Common Sites and Etiologies of Residents' Misinterpretation of Head CT Scans in the Emergency Department of a Level I Trauma Center

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ABSTRACT: **Background:** Misinterpretation of head computerized tomographic (CT) scans by radiology residents in the emergency department (ED) can result in delayed and even erroneous radiology diagnoses. Better knowledge of pitfalls and environmental factors may decrease the occurrence of these errors.

Objectives: To evaluate common misinterpretations of head CT scans by radiology residents in a level I trauma center ED.

Methods: We studied 955 head CT scans of patients admitted to our ED from January 2010 to May 2011. They were reviewed separately by two senior neuroradiologists and graded as being unimportant (score of 1), important but not requiring emergent treatment (score of 2), and important requiring urgent treatment (score of 3). We recorded the time of day the examination was performed, the year of residency, the site, subsite and side of the lesion, the pathology, the anatomical mistake, false-positive findings, and the attending neuroradiologists' score.

Results: A total of 955 examinations were interpreted of which 398 had misinterpreted findings that were entered into the database, with the possibility of multiple errors per examination. The overall misinterpretation rate was 41%. The most commonly missed pathologies were chronic infarcts, hypodense lesions, and mucosal thickening in the paranasal sinuses. The most common sites for misdiagnosis were brain lobes, sinuses and deep brain structures. The highest percentage of misinterpretation occurred between 2.30 p.m. and 8 p.m. and the lowest between midnight and 8 a.m. ($P < 0.05$). The overall percentage of errors involving pathologies with a score of 3 by at least one of the neuroradiologists was 4.7%. Third-year residents had an overall higher error rate and first-year residents had significantly more false-positive misinterpretations compared to the other residents.

Conclusions: The percentage of errors made by our residents in cases that required urgent treatment was comparable to the published data. We believe that the intense workload of radiology residents contributes to their misinterpretation of head CT findings.

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KEY WORDS: computed tomography (CT), head scans, misinterpretation, residents, emergency department

Sheba Medical Center at Tel Hashomer is the largest hospital in Israel and has one of the busiest emergency departments. With an average of 50 head computed tomograms and 15–20 body CT scans per shift, there is an urgent need for a precise and rapid radiological interpretation of these studies as part of the routine ED workload. Coverage by radiology residents is reportedly more accurate than coverage by emergency medicine physicians [1]. It is common practice in our academic institute that a new radiology resident undergoes an intense 4 month training program and then gradually begins to do overnight shifts in the ED. This is in contrast to the American Radiology Resident Review Committee of Accreditation Council for Graduate Medical Education which requires at least 12 months of training before assignment to overnight shifts [2,3]. Most studies have shown that there is a small rise in the percentage of mistakes made by less experienced residents [4-11].

Radiology misses can be classified as perceptual errors, i.e., not recognizing a finding, or cognitive errors, i.e., not correctly interpreting or understanding a finding. While perceptual errors are false-negative errors, cognitive errors can be either false-positive errors or true-positive errors but with misclassification if the conclusion or diagnosis it leads to is incorrect [12,13].

The first objective of this study was that it would serve as a quality assurance program in our department in place of data derived from the international literature [2,8,14-18]. The second objective was to identify the most common sites of occurrence of the residents' error with the purpose of reducing their frequency, and the third objective was to determine the reasons for these mistakes. To the best of our knowledge, this is the first such study in Israel. We aimed not only to improve the quality of head CT interpretation in our department but also to implement the findings of this study in order to prevent future misinterpretation by our radiology residents.

***Both authors contributed equally to this study**

ED = emergency department

CT = computerized tomography

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SUBJECTS AND METHODS

This study was conducted between January 2010 and May 2011 at the Sheba Medical Center, Tel Hashomer, Israel, a level I trauma center. The study received institutional review board permission. Informed consent was waived for this analysis of radiological images and subsequent diagnoses.

The aim of this retrospective study was to assess the interpretation of head CT by residents at different periods of the day and night. Radiology residents prospectively interpreted 955 head CT scans during regular working hours (0800–1500) as well as during on-call hours (1500–0800). The CT scans are requested by the physicians within our ED between 0800 and 1500 and then additionally by physicians throughout the hospital between 1500 and 0800. The interpretations of the images are reviewed the following morning by an attending neuroradiologist who immediately contacts the primary physician in the event that there had been an error that might affect treatment.

The retrieved data for this study included the identification number of the patient, the date and time of the CT examination, and the names of the radiology resident and the senior neuroradiologist. Table 1 displays the errors made by the resident according to the main site and subsite of the lesion. The errors were also categorized according to the pathology [Table 2], and anatomic errors or false-positive findings were noted (e.g., the resident reporting a non-existing finding). After collecting the errors in CTs that were performed during the night shift, the interpretation of the CT findings, including the corrections by the senior neuroradiologist, were photocopied and distributed to the two other senior neuroradiologists who participated in the current study. Each senior neuroradiologist graded the errors as unimportant (a score of 1), important but not requiring emergent treatment (score of 2), and important with urgent treatment needed (score of 3).The data were analyzed for trends according to year of residency in terms of interpretation errors and errors with a score of 3 by at least one of the neuroradiologists.

Further analysis included anatomical errors (e.g., common sites of errors and the frequency of errors in each of them), interpretation of anatomical errors (i.e., wrong side or wrong description of anatomic site), and false-positive errors (i.e., description of a finding that was later ruled out by a neuroradiologist).

All CT exams were performed with a multi-detector CT scanner (Phillips Brilliance 64 slices, The Netherlands) with the following scanning protocol: transaxial contiguous slices of 3 mm from base of skull to vertex with standard filter, 120 kV and 310 mAS, Pitch 0.578 and Matrix 512 x 512.

STATISTICAL ANALYSIS

The subject of interest was the ratio of the errors to the number of tests, the year of residency and the time of day or night. We also compared the proportion of errors by site among all errors. The data were analyzed using logistic regression with subsequent pair-wise comparisons of all categories with Bonferroni adjustment for multiple comparisons. All *P* values are two-sided. All calculations were done using STATA SE 12 software.

Table 1. Common misinterpretations

Site	Common subsites in descending frequency			
Lobe	Frontal ›	Periventricular ›	Cerebellum ›	Temporal
Sinus	Ethmoid ›	Maxillary ›	Mastoid ›	Sphenoid
Structure	Basal ganglia ›	Thalamus ›	Brain stem ›	NS
Soft tissue	Frontal ›	Occipital ›	Parietal ›	Parotid
Extra-axial	Temporal ›	Occipital ›	Tentorium ›	NS
Skull bones	Frontal ›	Occipital ›	Mastoid ›	NS

NS = subsites less than 3% in prevalence

Table 2. Misinterpretations of common pathologies according to site in descending frequency

Site	Common pathologies		
Lobe	Chronic infarct ›	Hypodense lesion ›	Herniation
Sinus	Mucosal thickening ›	Fluid ›	Fullness
Structure	Chronic infarct ›	Hypodense lesion ›	NS
Soft tissue	Swelling ›	SOL ›	Foreign body
Extra-axial	Pathologic calcification ›	SOL ›	NS
Skull bones	Acute fracture ›	Sclerotic lesion ›	NS

SOL = space-occupying lesion, NS = pathologies less than 3% in prevalence

RESULTS

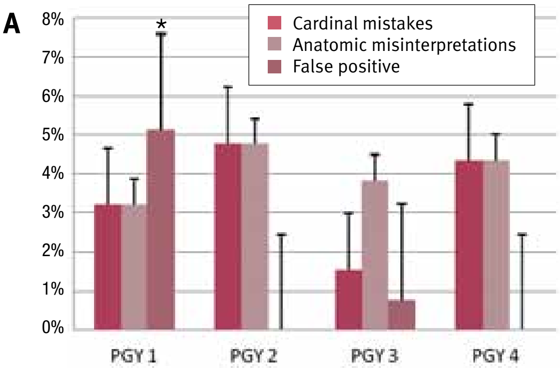
A total of 955 examinations were interpreted between January 2010 and May 2011 by residents with different levels of experience: 32% by first-year residents, 11.5% by second-year residents, 44.5% by third-year residents, and 12% by fourth-year residents. A total of 398 misinterpreted findings were entered into the database, with the possibility of multiple errors per examination. The overall misinterpretation rate was 41%.

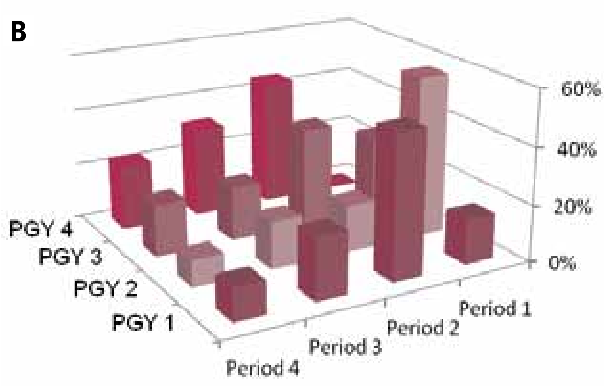
EXPERIENCE-DEPENDENT MISINTERPRETATIONS

Several types of mistakes were analyzed in relation to the residents' experience in order to define the specific areas where newer residents are prone to make more errors. Highly important mistakes were those that required urgent contact with the patient's primary physician for possible change in treatment and had been given a score of 3 by two neuroradiologists in consensus. Anatomic misinterpretations were defined as errors in identifying the correct anatomic location of the pathology. For example, a brain contusion could be

Figure 1. Misinterpretation rates.
[A] According to post-graduate year (PGY 1–4) (*$P < 0.05$)

[B] According to PGY and period of the day and night. Period 1 = 08:00–15:00, period 2 = 15:00–20:00, period 3 = 20:00–24:00 and period 4 = 00:00–08:00





identified on the wrong brain lobe, or a subdural location of a hemorrhage could be confused with an epidural location. A false-positive mistake in interpretation was defined as a positive pathologic finding by the resident which was later ruled out by the neuroradiologist. As shown in Figure 1A, a significantly higher percentage of false-positive errors were made by first-year residents, but there was no significant difference between them and more experienced residents in anatomic mistakes and errors that were given a score of 3 by the neuroradiologists.

MISINTERPRETATIONS ACCORDING TO YEAR OF RESIDENCY AND TIME OF DAY AND NIGHT

The errors in interpretation that were made by the residents were categorized by the time of day and night: 21% were made during period 1 (08:00–15:00), 41 during period 2 (15:00–20:00), 22% during period 3 (20:00–24:00), and 16 during period 4 (00:00–08:00) [Figure 1B]. The rates of errors during period 4 were significantly lower (35%, $P < 0.05$) compared to the other three periods ($P < 0.05$). Moreover, while third-year residents had the highest error rates, fourth-year residents had the lowest error rates compared with all other groups of residents ($P < 0.05$) (data not shown).

MISINTERPRETATION ACCORDING TO SITE AND PATHOLOGY

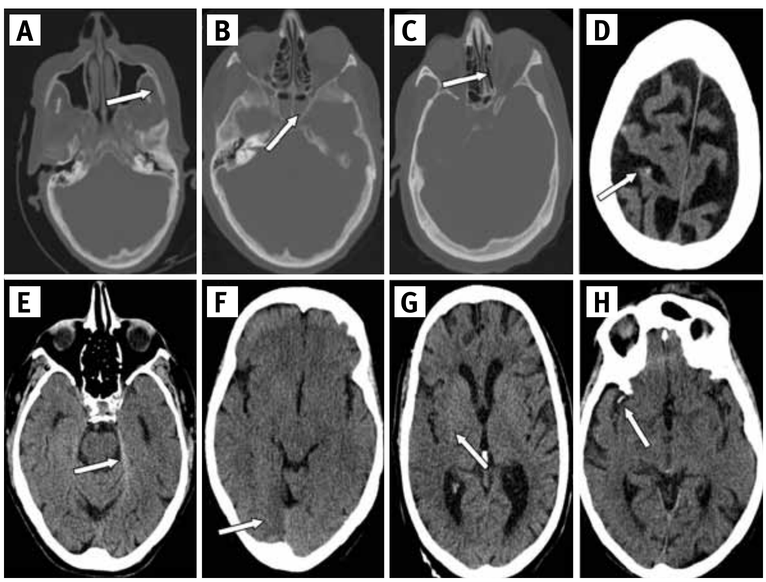
The misinterpretations were categorized according to the main site of the error and according to its subsite. The most common sites of interpretation errors were the lobes (34%), sinuses (17%), structures (10%), soft tissue (10%), and extra-axial locations (7%). The most common subsites for errors are described in Table 1.

Errors according to sites of the brain were also categorized by the frequency of a common pathology in each specific site [Table 2]. Pictorial examples of common misinterpretations are presented in Figure 2.

DISCUSSION

The main goal of our study was to pinpont the extent of misinterpretations and delineate the misinterpretations of common sites, subsites and pathologies by radiology residents in the ED setting. We analyzed 955 consecutive head CT scans and asked our senior neuroradiologists to identify each misinterpretation or miss, however slight or minor. Of these 955 scans, 254 (26%) contained one or more errors, yielding an overall misinterpretation rate of 41%. This is an extremely high percentage of misses compared to the rates cited in the

Figure 2. Examples of misinterpretations according to fractures (indicated by white arrows). Fractures at left zygoma **[A]** and sphenoid sinus **[B]**. Old ethmoidal sinus fractures **[C]**. Subarachnoid **[D]** and left tentorial subdural **[E]** hemorrhage. Right occipital **[F]** and right middle cerebral artery territory acute stroke **[G]**. Dense middle cerebral artery sign **[H]**



literature (range 0.9%–9%) [4-6,14,16,19]. We attribute this difference to several factors. First, we included errors that may be considered minor findings, such as mucosal thickening in the nasal sinuses, ischemic changes in white matter, lacunar infarcts, etc. Our rationale was that every finding can emerge as being significant in the clinical setting, as will be discussed later. The fact that the percentage of highly important errors (34.7% with a score of 3, data not shown) is comparable to the rate reported in the literature [17] implies that the absolute majority of our documented mistakes were minor and mostly insignificant in the ED setting.

Another explanation for our high percentage of misdiagnoses from misinterpretations of CTs is the intensive workload in our hospital. Sheba Medical Center is a major level I trauma center located in the center of Israel, and an average of 50 different head CT and 15–20 different body CT scans are performed in a single shift (15:00–08:00), which by any standard is a very intense workload. These numbers do not include additional ultrasound examinations (1–2 per shift) and telephonic radiological support for the entire hospital. Our results have shown that period 2 (15:00–20:00), which is the busiest part of the day, has the highest percentage of mistakes compared to other periods [Figure 1B] even though these are the first hours of the night shift. Moreover, this observation was true for almost all the residents [Figure 1B]. It is interesting to note that a recent study by Walls et al. [20] showed that the period with the highest percentage of mistakes was actually between 04:00 and 08:00, the last hours of the shift, which the authors attributed to fatigue. In contrast, our period 4 (00:00–08:00) had significantly lower error rates compared to other periods of the day and night. We attribute our results to the intense workload during period 2, during which there were far more telephone calls and consultations with the ED physicians. The ED is usually less hectic during period 4 and the residents are exposed to less "background noise" when interpreting the CT scans. Contrary to our expectations, we did not find any significant difference in the multiple-examination misinterpretation percentage (data not shown), which we interpret as probably not related to workload or fatigue but rather to the number of pathological findings in a single exam. As a result of the findings of the current investigation, we implemented a new working routine in the ED that allows a maximum of five CT scans per hour in order to reduce the workload of the radiology residents. Future studies will show whether this change has improved their accuracy in interpreting CTs.

According to our results, third-year residents made more absolute mistakes than the others during different periods of the day and night [Figure 1B]. However, first-year residents made significantly more false-positive errors, but not anatomical mistakes. Importantly, more mistakes by first-year residents involved CTs that had important findings requiring urgent treatment (score of 3), the most common of which were acute infarcts (40% of all score 3 errors, data not shown).

Radiology residents in the United States are required to undergo 12 months of training before being assigned to work an overnight shift [3], unlike our residents who undergo an intensive 4 months of preparation (this is comparable to countries other than the USA, such as Canada [20]). This fact no doubt contributes further to the higher percentage of misses compared to the reported data emerging mostly from the U.S. [2,5,15,17,20,21], i.e., the percentage of misses or mistakes declines as the resident is more experienced. Our finding that third-year residents had significantly higher error rates than the other residents was not unexpected: while first- and second-year residents are accompanied by more experienced residents and senior neuroradiologists, third-year residents are considered to be somewhere in-between. It would appear that only during the fourth year of residency does the combination of sufficient experience and accumulation of the right amount of radiology skills achieve the significantly lower error rates compared to the other residents.

Very few published works have focused on the exact sites, subsites and different pathologies missed by radiology residents during night shifts. Some studies have focused mainly on major misses [10,16,20], while others focused on specific misses, such as intracranial hemorrhage [16], CT angiography misses [18,21], middle cerebellar artery infarcts [22], or magnetic resonance imaging misses [19]. The few studies on the most prevalent missed pathologies [5,23] did not include their correlations to anatomic sites or relation to residents with different levels of experience or night shift parameters, as analyzed in the present work. Our results show that the most common site for missed pathologies is the brain lobes, followed by sinuses and deep brain structures. Analysis of the most frequently missed pathologies revealed that chronic infarcts and hypodense lesions are by far the most prevalent among them.

An observation worth noting is that the frontal area of the head appears to be more prone to misses and misinterpretations compared to other regions [Table 1]. Specifically, the frontal lobe, the ethmoid sinuses, frontal bone and soft tissue are the most prevalent sites among the various anatomical categories. The comparatively high rate of errors can be explained by the potential abundance of findings in a relatively small area of a CT scan. Since so many different pathologies can coexist in the frontal area, it is sometimes difficult even for the experienced eye to detect them all.

We are aware that this study has a number of limitations, the most significant of which is the relatively small number of examinations. The main purpose of this study was to show trends in radiology residents' errors in interpreting CT studies in the ED setting and to provide as detailed an analysis of them as possible. This is the first detailed illustration of Israeli radiology residents' misinterpretations according to sites, subsites and pathologies of lesions as demonstrated on head CTs. Our total percentage of mistakes in interpreting important findings (score of 3) is not significantly different from that in other reports. We have also shown that our third-year residents are more prone to making overall mistakes, while our first-year residents are more prone to making false-positive mistakes. We propose that ED misses are probably due to an intense workload rather than to fatigue. We hope that these findings will help radiology departments reduce the number of their residents' misinterpretations of imaging studies.

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Capsule

FOXO3A directs a protective autophagy program in hematopoietic stem cells

Blood production is ensured by rare, self-renewing hematopoietic stem cells (HSCs). How HSCs accommodate the diverse cellular stresses associated with their life-long activity remains elusive. Warr and co-workers identified autophagy as an essential mechanism protecting HSCs from metabolic stress. They show that mouse HSCs, in contrast to their short-lived myeloid progeny, robustly induce autophagy after ex vivo cytokine withdrawal and in vivo calorie restriction. They demonstrate that FOXO3A is critical to maintain a gene expression program that poises HSCs for rapid induction of autophagy upon starvation. Notably, they found that old HSCs retain an intact FOXO3A-driven pro-autophagy gene program, and that ongoing autophagy is needed to mitigate an energy crisis and allow their survival. These results demonstrate that autophagy is essential for the life-long maintenance of the HSC compartment and for supporting an old, failing blood system.

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