI 3.92 to 7.56%; p <0.001). This corresponded to a 37.6% relative reduction in the test ordering rate (95% CI 25.7 to 49.5%; p<0.001). Demographic and clinical characteristics of patients in both groups are shown in Table 3. Table 4 shows the radiological findings of cranial CTs requested, classified into groups of no findings, incidental irrelevant finding, and pathological finding. In the pre-implementation period, there were 70 cases with pathological findings (18.5% of the total cranial CTs requested due to headache), while after implementation, pathological findings were found in 35 cases (14.3%). These differences were not statistically significant (pre-post difference -4%; 95% CI -10 to 1.6%; p = 0.170).

Evaluation of the safety:

During the 6-month safety evaluation period, 1,275 patients presented in the ED with unusual severe non-traumatic secondary headache as the reason for consultation. A CT scan was requested for 369 patients (28.9%). Of these, 249 CT scans followed the implemented CDSS and 120 did not. Pathological findings were present in 47 patients (12.7%), 34 findings in the 249 CT scans with risk factors that were ordered using the CDSS (13.7%), and 13 out of 120 patients (10.8%) who did not follow the algorithm to undergo CT. We did not find any statistically significant difference when comparing

rates of new ED visits during the next 90 days (33.2% in patients without CT request, compared to 35.7% in patients with a CT request via the CDSS, and 35.0% in patients with a CT scan ordered without following the algorithm, p = 0.731).

Patients with no CT scan request had fewer hospital admissions than patients with a CT scan (6% vs 12%, p = 0.001). The rate of admission was similar independently of whether the CT was ordered using the decision support or not. There were seven deaths (0.78%) in the group with no CT request and 4 (1.1%) in the group with a CT request (two in each group). Only two patients died from causes related to headache, one in each group. The patient who died in the group with no CT scan had brain metastases diagnosed prior to the ED visit.

DISCUSSION

We found that in unusual severe non-traumatic secondary headache among adults seen in the ED, implementing a CDSS decreased the cranial CT request rate, but did not increase the diagnostic yield. The algorithm aimed to target cases with a greater probability of having one of the three main causes of potentially serious secondary headache (subarachnoid haemorrhage, intracranial tumour, or intracranial infection). As a proof of concept, this decision algorithm has changed our clinicians' behaviour and we have observed fewer requests for CT scans, but no increase in the diagnostic yield of CT scans. The algorithm was based on the presence of clinical features selected by a multidisciplinary expert panel in a way that maximized the sensitivity of the CDSS, in order to reduce the risk of false negatives. However, given that the diagnostic yield did not increase, we cannot rule out the possibility that some pathology was missed after decision support implementation. Future implementations of this CDSS will require close local monitoring of its clinical impact on patients.

We have also found that the likelihood of a hospital admission was higher in patients with a cranial CT scan performed compared to patients without cranial CT. This could be a consequence of the presence of risk factors that could have prompted not only a request for a cranial CT scan but also a hospital admission, and could also have been triggered by CT scan findings.

Other authors have previously published CPRs for the management of patients with headache. Perry et al (17,19) created the Canada and Ottawa rules for the detection of patients with suspected subarachnoid haemorrhage based on the characteristics of the headache, that was subsequently validated by Matloob et al (16). However, these guidelines do not cover conditions other than subarachnoid haemorrhage, limiting

212 their general usefulness. Cortelli et al (18,21) did address other conditions, but their
213 presentation in the form of clinical scenarios makes this algorithm unwieldy and
214 difficult for an ED to adopt. None of these proposed rules have had their impact
215 evaluated following implementation, as in our study.
216 Our study has limitations. The number of cranial CT scans performed has decreased,
217 but contrary to our expectation, the proportion of positive findings has not increased.
218 Reducing the number of CT scan requests after the CDSS implementation should have
219 been followed by an increase in the rate of pathological findings. However we did not
220 observe such an effect. Although the numbers are small for drawing firm conclusions
221 we cannot rule out the possibility that some cases were underdiagnosed after CDSS
222 implementation. This should be carefully monitored in future evaluations of any CDSS
223 implementation. The resistance of healthcare professionals to change in the ED is one
224 of the limitations that could have negatively affected the impact of our CDSS. Despite
225 the training sessions held in the ED, the clinicians may have failed to adhere to the
226 protocol, and we cannot rule out that some episodes of non-traumatic secondary
227 headache were managed by a diagnostic work-up undertaken outside the CDSS. In
228 fact, we found that in the safety analysis period, some of the cranial CT scans for a
229 headache episode were indeed performed outside the CDSS. Unfortunately, the safety
230 analysis period encompasses a different season than the pre-post intervention
231 assessment periods which included summer, when much fewer patients attend the ED.
232 This fact could explain the apparent rebound in the number of CT scans ordered in the
233 safety period. The pre-post comparison of the pathological findings may be limited by
234 the low frequency of events, precluding us from obtaining meaningful conclusions
235 about changes in diagnostic yield.

On the other hand, it is possible that the CDSS had a positive impact on the confidence and certainty with which clinicians selected imaging tests in our study. This is because the CDSS that we developed used a set of simple, easy-to-identify risk factors based on scientific evidence of varying levels of quality and the consensus of a multidisciplinary panel of experts. The degree of satisfaction with the use of the system has not been evaluated, and we will appraise this factor in future studies. Finally, we conducted the study in a single ED of a tertiary care academic hospital. It is unclear whether this system will transfer to other settings and whether acceptability and impact will be similar. These factors should be investigated in future studies.

With regard to safety, we compared death and hospital admission rates in the 90 days following the event in the two groups, those with CT scan requested, and those without. For a more comprehensive evaluation of safety, future studies would need to evaluate the misdiagnosis rate in patients who do not undergo a CT scan.

CONCLUSION

Cranial CT should be performed urgently in an adult patient attending the ED with unusual severe non-traumatic secondary headache who presents any of the following risk factors: > 40 years of age, neck pain or stiffness experienced by the patient, loss of consciousness or neurological focus, onset during exertion, sudden onset of pain, presence of fever that is not explained in the clinical context, meningism observed on physical examination, HIV or immunosuppression, progressive worsening of headache or permanent pain, and first episode in a cancer patient.

The implementation of the CDSS using these criteria had a significant impact by reducing the frequency of cranial CT requests for headache, however we did not find an improvement in the diagnostic yield of the test. Extending the system to include reasons for consultation other than headache will favour progress towards optimizing the overall use of ionizing radiation for testing in the ED.

Article Summary

1) Why is this topic important?

The unnecessary use of cranial CT can involve avoidable exposure to ionizing radiation and delay the diagnosis and treatment of other patients who need a CT scan.

2) What is this study trying to show?

This study aims to optimize cranial CT request rates in unusual severe non-traumatic secondary headaches by implementing a computerized decision support system based on a list of 10 risk factors.

3) What are the key findings?

In patients with unusual severe non-traumatic secondary headaches, requesting a cranial CT only in those cases with at least one risk factor, significantly reduces the TC request rates by 38%. There is no reduction in the rate of pathological findings.

4) How is patient care affected?

This study shows that implementation of the CDSS with these criteria had a significant impact by reducing the frequency of cranial CT requests for headache, however we did not find an improvement in the diagnostic yield of the test.

282 **Conflict of interest**

283 The authors declare that they have no conflict of interests.

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Table1

Table 1. Characteristics of the 10 selected studies for the synthesis phase.

Study (Author and year of publication)	Step in the process of development of a CDR*	Considered outcomes or CT findings	Study characteristics (design, inclusion criteria, number of patients)	High-risk clinical characteristics which increase pre-test probability	Performance of CDR/algorithms: Sensitivity % (CI 95%) Specificity % (CI 95%)
Tung C, 2014	Step 2: Modified Rothrock criteria	Intracranial pathology: Acute cerebral infarction, intracranial hemorrhage, malignancy, infection, cerebral edema, or hydrocephalus	Retrospective cohort Patients undergone urgent cranial CT with no head trauma, no age limit N=346 patients	Age ≥60 years New onset focal neurological deficit Headache with vomiting RLS (Reaction Level Scale) ≥2 (GCS <14)	Sen: 97.1 (85.1-99.9) Spe: 25.1 (20.4-30.3)
Matloob SA, 2013	Step 2: Canadian SAH CDR	SAH	Retrospective case note review All adult patients (> 16 years) presenting with acute headache N=112 patients	RULE 1 Age>40 Complaint of neck pain or stiffness Witnessed loss of consciousness Onset during exertion RULE2 Arrival by ambulance Age=>45 Vomiting at least once Diastolic blood presure =>100 RULE 3 Arrival by ambulancce Systolic blood presure =>160 Complaint of neck pain or stiffness Age 44-55	RULE 1 Sen: 100 (40 – 100) Spe: 43 (33 – 52) RULE2 Sen: 100 (40 – 100) Spe: 27 (19 – 36) RULE3 Sen: 100 (40 – 100) Spe: 37 (28 – 47)
Perry JJ, 2013	Step 2: Canadian SAH CDR →Ottawa SAH Rule	SAH	Prospective multicenter cohort Consecutive adults with a headache peaking within 1 hour and no neurologic deficits N=2131	Age≥40 Neck pain or stiffness Witnessed loss of consciousness Onset during exertion Thunderclap headache (instantly peaking pain) Limited neck flexion on examination	Sen: 100 (97.2-100) Spe: 15.3 (13.8-16.9)
Perry JJ, 2010	Step1: Canadian SAH CDR	SAH	Prospective multicenter cohort Alert patients (GCS=15) aged ≥16 who presented to an emergency department with a chief complaint of non-traumatic headache peaking within an hour or of syncope associated with a headache N=1999	Rule 1 Age >40 Complaint of neck pain or stiffness Witnessed loss of consciousness Onset with exertion Rule 2 Arrival by ambulance	RULE 1 Sen: 100 (97.1 – 100) Spe: 28.4 (26.4 – 30.4) RULE2 Sen: 100 (97.1 – 100) Spe: 36.5 (34.4 – 38.8) RULE3

				Age >45 Vomiting at least once Diastolic blood pressure >100 mm Hg Rule 3 Arrival by ambulance Systolic blood pressure >160 mm Hg Complaint of neck pain or stiffness Age 45-55	Sen: 100 (97.1 – 100) Spe: 38.8 (36.7 – 41.1)
Grimaldi D, 2009	Step 2: Cortelli algorithm based on four clinical scenarios	Serious headaches scenarios : SAH, neoplasm, ischemic stroke, meningitis Benign headaches: scenario 4	Prospective multicenter cohort Consecutive alert patients ≥ 18 years of age who presented to the ED with non-trauma headache N=256	SCENARIO 1 (Malignant secondary headache) Adult patients admitted to ED for severe headache (”worst headache”): - with acute onset (thunderclap headache), or - with neurological signs (or non-focal as decreased level of consciousness), or - with vomiting or syncope at the onset of headache. SCENARIO 2 (Malignant secondary headache) Adult patients admitted to ED for severe Headache: - with fever and/or neck stiffness. SCENARIO 3 (Malignant secondary headache) Adult patients admitted to ED for: - headache of recent onset (days or weeks), or - progressively worsening headache, or persistent headache. Scenario 4 (Benign primary headaches) Adult patients with a previous history of headache: -complaining of a headache very similar to previous attacks in term of intensity, duration and associated symptoms.	Sen: 100 (81 – 100) Spe: 64 (56 – 7)
Locker TE, 2006	Step 1: Diagnostic performance of clinical features	Serious Intracranial Pathology (carbon monoxide poisoning, central retinal artery occlusion, cerebellar cyst, cerebral infarct, glaucoma, hydrocephalus, hypertension/hypertensive encephalopathy, intracerebral hemorrhage, meningitis, neoplasia, SAH, single demyelinating episode, temporal arteritis, TIA, vertebral artery dissection)	Prospective cohort Consecutive alert patients (GCS=15) > 15 years of age who presented to the ED with non-trauma headache N=558	Age >50 Sudden onset of headache Abnormality on neurological examination	Sen: 98.6 Spe:34.4
Cortelli P, 2004	Step 1: Cortelli	Guideline for diagnostic and therapeutic management of	Secondary research Literature search and	SCENARIO 1 (Malignant secondary headache) Adult patients admitted to ED for severe	Not Available

	algorithm	adult patients presenting non-traumatic headache at ED	consensus statement	headache ("worst headache"): - with acute onset (thunderclap headache), or - with neurological signs (or non-focal as decreased level of consciousness), or - with vomiting or syncope at the onset of headache. SCENARIO 2 (Malignant secondary headache) Adult patients admitted to ED for severe Headache: - with fever and/or neck stiffness. SCENARIO 3 (Malignant secondary headache) Adult patients admitted to ED for: - headache of recent onset (days or weeks), or - progressively worsening headache, or persistent headache. Scenario 4 (Benign primary headaches) Adult patients with a previous history of headache: -complaining of a headache very similar to previous attacks in term of intensity, duration and associated symptoms.	
Rothman RE, 1999	Step 1	New focal lesions on head CT in HIV-infected patients	Prospective cohort Convenience sample of HIV-infected patients (>15 years) with any new or changed neurologic sign or symptom into ED and had a head CT N=110	New seizure Depressed or altered orientation Headache (different in quality) Headache (prolonged, ≥3 days)	Sen: 100 Spe: Not available
Ramirez-Lassepas M, 1997	Only univariate approach	Intracraneal pathologic findings: SAH, Tumor, ICH, Meningitis, cerebral acute infarction, herpes encephalitis	Case-control study Cases: N=139 hospitalized patients as a direct result of a ED visit for headache Controls: N=329 randomly selected patients who went to the ED for headache and were discharged	Acute onset Occipitonuchal location Associated symptoms Age>55	Not Available
Reinus WR, 1993	Step 1	Predictors of a intracranial CT abnormality	Retrospective multicenter cohort Consecutive ED patients who underwent cranial CT (from 2 trauma centers) N=1174	Unresponsiveness Focal neurologic déficit Hypertension (diastolic >90) Trauma Loss of conciousness Headache Dizziness	Not available

*Steps in the process of Development of a Clinical Decision Rule (CDR): Step 1: creating or deriving the rule; Step2: testing or validating the rule; Step3: assessing the impact of the rule on clinical behavior (impact analysis) (10). SAH: Subarachnoid haemorrhage; TIA: Transient ischemic attack; ED: Emergency department; ICH: Intracranial haemorrhage; Sen: sensibility; Spe: specificity.

Table2

Table 2. List of the 10 risk factors associated with intracranial pathology findings in a cranial CT scan. The presence of at least one of these factors recommends the performance of a cranial CT scan.

For adult patients with unusual severe headache (not similar to previous ones), without traumatic brain injury who come to the ED. Perform cranial CT if at least 1 of the following factors is present:
1. Age > 40 years 2. Neck pain or stiffness 3. Loss of consciousness/neurological focus 4. Onset with exertion 5. Thunderclap headache (instantly peaking pain) 6. Fever (not explained in the clinical context) 7. Meningism observed 8. HIV or immunosuppression 9. Progressive worsening of headache or permanent pain 10. First episode in a cancer patient

Table3

Table 3. Characteristics of patients who received CT before and after CDSS implantation.

	Patients who received CT before implementation (March - August 2015) (n=377)	Patients who received CT after implementation (March - August 2016) (n=244)
Age*	56.1 (21.2)	54.8 (20.3)
Sex (female)**	258 (68.4)	149 (61.0)
Neck pain or stiffness (Yes)**	36 (9.5)	59 (24.2)
Loss of consciousness/neurological focus (Yes)**	88 (23.3)	59 (24.2)
Onset with exertion (Yes)**	15 (4.0)	6 (2.5)
Thunderclap headache (instantly peaking pain) (Yes)**	71 (18.8)	66 (27.1)
Fever (not explained in the clinical context) (Yes)**	36 (9.5)	24 (9.8)
Meningism observed(Yes)**	9 (2.4)	10 (4.1)
HIV or immunosuppression (Yes)**	16 (4.2)	5 (2.1)
Progressive worsening of headache or permanent pain (Yes)**	78 (20.7)	123 (50.4)
First episode in a cancer patient (Yes)**	37 (9.8)	21 (8.6)

**Mean(SD); **Frequency(%)*

Table4

Table. 4. Comparison between the number of CT scan findings for headache during the pre- and post-implementation periods

	Number CT scans pre-implementation period	Number CT scans post-implementation period
No pathological finding	187 (49.6%)	105 (43.0%)
Pathological finding but irrelevant	120 (31.8%)	104 (42.6%)
Pathological finding according to the reason of headache consultation or suggestive of another diagnosis	70 (18.6%)	35 (14.3%)
Total	377	244

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	N/A
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	4
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	4
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	4
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	N/A
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	N/A

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	N/A
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table1
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	10
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	12
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	12

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

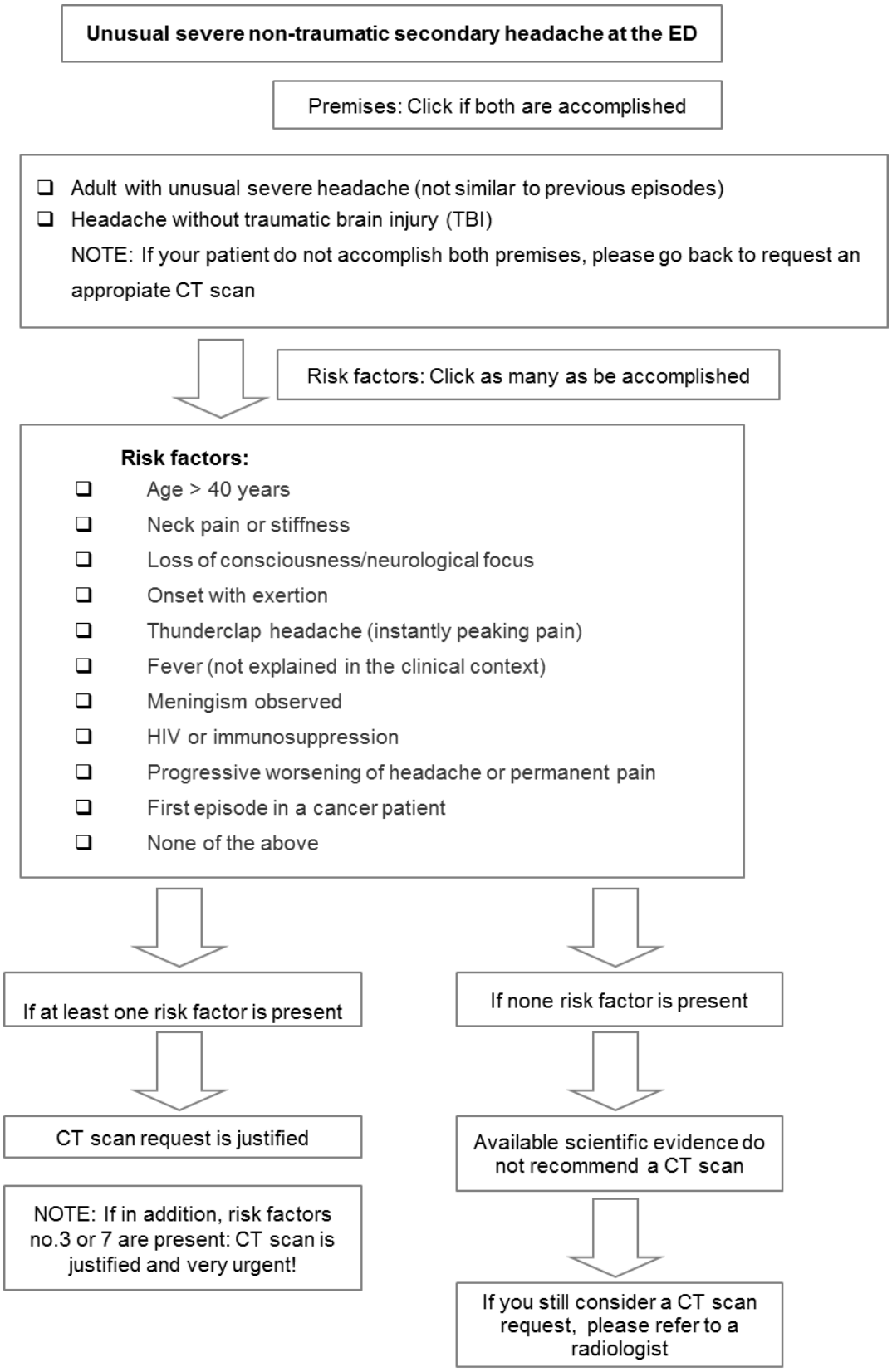
Appendix

Appendix. Search strategy

Search term according to each diagnostic outcome	
Subarachnoid Hemorrhage	(Subarachnoid Hemorrhage OR intracerebral hemorrhage)
Headache	(Headache) OR (Headache) OR (Head pain) OR (Cephalgia) OR (Cephalea)
Non-traumatic intracranial hemorrhage	(Intracranial Hemorrhage) OR (Subarachnoid Hemorrhage) OR (SAH) OR (Aneurysmal) OR (Brain Hemorrhage) OR (Cerebral Hemorrhage)
Intracraneal infection	(Encephalitis) OR (Meningitis) OR (Cerebritis) OR (Abscess) OR (Intracranial complication and headache)
Brain tumor	(Brain tumor) OR (Metastatic brain tumors)
AND	
Clinical Prediction Guides filter (Pubmed clinical queries)	
(Haynes HBF filter) AND (TMIF-26)	
AND	
Emergency Department filter	
("Emergency Service, Hospital"[Mesh])	
NOT	
Exclusion filter	
TMEF	

Figure1
Click here to download Figure: Figure1.docx

Figure 1. Clinical algorithm implemented when a cranial CT scan is requested for an unusual severe non-traumatic secondary headache at the ED.



CT: Computed Tomography; ED: Emergency department.