ORIGINAL ARTICLE

Analysis of the appropriateness of the clinical indications for neuroimaging studies

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KEYWORDS
Neuroradiology; Criteria for appropriateness; Imaging tests

Abstract
Objectives: To determine the most common clinical indications for different diagnostic neuroimaging tests. To analyze the diagnostic yield for each type of test in function of its clinical indication. To quantify the number of additional imaging tests generated as a consequence of pathological findings on the initial study or of the physician’s requesting an inappropriate study.

Material and methods: We reviewed the clinical indications and radiological report for computed tomography (CT) and magnetic resonance imaging (MRI) studies of the brain, head, and neck carried out during a 30-day period in three intermediate level hospitals with similar characteristics. We counted the studies with pathological findings and those with normal findings. We recorded cases that required additional imaging studies.

Results: CT and MRI studies of the brain are the most frequently requested neuroimaging studies. The most common indications for examinations requested from the neurology department were headache, head trauma, and acute neurological deficit. The most common indication for examinations requested from the ear, nose, and throat department was hearing loss. The percentage of examinations with pathological findings ranged from 6% to 71% depending on the clinical indication. Additional imaging studies were necessary in 3.5% of the cases.

Conclusions: Most neuroimaging studies are performed for especially prevalent clinical indications; however, in many cases the degree of concordance between the clinical and radiological diagnosis shows there is much room for improvement.

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PALABRAS CLAVE
Neurorradiología; Criterios de adecuación; Pruebas radiológicas

Análisis de la adecuación de las indicaciones clínicas en los estudios de neurorradiología

Resumen
Objetivos: Conocer las indicaciones clínicas más frecuentes que dan lugar a las distintas pruebas diagnósticas en neurorradiología. Analizar para cada tipo de exploración la rentabilidad


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Introduction

Appropriateness of requested radiological tests is an issue of great controversy at the moment. Both scientific societies and independent authors have shown an interest in this subject and a number of guidelines have been published, with varying degrees of success and results, that try to provide an overview of the degree of clinical indication for certain tests.\(^1,2\)

The present study aims to perform a descriptive analysis within the neuroradiology field to evaluate the appropriateness between a suspected or objective pathology and the imaging tests requested for diagnosis. In order to do so, the purpose is to identify the most prevalent clinical indications responsible for the majority of computed tomography (CT) and magnetic resonance imaging (MRI) studies of the brain, head and neck, as well as the percentage of examinations with pathological findings, and the cases that required additional imaging studies requested as a consequence of the initial imaging test.

Material and methods

In this study, we analyze the neuroimaging tests performed based on the clinical reasons for requesting them, as well as their diagnostic yield. The aim is to provide answers to the following questions: What do we do? Why do we do it? What are the benefits? Three stages have been defined to this end:

1. Analysis of the examinations performed.
2. Review of clinical indications.
3. Interpretation of the studies according to the clinical indication.

Analysis of examinations performed

We reviewed the neuroimaging examinations, excluding conventional and spinal imaging studies, performed in September 2009 in three intermediate-level hospitals (with neurology and an ear, nose and throat departments, but without neurosurgery or vascular surgery departments) with 247–283 beds for a population of approximately 300,000 people. The following data were recorded:

- **Type of examination requested** (cranial CT, sinuses CT, etc.). According to the criteria stated in the *Catálogo de Exploraciones Radiológicas* (Guidelines for Imaging) issued by the SERAM (Spanish Society of Medical Radiology) in 2004,\(^3\) without considering whether the study was performed with or without contrast material.
- **Clinical indication** (headache, vertigo, etc.). Given the great variety of clinical indications, different groups of indications were set up according to the International Statistical Classification of Diseases and Related Health Problems ICD-10 (Table 1).
- **Additional radiological examinations** requested after an initial study (for example, an MRI study requested after a cranial CT). We counted only additional imaging studies recommended by the radiologist and stated in the radiological report, whereas those requested on the own initiative of the clinician were excluded, whose identification is not possible in many cases given the information system used.

Review of clinical indications

From the groups of clinical indications previously established (Table 1), the conditions accounting for most of the activity were identified. The diagnostic accuracy of each test for these conditions was subsequently evaluated. The recommendations estated by the Referral Guidelines for imaging were examined as a reference for the degree of indication. These Guidelines differentiate five categories regarding the degree of indication for a specific radiological examination based on three levels of scientific evidence (Table 2). Table 3 shows the level of indication established for the main clinical indications studied in this paper.
Table 1  Diagnostic groups established based on a modified ICD-10 classification, used for the assessment of the imaging studies performed according to the clinical indication.

<table>
<thead>
<tr>
<th>Diseases of the nervous system</th>
<th>Ear, nose and throat diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflammatory-infectious diseases of the CNS</td>
<td>External ear diseases</td>
</tr>
<tr>
<td>Endocrine diseases</td>
<td>Middle ear and mastoid diseases</td>
</tr>
<tr>
<td>CNS neoplasms</td>
<td>Inner ear diseases</td>
</tr>
<tr>
<td>CNS demyelinating diseases</td>
<td>Hearing loss</td>
</tr>
<tr>
<td>CNS degenerative diseases</td>
<td>ENT neoplasms</td>
</tr>
<tr>
<td>Episodic or paroxysmal disorders: headaches</td>
<td>Acute upper respiratory infections</td>
</tr>
<tr>
<td>Episodic or paroxysmal disorders: acute neurological deficit (ischemic or hemorrhagic)</td>
<td>Chronic rhinitis and polyposis</td>
</tr>
<tr>
<td>Episodic or paroxysmal disorders: epilepsy</td>
<td>Vocal cord and larynx diseases</td>
</tr>
<tr>
<td>TBI</td>
<td>TBI*</td>
</tr>
<tr>
<td>Neurology miscellaneous</td>
<td>ENT miscellaneous</td>
</tr>
</tbody>
</table>

ENT: ear, nose and throat; CNS: central nervous system; TBI: traumatic brain injury.

Adapted from the groups of the International Statistical Classification of Diseases and Related Health Problems: Tenth Revision.4

Study interpretation according to clinical indications

Once the clinical indications leading to the performance of the majority of studies were determined, a significant number of examinations were gathered (30 cases or over) in three hospitals of similar characteristics. The radiological reports were reviewed to determine how many examinations showed findings supporting the presence of the studied condition, differentiating between positive or negative examination, always in accordance with the cause of the test request. For example, if a test that was requested for a traumatic brain injury (TBI) demonstrated a fracture, it was then considered positive. However, if for the same clinical indication, the examination showed an area of previous infarction, it was then considered negative.

It has to be stressed that the objective was not to assess the sensitivity for each test, but to determine whether the examination shows or not findings related to the suspected clinical condition. For instance, an acute cerebrovascular accident (CVA) with normal cranial CT was considered negative, although it is likely that some of those patients had in fact an acute CVA that was not visible on CT because it was at an early stage.

Results

Analysis of examinations performed

A total of 595 brain, head and neck CT and MRI examinations were performed in our centre during the study period. They account for 41.2% of the total of CT and MRI carried out, being brain CT and MRI the most requested examinations within their respective techniques. The overall results are shown in Figs. 1 and 2. The activity carried out during that period in the other two participating hospitals had a similar distribution (Figs. 3 and 4).

Table 2  Criteria used for the classifications based on the levels of indication (indicated, specialized investigation, not indicated initially and not indicated routinely) and the degree of scientific evidence (A, B or C) stated in the Referral Guidelines for Imaging.

<table>
<thead>
<tr>
<th>Level of indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Indicated: this shows the investigation most likely to contribute to clinical diagnosis and management.</td>
</tr>
<tr>
<td>2. Specialized investigation: these are complex or expensive examinations that will usually be performed only for doctors who have the relevant clinical expertise to evaluate the clinical findings and act on the imaging results. They usually involve discussion with a specialist in radiology or nuclear medicine.</td>
</tr>
<tr>
<td>3. Not indicated initially: situations where experience shows that the clinical problem usually resolves with time, therefore it is suggested to postpone the study three to six weeks and only performing it if symptoms continue.</td>
</tr>
<tr>
<td>4. Not indicated routinely: this emphasizes that, while no recommendation is absolute, the request will only be carried out if a clinician gives cogent arguments for it.</td>
</tr>
<tr>
<td>5. Not indicated: when requesting that given examination is untenable.</td>
</tr>
</tbody>
</table>

Degree of evidence

A. Randomized controlled trials, meta-analyses and systematic reviews.

B. Robust experimental or observational studies.

C. Other tests where indication is based on the opinion of experts, endorsed by relevant authorities.

Referral Guidelines for Imaging. Adapted by the European Comission and European experts in radiology and nuclear medicine in conjunction with the UK Royal College of Radiologists. 2000.
The additional radiological examinations requested after a study were also counted, with 21 (3.5%) additional studies requested out of a total of 595, while seven tests were directly replaced by other type of examinations (1.2%). It has to be highlighted that these values probably underestimated the actual figures, since those cases where modifications of the requests were not documented were not included in the study, as well as the additional radiological examinations that were not specifically recommended in the radiological report.

**Review of clinical indications**

Table 4 shows the results regarding the number and percentage of examinations performed for each clinical condition.

### Table 3 Level of indication designated by the Referral Guidelines for Imaging for those clinical indications with the highest volume of neuroimaging studies performed in our centre.

<table>
<thead>
<tr>
<th>Type of examination</th>
<th>Clinical problem</th>
<th>Recommendationa</th>
<th>Degree of evidencea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain CT</td>
<td>Acute neurological deficit</td>
<td>Indicated</td>
<td>C</td>
</tr>
<tr>
<td>Brain CT</td>
<td>TBI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>Acute headache</td>
<td>Indicated</td>
<td>B</td>
</tr>
<tr>
<td>Brain CT</td>
<td>Chronic headache</td>
<td>Not indicated routinely</td>
<td>B</td>
</tr>
<tr>
<td>Brain CT</td>
<td>Epilepsy/seizure</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Brain CT</td>
<td>CNS degenerative diseases</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Brain CT</td>
<td>CNS neoplasms</td>
<td>Indicated</td>
<td>B</td>
</tr>
<tr>
<td>Face and sinuses CT</td>
<td>Chronic rhinitis and polyposis</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Face and sinuses CT</td>
<td>Acute upper respiratory infections</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Cranial MRI</td>
<td>Acute neurological deficit</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Cranial MRI</td>
<td>Acute headache</td>
<td>Indicated</td>
<td>B</td>
</tr>
<tr>
<td>Cranial MRI</td>
<td>Chronic headache</td>
<td>Not indicated routinely</td>
<td>B</td>
</tr>
<tr>
<td>Cranial MRI</td>
<td>CNS neoplasms</td>
<td>Indicated</td>
<td>B</td>
</tr>
<tr>
<td>Base of the cranium MRI</td>
<td>Inner ear diseases</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
<tr>
<td>Base of the cranium MRI</td>
<td>Hearing loss</td>
<td>Specialized investigation</td>
<td>B</td>
</tr>
</tbody>
</table>

MRI: magnetic resonance imaging; CNS: central nervous system; CT: computed tomography; TBI: traumatic brain injury.

*a Data obtained from the Referral Guidelines for Imaging issued by the European Commission (2000).

### Figure 1 Number and percentage of neuroimaging CT studies performed in our centre during the study period.

### Figure 2 Number and percentage of neuroimaging MRI studies performed in our centre during the study period.
It can be observed that there is a series of more prevalent indications that justify the majority of examinations:

- 81% brain CT are requested for acute neurological deficit, TBI, headache or central nervous system (CNS) degenerative processes.
- The assessment of chronic rhinitis, polyposis and acute upper respiratory infections accounts for 68% of all face and sinuses CT studies.
- 80% of petrous bone CT studies are indicated in cases of suspected middle ear and mastoid inflammatory pathology and hearing loss.
- 51% of cranial MRI studies are requested for suspected acute neurological deficit, headache and CNS neoplasms.
- Hypoacusia and suspected inner ear diseases account for 82% of MRI of the base of the cranium.

**Study interpretation according to clinical indication**

The most common clinical indications were obtained from the data of the activity analysis, overall accounting for 68% of the total of examinations performed.

**Table 5** shows the number of examinations that showed findings supporting the presence of the studied condition. In total, the percentage of pathological examinations for each clinical indication in our centre is set around 15% (47 pathological cases out of 314) for cranial CT. Similarly, there are 40 positive tests out of 92 examinations for brain MRI, that is, 43%. For MRI of the base of the cranium, only 10% of the examinations were positive.

**Discussion**

The rapid development of radiology over the last decades has lead to a proliferation of clinical indications and, consequently, of demand of examinations; however, this has not always been accompanied by a similar increase of the available resources, thus increasing pressure on healthcare and waiting times. On the other hand, the fact that the diagnostic examinations have low rates of iatrogenesis and that adverse effects of diagnostic radiation are not immediate can lead doctors to underestimate the risks and thus to request a high number of examinations. This highlights the need to supervise the clinical indications in order to streamline the available resources and avoid unnecessary tests to patients.

Multiple manuals and clinical guidelines deal with the appropriate diagnostic tests for each disease. Among the most relevant, in 1989 the UK Royal College of Radiologists published a guideline for clinicians regarding the radiological examination recommended for each clinical indication. These guidelines have been re-edited and adapted a number of times, and among these re-editions stand out the guidelines issued in 2000 by the European Commission and the UK Royal College of Radiologists. The American College of Radiology (ACR) offers a guide that assigns a level of
Several publications have dealt with the analysis of the appropriateness of examinations for their clinical indication. In an American study, 40% of the radiological tests were classified as inappropriate and, although the authors admitted that a percentage of inappropriate requests should be considered valid, it seems that the results obtained allow for a wider margin of improvement. The application of the ACR criteria seems to improve the results, at least regarding MRI examinations. Several studies at a local and autonomic level also analyze the appropriateness of radiological examinations in primary care and medical specialties.

In our study, brain, head and neck CT and MRI examinations accounted for 42.1% of the total, in accordance with other studies. This confirms the important share of this type of examinations within the whole of the activity. When comparing the most common clinical indications with the recommendations of the Referral Guidelines for Imaging, the clinical indication is considered completely appropriate for cranial CT studies requested to evaluate acute neurological deficit (which comprises ischemic or hemorrhagic vascular syndromes) and suspected neoplasms. Similarly, the indication is considered appropriate for MRI requested for suspected neoplasm (44.5% of the total of examinations). As reported by previous studies, the degree of clinical indication for examinations requested for evaluation of headache cannot be determined because in many cases the clinical information provided does not distinguish between chronic or acute headache, information that modifies the level of indication. If we assume that with a good anamnesis and clinical examination the suspected diagnosis should be corroborated by the radiological report in a high percentage of cases, the agreement between both diagnoses can then be considered an indirect estimation of the quality of healthcare.
Analysis of the appropriateness of the clinical indications for neuroimaging studies

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Number and percentage of tests performed during the study period for each type of examination according to the clinical indication groups established.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical indications according to the type of neuroradiology examination</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Type of study</strong></td>
<td><strong>Clinical indication: number and %</strong></td>
</tr>
<tr>
<td>Brain CT</td>
<td>Acute neurological deficit 84 (27%)</td>
</tr>
<tr>
<td></td>
<td>TBI 79 (25%)</td>
</tr>
<tr>
<td></td>
<td>Headaches 55 (18%)</td>
</tr>
<tr>
<td></td>
<td>CNS degenerative diseases 34 (11%)</td>
</tr>
<tr>
<td></td>
<td>Epilepsy/crisis 13 (4%)</td>
</tr>
<tr>
<td></td>
<td>CNS neoplasms 9 (3%)</td>
</tr>
<tr>
<td></td>
<td>CNS demyelinating diseases 3 (1%)</td>
</tr>
<tr>
<td></td>
<td>Inner ear diseases 3 (1%)</td>
</tr>
<tr>
<td></td>
<td>Inflammatory-infectious diseases of the CNS 2 (&lt;1%)</td>
</tr>
<tr>
<td></td>
<td>Vocal cord and larynx diseases 1 (&lt;1%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 25 (8%)</td>
</tr>
<tr>
<td></td>
<td>Not shown/badly completed 2 (&lt;1%)</td>
</tr>
<tr>
<td></td>
<td>Middle ear and mastoid diseases 9 (42%)</td>
</tr>
<tr>
<td></td>
<td>Loss of hearing 8 (38%)</td>
</tr>
<tr>
<td></td>
<td>ORL neoplastic pathology 2 (10%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 2 (10%)</td>
</tr>
<tr>
<td>Face and sinuses CT</td>
<td>Chronic rhinitis and polyposis 16 (42%)</td>
</tr>
<tr>
<td></td>
<td>Acute upper respiratory infections 10 (26%)</td>
</tr>
<tr>
<td></td>
<td>Traumatic brain injury 4 (10%)</td>
</tr>
<tr>
<td></td>
<td>Neoplasms 3 (10%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 5 (12%)</td>
</tr>
<tr>
<td>Neck CT</td>
<td>ORL neoplastic pathology 11 (41%)</td>
</tr>
<tr>
<td></td>
<td>Acute upper respiratory infections 6 (22%)</td>
</tr>
<tr>
<td></td>
<td>Vocal cord and larynx diseases 3 (11%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 7 (26%)</td>
</tr>
<tr>
<td>Cranial MRI</td>
<td>Acute neurological deficit 20 (18%)</td>
</tr>
<tr>
<td></td>
<td>Episodic or paroxysmal pathology: headaches 20 (18%)</td>
</tr>
<tr>
<td></td>
<td>CNS neoplasms 17 (15%)</td>
</tr>
<tr>
<td></td>
<td>CNS demyelinating diseases 9 (8%)</td>
</tr>
<tr>
<td></td>
<td>CNS degenerative diseases 8 (7%)</td>
</tr>
<tr>
<td></td>
<td>Episodic or paroxysmal pathology: epilepsy 7 (6%)</td>
</tr>
<tr>
<td></td>
<td>Inflammatory-infectious diseases of the CNS 6 (5%)</td>
</tr>
<tr>
<td></td>
<td>Inner ear diseases 6 (5%)</td>
</tr>
<tr>
<td></td>
<td>TBI 3 (2%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 16 (14%)</td>
</tr>
<tr>
<td>Skull base MRI</td>
<td>Loss of hearing 31 (58%)</td>
</tr>
<tr>
<td></td>
<td>Inner ear diseases 13 (24%)</td>
</tr>
<tr>
<td></td>
<td>ENT neoplastic pathology 2 (4%)</td>
</tr>
<tr>
<td></td>
<td>External ear diseases 1 (2%)</td>
</tr>
<tr>
<td></td>
<td>Middle ear and mastoid diseases 1 (2%)</td>
</tr>
<tr>
<td></td>
<td>Inflammatory-infectious diseases of the CNS 1 (2%)</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous 4 (8%)</td>
</tr>
<tr>
<td>Pituitary MRI</td>
<td>CNS neoplasms 7 (50%)</td>
</tr>
<tr>
<td></td>
<td>Endocrine diseases 6 (43%)</td>
</tr>
<tr>
<td></td>
<td>Badly completed/not shown 1 (7%)</td>
</tr>
</tbody>
</table>

ENT: ear, nose and throat; MRI: magnetic resonance imaging; CNS: central nervous system; CT: computed tomography; TBI: traumatic brain injury.
Clearly, a 100% correlation between the clinical and the radiological diagnosis cannot be required, but very low percentages should not be accepted either. There are not specific data in the literature regarding the admissible percentage of clinical-radiological disagreement, possibly because this percentage varies depending on the condition under study and the examination performed. However, in light of the results, it would be desirable to establish stricter criteria in the selection of patients for those clinical indications with higher disagreement.

In this review, the percentage of pathological examinations ranges between 6 and 71% depending on the clinical indication (mean 26.5%). In general, most of the clinical indications in the three hospitals compared show a similar percentage of pathological studies (Table 5). However, some degree of disagreement has been found in some techniques that, since it cannot be attributed to differences in population characteristics, might indicate an erroneous diagnostic approach for a specific pathology, being necessary to know the peculiarities and internal procedures of each centre.

In conclusion, knowing the activity developed in a radiology department and relating this activity to the clinical indications leading to the request of studies and to the results obtained from the examinations should improve the quality of the healthcare and streamline the use of diagnostic resources.

**Table 5** Absolute numbers and percentage of pathological examinations for each group of clinical indication established in three hospitals with similar characteristics. The number of cases is 30 or greater for each clinical indication.

<table>
<thead>
<tr>
<th>Type of examination</th>
<th>Indication</th>
<th>Hospital 1</th>
<th>Hospital 2</th>
<th>Hospital 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain CT</td>
<td>Acute neurological deficit</td>
<td>22 (26%)</td>
<td>6 (20%)</td>
<td>4 (13%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. = 84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>TBI</td>
<td>11 (14%)</td>
<td>6 (20%)</td>
<td>8 (27%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. = 79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>Headaches</td>
<td>6 (11%)</td>
<td>2 (7%)</td>
<td>2 (7%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. = 55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>CNS degenerative diseases</td>
<td>2 (6%)</td>
<td>9 (30%)</td>
<td>4 (13%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>Epilepsy/seizure</td>
<td>4 (13%)</td>
<td>5 (16%)</td>
<td>6 (20%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain CT</td>
<td>CNS neoplasms</td>
<td>2 (7%)</td>
<td>8 (27%)</td>
<td>8 (27%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face and sinuses CT</td>
<td>Chronic rhinitis and polyposis</td>
<td>16 (55%)</td>
<td>15 (50%)</td>
<td>21 (70%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face and sinuses CT</td>
<td>Acute upper respiratory infections</td>
<td>21 (71%)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain MRI</td>
<td>Acute neurological deficit</td>
<td>16 (50%)</td>
<td>11 (37%)</td>
<td>10 (33%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain MRI</td>
<td>Headaches</td>
<td>7 (23%)</td>
<td>4 (13%)</td>
<td>4 (13%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain MRI</td>
<td>CNS neoplasms</td>
<td>17 (58%)</td>
<td>17 (57%)</td>
<td>10 (33%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base of cranium MRI</td>
<td>Inner ear diseases</td>
<td>3 (10%)</td>
<td>18 (60%)</td>
<td>5 (17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base of cranium MRI</td>
<td>Hearing loss</td>
<td>3 (10%)</td>
<td>4 (13%)</td>
<td>12 (40%)</td>
</tr>
</tbody>
</table>

Cases in which the difference with the other two centres is >20% are in bold.
When no other figure is specified, the number of examinations reviewed is 30.
MRI: magnetic resonance imaging; CNS: central nervous system; CT: computed tomography; TBI: traumatic brain injury.

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**Conflicts of interests**

The authors declare not having any conflict of interests.

**References**

Analysis of the appropriateness of the clinical indications for neuroimaging studies


