# ADDIS ABABA UNIVERSITY

## COLLEGE OF HEALTH SCIENCES

### SCHOOL OF MEDICINE


### DEPARTMENT OF EMERGENCY AND CRITICAL CARE MEDICINE

# Thesis on accuracy of emergency and critical care residents in interpreting emergency cranial CT scans as compared to neuroradiologist experience from two medical schools in Ethiopia

**Nathan Muluberhan** (MD, EMCC RIII)

**August 2019**

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**August 2019**

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I would also like to thank the department of research committee of Addis Ababa University, college of health and medical for approving my research.

# Abbreviations and Acronyms

**AAU**: Addis Ababa University

**AUROC:** Area under Receiver Operator Curve

**CT:** computed tomography

**DAI:** Diffuse axonal injury

**DSF:** Depressed skull fracture

**ED**: Emergency Department

**EMCC**: Emergency and critical care

**EP:** Emergency Physician

**EDH:** Epidural hematoma

**PGY:** post-graduation year

**ROC:** Receiver Operator Curve

**SAH:** Subarachnoid hemorrhage

**SDH:** Subdural hematoma

**SPSS:** Statistical Package for Social Sciences

**SMMC:** St ’Paul millennium medical college

**TASH**: Tikur Anbessa specialized hospital

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# Abstract

***Introduction****:* Emergency departments are crucial entry points to healthcare services and usually overcrowded. A computed tomography is a diagnostic medical device with computers and rotating X-ray machines creating cross-sectional images of the body. It is often used in the emergency room. The use of cranial CT in ED patients could be influential in clinical decision making by improving diagnostic confidence and have impact on treatment plan. While the accuracy of interpretation of brain CT scan by emergency physicians is of crucial importance, many EM residency programs do not allocate enough time to brain CT scan interpretation training

***Objective****s*: was to determine competence of emergency medicine residents of TASH in the assessment of cranial CT scans, May 2019

***Methodology:*** A prospective cross-sectional study employed on the EMCC residents of AAU, and St' Paul MMC. Data collected from May 2019-June 2019 by using structured questionnaires as well as through radiant view software by displaying the full slices of the cranial CT scans. Data have entered, cleaned, edited and analyzed by using SPSS 20.0 version statistical software. And analysis was also done in SPSS & excel 2016.

**Results:** Forty two EMCC residents were enrolled in this study. 24 from AAU and 18 from St' P aul MMC. Over all accuracy rate in interpretation cranial CT scans was 57.6%. The overall di screpancy rate was very high (42.4%) compared to prior studies. The sensitivity of the residen ts in detecting normal radiographs was 62.6% with specificity of 96%, PPV of 66.3% and NP V of 95.3%. Most residents correctly identified haemorrhage (97.6%) & hydrocephalus (90.5 %). All residents miss CT scan of herniation and 92.9% of the residents miss meningeal enha ncement. There is moderate agreement between EMCC and neuroradiologist (kappa 0.5).The re is no factor identified that has significant statistical association with the outcome of the inte rpreting emergency cranial CT scans.

**Conclusion:** The skills of residents in interpreting cranial CT results are very low regardless of the prevalence of the condition in the ER or the relative clinical importance of the conditions. Poor sensitivity and high false positive results with misinterpretations were common. This can result in potentially dangerous patient mismanagement.

**Key words:** Cranial CT scans, Emergency medicine residents, neuroradiologist

# Introduction

## Background

A computed tomography (CT or CAT) is a diagnostic medical device with computers and rotating X-ray machines creating cross-sectional images of the body and reformat in multiple planes, and can be generate in to three-dimensional images.[1] CT has revolutionized radiology and medicine as a whole. It has been used in the modern medical system since its invention in 1972 by British engineer Godfrey Hounsfield of EMI Laboratories. [2] It can scan any part of the body and it is painless, non-invasive and rapid imaging modality, which makes one of the frequently ordered diagnostic tests. The current CT scanners are capable of acquiring sub millimeter-resolution images of the entire body in seconds. The use of CT has increased exponentially. Factors that promote the increased use of CT in the ED include its availability, efficiency, image resolution, noninvasive nature and the higher ED patient throughout it allows patient expectations, and providers' fear of medico legal repercussions. It is frequently used in the differential diagnosis of intracranial pathology during emergency department (ED) visits. [3]

Emergency departments (ED) are crucial entry points to healthcare services and usually overcrowded. Furthermore, the urgent nature of the medical conditions that bring patients to ED, add to the value of accurate and fast diagnosis and management.[4] In traumas and other critical cases, time is the essence and the emergency physician (EP) must act quickly according to his ordered and related investigations. [4] The use of Non-contrast CT in ED patients could be influential in clinical decision making by improving diagnostic confidence and also have impact on treatment plan. In many centers, radiology specialists report cranial CT scans in an elective manner after ED presentation. Emergency physicians and residents are required to interpret CT scans and make therapeutic decisions accordingly. [6].

While the accuracy of interpretation of brain CT scan by emergency physicians is of crucial importance, many EM residency programs do not allocate enough time to brain CT scan interpretation training. There are many studies from different centers that compare emergency

physicians and residents' cranial CT scan reading ability to the radiologist with different and contradict results. [7]

## Statement of the problem

The emergency physicians and emergency residents encounter enormous and variety of cases as they are the frontline of the hospital. They work in all hours of the day and there are no attending radiologists in the duty hours. It is the sole role of the emergency medicine residents and emergency physicians to identify normal investigations as well as the abnormalities to reach a diagnosis and act accordingly. They are likely to experience mistakes such as misleading diagnosis, missed diagnosis, or diagnosis of a nonexistent disorder.[23] It is possible to prevent undesired outcomes through accurate assessment of cranial CT scans by emergency physicians and emergency medicine residents. [8]

The cranial CT scan is one of the frequently ordered investigations in the emergency room and it's expected from these first line physicians to be competent in reading this scans. As there is no separate radiology attachment in the curriculum of the emergency medicine residency training of AAU as well as SPMMC, thus their skill is solely depending on the emergency room teachings and individual effort. It is essential to know the accuracy of emergency medicine residents interpretation of cranial CT scans.

In Ethiopia, emergency medicine is young field of study. It has been only 10 years after it establishment and there are few emergency physicians and there are currently two teaching schools of emergency medicine. Very little is known whether current curriculum of emergency medicine is guarantees higher accuracy of in the interpretation of emergency cranial CT scans. There is no published data in this regard in Ethiopia. Therefore, this study aimed to assess the basic skills in the interpretation of cranial CT scan and analyze whether the skills are developed during the process of residency training for emergency and critical care medicine specialization. And this study also study the adequacy of the curriculum of emergency medicine residency in basic skills in the interpretation of cranial CT scans.

# Literature review

The use of cranial CT scan has been rapidly increased in the emergency room and there are different comparison studies of emergency room staff cranial CT reading competency and accuracy as compare the radiologist.

On the prospective cohort study done by Dr. Dennis Alfaro et al at the county hospital emergency medicine residency program, five hundred fifty-five patients undergoing CT scanning during emergency department evaluation. Forty-nine percent (272) of the indications for CT scanning were for trauma, 14.2% (79) were for cerebrovascular accident, 25.1% (139) were for headache, 15.1% (84) were for seizure, and 13.7% (76) were for miscellaneous reasons. The radiologists interpreted 46.1% (256) of the CT scans as abnormal. The most frequent abnormalities were scalp hematoma, 15.2% (39); infarction, 14.1% (36);calcification, 6.3% (16); contusion, 6.3% (16); parenchymal hemorrhage, 5.1% (13);and mass, 5.1% (13). Non-concordance between radiologists and emergency physicians was found in 38.7% (206) of the cases. Potentially clinically significant misinterpretations were found in 24.1% (131) of the total sample. These misinterpretations included 62 missed major findings (11.4% of total sample): 25new infarcts, 10 mass lesions, 8 cases of cerebral edema, 8parenchymal hemorrhages, 5 contusions, 4 subarachnoid hemorrhages, 1 epidural hematoma, and 1 subdural hematoma. [7].

A study done in Tehran teaching hospital in Tehran, Iran, from March to May 2009 head CT scans from 544 patients were enrolled based on the reports from the radiologist, abnormalities were found in 259 (47.6%) of cases (acute). Head trauma was the most common reason for CT scan (291, 53.49%) and 23% of the patients with head traumas had no other complaints. The comparison between the reports from emergency physicians and radiologist, as the gold standard, revealed that 88 (16.2%, 95%CI) of the interpretations differed. There were 35 (6.44%, 95% CI) false negative and 53 (9.73%, 95% CI) false positive cases. This difference was statistically significant ($P < 0.0001$). These findings revealed a sensitivity and specificity of 86.5 % and 81.4% respectively for the interpretations done by the emergency physicians. PPV of 86.9%, NPV of 86.9%, PLR of 4.6 and NLR of 0.16 were the other statistical characteristics of the interpretations of emergency physicians. On the other hand, the reports from senior residents

were different from those of the radiologist, as the gold standard, for 86 (15.8%, 95%CI) cases. There were 12 (2.21%, 95%CI) false positive cases while false negative cases accounted for 74 (13.6%, 95%CI) of the discordances and the difference was statistically significant ($P < 0.0001$). Other statistical attributes related to interpretations from senior residents had a sensitivity of 71.4%, specificity of 95.8%, PPV of 93.9% and NPV of 78.7%. Therefore, PLR and NLR were calculated to be 17 and 0.29 respectively [10]

A similar study done at King Khalid University Hospital (KKUH), Riyadh to determine the accuracy of non-contrast CT brain interpretation by emergency physicians. Dr. Anas Khan and his colleagues found the following result, from the 241cases.The concordance analysis between emergency physician and Radiologist shows that, they agreed upon 185 cases to be normal, and agreed on the abnormalities of another 25 cases. So, the agreement was observed in 210 cases (87.14 %). disagreement (discordance) was noticed on 31 cases, whereas 15 cases reported normal by the emergency physicians were found to have abnormalities as per radiologist. Seven cases reported to have abnormalities by the emergency physicians but found to be normal by the radiologist. In nine cases, incomplete or different abnormalities were reported among the emergency physicians and the radiologist. The results demonstrate that agreement between EPs and radiologist specialists' interpretation of NCCT Brain scans is reasonable, with an overall concordance rate of 87.14%. And accuracy of emergency physician to read brain CT scan is 90.5 (95% CI: 86.2--93.8, sensitivity of 96.3 (95% CI: 92.6--98.5) and specificity of 96.3 (95% CI: 92.6--98.5) [11]

On a study by Dr. Mohammad-Taghi et al at Tehran University about the impact of incorrect brain CT scan interpretations by emergency medicine team on patients' primary and secondary outcome was evaluated in the setting where neuroradiologists reports are not always available. In this 03-month study,450 patients were enrolled and followed for 28 days. The emergency medicine team interpreted all CT scans and the patients were managed accordingly. Neuroradiologists' reports were considered as gold standard, and the patients were then grouped into the agreement or disagreement group. A panel of experts further evaluated the disagreement group and placed them in clinically significant and insignificant. The agreement rate between emergency medicine team and neuroradiologists was 86.4%. The inter-rater reliability between

emergency team and neuroradiologists was substantial (kappa=0.68) and statistically significant ($p$<0.0001). Only five patients did not receive the necessary management, and among them, only one patient died, and 12 patients received unnecessary management including repeated CT scan, brain MRI, and lumbar puncture. Forty-one patients were managed clinically appropriate in spite of misinterpretation. A 28-dayfollow-up showed a mortality rate of 0.2 %; however, expert panel believed the death of this patient was not related to the CT scan misinterpretation. [12]

On the same study done by Dr. David et al to determine the accuracy of physician in reading cranial CT scan and determine eligibility for thrombolytic therapy, they found that for those patients out of 569 cases read by the emergency physicians 67% were correct and the overall sensitivity of detecting hemorrhage were 82% with 95% confidence interval .[8]

Another cohort study, by Senol Ardic et al in Dr Lutfi Kirdar Kartal education and research hospital department of emergency medicine between January 1$^{st}$ and July 1$^{st}$ 2012. It showed that out of 525 cases, the cranial CT scans from the radiologist reported abnormal CT findings in 17.9% (94) and normal CT findings in 82.1% (431) of scans, whereas emergency medicine residents reported abnormal CT findings in 20.8%(109) and normal CT findings in 79.2% (416) of scans). There was inconsistency in 42 (36.2%) and consistency in 74 (63.8%) of 116 CT scans reported to have abnormal findings by both groups. Both groups reported abnormal CT findings but different diagnoses in 13 of 42 cases with inconsistency. Twenty-two cases were reported as normal CT findings by radiologists, but as abnormal CT findings by emergency medicine residents, seven cases were reported as normal CT findings by emergency medicine residents but as abnormal CT findings by radiologists. Non-coincidental consistency was 82.3% between radiologists and emergency medicine residents regarding CT scan assessments. Abnormal CT findings were found in 17.9% of CT scans reported by radiologists and in 20.8% of those reported by emergency medicine residents. Of 94 cases reported as abnormal CT findings by radiologists, 87 (16.6%) were also interpreted as abnormal; whereas the remaining seven cases (1.3%) were interpreted as normal CT findings by emergency medicine residents. These cases were subarachnoid hemorrhage, sinusitis, and minor fractures. The sensitivity, specificity, positive predictive value, and negative predictive value of the test were calculated as 92.55%, 94.9%, 79.81%, and 98.32%, respectively [14]

A retrospective cohort study form Princess Margaret Hospital in three years (from 2008 to 2010) with head injuries requiring CT brain during ED stay. The findings of CT brain by ED medical staff were compared with those by radiologists, the reference standard. A total of 1716 cases were assessed. The overall sensitivity and specificity for detecting an abnormal CT were 0.66 (95% confidence interval [CI] 0.60-0.71) and 0.96 (95% CI 0.95-0.97), respectively. The sensitivity showed an increasing trend from 0.63 (95% CI 0.54-0.72) in ED staff with0-3 years of working experience, to 0.71 (95% CI 0.59-0.84) with 4-6 years of experience and 0.75 (95%CI 0.63-0.86) with 7-10 years of experience. It dropped to 0.59 (95% CI 0.47-0.71) with more than10 years of experience [6]

On another study done by Matthew et al to assess clinically Significant Radiograph misinterpretations at an emergency medicine residency program, A total of 12,395 radiographic studies interpreted by emergency physicians during a consecutive 12-month period and Four hundred seventy-five (3.4%) total errors and 350 (2.8%) clinically significant errors were found. There was a difference in clinically significant misinterpretation rates among the seven most frequently obtained radiograph studies (P < .0005, X2). No difference (P 0.421) was noted among fulltime, part-time, third-year, second-year, and "other" physicians. Head computed tomography out of the 216 total scan total errors and significant errors were seven (3.2 %) & seven (3.2 %) respectively. [16]

Over all the accuracy of emergency medicine residents in the interpretation skill of cranial CT scan is varied in different areas and in different study method, and studies have shown that after giving formal training interpreting ability has improved.

# Significance of study

In 2012, the Academic Emergency Medicine consensus conference focused on education research in emergency medicine (EM). [17] In particular, reviewed diagnostic reasoning and training. They highlighted that the assessment of an emergency physician's (EP) diagnostic reasoning skills is vital to effective training and patient safety. [18] The ability to select and interpret diagnostic imaging is an integral skill for all EM practitioners. [19] Diagnostic accuracy, diagnostic delay, and communication of critical findings by radiologists are common liability concerns in emergency radiology.[20] One study reported only 39% of emergency departments (EDs) have access to a radiologist's interpretation of all images within hours of image acquisition during day weekday hours, with even fewer in this same time frame on nights and weekends. The rest of interpretation may fall outside of this time window. [21] The diagnostic error from failure to detect an abnormal radiograph in a timely manner may result in poor patient outcomes in the emergency setting. [22]. this study evaluated the accuracy of EMCC residents of AAU and SPMMC in assessing cranial CT scans as compared to the neuroradiologists.

To the author's knowledge, there has not been any study that has evaluated the accuracy of EMCC residents on interpretation of emergency cranial CT scans in Ethiopia and Africa. This study can be used as baseline for further studies on this area as well as feedback for the department of emergency medicine of both AAU and SPMMC.

# Objectives

## General objectives

- To determine accuracy of EMCC residents of AAU and St' Paul millennium medical college in the assessment of cranial CT scans, June 2019

## Specific Objectives

- To determine the level of consistency on reading cranial CT scan by EMCC residents of AAU and St' Paul millennium medical college, June 2019.
- To determine the specificity, sensitivity, PPV & NPV of cranial CT scan reading by EMCC residents of AAU and St' Paul millennium medical college, June 2019.
- To determine the concordance and discordance rate of EMCC residents of AAU and St' Paul millennium medical college, in the assessment of cranial CT scans, June 2019.
- To identify factors associated with ability to read cranial CT scans of EMCC residents of AAU and St' Paul millennium medical college, June 2019.

# Methodology

**4.1. Study area:** The study was conducted in two tertiary teaching hospitals. The first one is Addis Ababa University Tikur Anbessa Specialized Hospital, located in Addis Ababa, Ethiopia. The emergency department was established in 2010 and it has been teaching emergency medicine since then. There are around 40 beds in the Adult Emergency room with daily patient visit of around 80patients. The emergency room is divided as red, orange and green area. There are 24 emergency and critical care medicine residents and 09 emergency and critical care specialist. There are 03 first year residents, 01 second year emergency resident and 1 third year emergency resident in the duty hours. In the radiology department there are 18 consultant radiologists, 05 neuroradiologist and 63 radiology residents (14 third, 22 second, and 27 first year). On night time & weekends two residents (01 second &01 third year) will be on duty to read CT scans. The second is Paul's Millennium Medical College. It is also located in Addis Ababa, Ethiopia. The College sees an average of 1200 emergency and outpatient clients daily. The hospital has also other affiliate for emergency care, which is Aabet. It is the center for trauma and burn. It was established in 2016. The emergency department started teaching residency program in 2016 and there are 45 EMCC residents (19 PGY1, 11 PGY2 and 15 PGY3). There are 05 red beds, 10 orange beds and 15 green beds in the Aabet center with around 11 ICU beds. There are emergency and critical care, general surgery, radiology, plastic surgery, orthopedics and forensic medicine departments in this center. There are 02 radiology residents on working hours but there are no radiology residents on duty hours.

**4.2. Study design:** Cross-sectional study was done on all EMCC residents in AAU Tikur Anbes sa specialized hospital and St Paul millennium medical college attending in 2019 G.C.

**4.3. Source population:** All Emergency and Critical care medicine residents in in AAU Tikur Anbessa specialized hospital and St Paul millennium medical college**.**

**4.4. Study population:** 42 Emergency and Critical care medicine residents in Tikur Anbessa S pecialized Hospital and St Paul's Millennium Medical College

**4.5. Sample size determination:** No sampling technique was used, all emergency residents in AAU Tikur Anbessa specialized hospital and St Paul millennium medical college who con sent for participation were included in the study.

## 4.6. Inclusion & exclusion criteria

**Inclusion criteria-** All EMCC residents in AAU Tikur Anbessa specialized hospital and St P aul millennium medical college who stayed more than 6 months on residency program.

**Exclusion criteria -**Those residents who refused to consent for participation

The principal investigator

Residents who stayed less than 6 months in the residency program.

## 4.7. Study variables

**Dependent variable:** accuracy in interpreting Emergency Cranial CT scans

**Independent variables:**

- Age
- Sex
- Cranial CT scan interpretations training
- The resident's class level (PGY1, PGY2 or PGY3)
- Frequency of cranial CT scan encounter per week
- Amount of previous Cranial CT scan
- Confidence of student
- Frequency of asking for help
- Self-learning
- Cranial CT scan abnormalities

## 4.8. Data collection analysis.

**4.8.1. Data collection methods:** Semistructured questionnaire was used to collect the personal and other information from the residents. The principal investigator did the data collection. 15 complete full slices of cranial CT scans were selected, they were interpreted by the neur oradiologists at Tikur Anbessa hospital. The scans were selected based 03 months data take n from the logbook of radiology residents. From this data emergency cases were selected an d sorted on their frequency. Top 15 CT scans with findings mentioned below were included . These were normal, hydrocephalus, meningitis, subdural hematoma, epidural hematoma, c ontusion, ischemic stroke, haemorrhagic stroke, midline shift, subarachnoid haemorrhage, d epressed skull fracture, and herniation. The clinical information was not given for resident. Resident asked to write their findings on the blank paper. It was then compared with radiolo gists reading and scored out of 27.

**4.8.2. Data analysis:** Collected data was then compiled, organized, and analysed using SPSS version 20.0.Statistical significance was set at P-value of 0.05. Descriptive analysis, binary logistic regression, area under ROC and Cohen's kappa to calculate the rate of agreement between the EMCC resident and the neuroradiologist. Cohen's kappa statistics a widely used measure to evaluate interrater agreement compared to the rate of agreement expected from chance alone on the basis of the overall coding rates of each rater. Kappa is scaled to be 0 when the amount of agreement is what would be expected to be observed by chance and 1 when there is perfect agreement.(k< 0 poor agreement, k 0.00–0.20 slight agreement, k:0.21–0.40 fair agreement, k: 0.41–0.60 moderate agreement, k: 0.61–0.80 substantial agreement, k: 0.81–1.00 almost perfect agreement) was used to produce a summary of statistics.

**4.8.3. Ethical considerations:** Ethical approval was taken from AAU, department of Emergenc y and critical care. Confidentiality of each residents keep unrevealed. The result of this stud y will be submitted to the department. And also abstract will be sent for different local and i nternational journals.

4.**8.4. Dissemination**: The finding of this study will be share with department of emergency me dicine of AAU and St Paul MMC.

### 4.8.5 Data Quality Assurance

During the data collection procedures, all the collected data were reviewed and checked daily for its completeness.

#### 4.8.6. Operational definition

Concordance: the agreement between the emergency residents and neuroradiologist

Discordance: the disagreement between the emergency residents and neuroradiologist

# Results

## Demographic

A total of 42 Emergency and critical care medicine residents were enrolled in this study. 51 % of the residents were from Addis Ababa University and the rest are from St' Paul millennium medical college. The mean age of the residents is 28 (SD, 2.44). The proportion of male residents was 76.2 % with female proportion of 23.8 %. PGY1 and PGY2 residents were 45.2% and 23.8 %, respectively, while PGY3 residents were 31%.

Only 40.5% have taken cranial CT scan reading training in their undergraduate training and 59.5% took CT scan reading training during the time of postgraduate trainings. 76% of the residents believe that level of training they got in postgraduate is not adequate for interpreting results of emergency cranial CT scans.

About 43% of the residents believe that Cranial CT scan reading is difficult. 76.2% of the respondent are confident in reading emergency cranial CT scans. 85.7% (36) of the residents read more than 10 emergency cranial CT scans per each month.

***Table 1: Background characters and attitudes of EMCC residents of AAU & St' Paul MMC, June 2019***

| Variable | | Frequency | % |
|---|---|---|---|
| School | AAU | 24 | 57.1 |
| | St' Paul | 18 | 42.9 |
| Gender | M | 32 | 76.2 |
| | F | 10 | 23.8 |
| Year of Residency | PGY1 | 19 | 40.5 |
| | PGY2 | 10 | 35.4 |
| | PGY3 | 13 | 24.1 |
| Postgraduate training | Yes | 25 | 59.5 |
| | No | 17 | 40.5 |
| Training adequate | Yes | 6 | 24 |
| | No | 19 | 76 |
| CT reading difficult | Yes | 24 | 57.1 |
| | No | 18 | 42.9 |
| Ask for Help | Always | 5 | 11.9 |
| | Sometimes | 32 | 76.2 |
| | Rarely | 5 | 11.9 |
| Radiology Attachment | Yes | 42 | 100 |
| | No | - | - |
| Level of confidence | Confident | 32 | 76.2 |
| | Not confident | 10 | 23.8 |
| Number of Cranial CT scans per month | =< 10 | 6 | 14.3 |
| | >10 | 36 | 85.7 |

## CT interpretation

All 42(100%) residents want to have separate radiology attachment in the radiology department in their residency training of Emergency and critical care specialization. And 88.1 % of the resident respond that, they ask help from others in interpretation of cranial CT scans of which 13.5% of them always ask for help. EMCC resident often seek help from radiologist and emergency senior residents with percentage of 59% and 57.1% respectively. They also ask help from radiology residents (4.7%), emergency physicians (28.5%), and their peers (26%). Around 86% of the EMCC residents have read supplemental material on interpreting of emergency cranial CT scan

No single resident correctly identified the all the 27 cases in the 15 emergency cranial CT scan. The mean of correctly answered CT cases was 14.4 (SD 3), the maximum score was 23 from 27 cases of emergency cranial CT scans and the minimum was 9cases. The most correctly interpreted case was intracranial hemorrhage, which is 97.6% (95 CI) of the residents got it correctly and the second one is hydrocephalus with 90.5% (95% CI) and no resident correctly identified herniation. Moreover, table 2 below shows all emergency cranial CT cases with their correctly and incorrectly answered percentiles.

The author used ROC curve to calculate the accuracy of the respondents in correctly interpreting a given emergency cranial CT scan as it drawn below in figure1, the area under the receiver-operating curve has become 0.576. Thus, the EMCC residents interpret emergency cranial CT scans with the accuracy of 57.6% (95% CI).

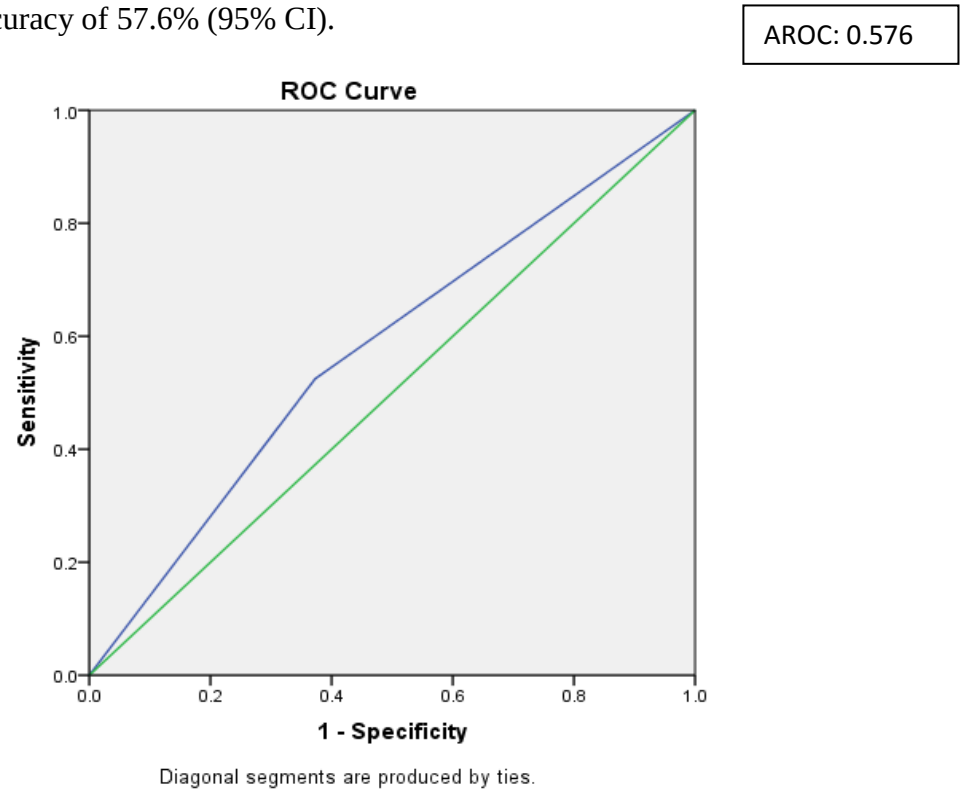


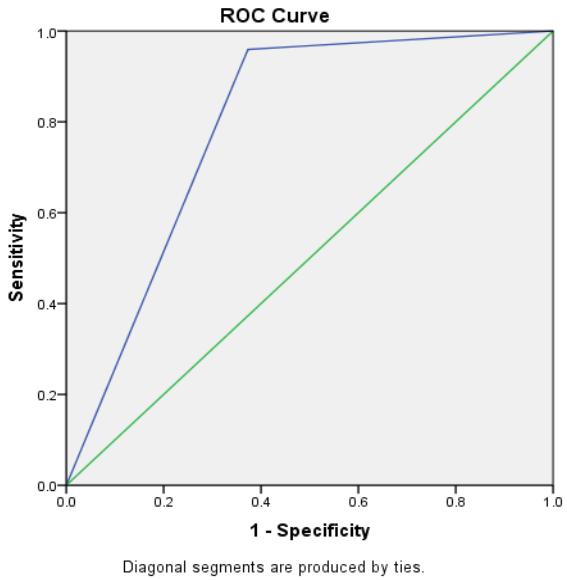



***Fig 1: The ROC of the accuracy rate of EMCC residents of AAU & St' Paul MMC, June 2019***

***Table 2: The percentage of correctly answered cases of EMCC residents of AAU & St' Paul MMC, June 2019***

| CT scan findings | Correct | Incorrect |
|---|---|---|
| Pneumocephalus | 38.1% | 61.9% |
| Hydrocephalus | 90.5% | 9.5% |
| Meningitis | 7.1% | 92.9% |
| DSF | 50% | 50% |
| SAH | 48.8% | 51.2% |
| SDH | 34.5% | 65.5% |
| EDH | 80.9% | 19.1% |
| Contusion | 54.7% | 45.3% |
| Midline shift | 36.9% | 63.1% |
| Hemorrhage | 97.6% | 2.4% |
| Ischemic | 71.4% | 28.6% |
| Herniation | - | 100% |

The ROC (fig 2) for EMCC residents in the correctly interpret normal cranial CT scan. The AUROC 0.793, thus the accuracy of EMCC residents in interpreting normal cranial CT scan is 79.3% with the specificity 96%, sensitivity 62.6% PPV 66.3% and NPV 95.3%.




**AUROC: 0.793**

***Fig 2: The ROC on the interpretation of Normal Cranial CT scans of EMCC residents of AAU & St' Paul MMC, June 2019***

***Table 3: The sensitivity, specificity, PPV and NPV of CT scan cases of EMCC residents of AAU & St' Paul MMC, June 2019***

| Cases | Sensitivity | Specificity | PPV | NPV | Kappa (CI 95%) |
|---|---|---|---|---|---|
| **Normal** | **62.6 %** | **96%** | **66.3%** | **95.3%** | **0.602** |
| **Pneumocephalus** | **38 %** | **98.2%** | **45.7%** | **97.6%** | **0.494** |
| **Hydrocephalus** | **90.4 %** | **99.3%** | **84.4%** | **99.6%** | **0.869** |
| **Meningitis** | **7.1 %** | **100%** | **100%** | **96.5%** | **0.129** |
| **DSF** | **50 %** | **98%** | **81.5%** | **91.8%** | **0.572** |
| **SAH** | **48.8 %** | **97.7%** | **63%** | **96.1%** | **0.383** |
| **SDH** | **34.5 %** | **93.3%** | **29%** | **94%** | **0.257** |
| **EDH** | **80.9 %** | **99.6%** | **94.4%** | **99.2%** | **0.845** |
| **Contusion** | **54.7 %** | **97.5%** | **89.2%** | **88.2%** | **0.414** |
| **Midline shift** | **36.9 %** | **96.6%** | **46.9%** | **95%** | **0.372** |
| **Hemorrhage** | **97.6 %** | **97.6%** | **78%** | **99.8%** | **0.856** |
| **Ischemic** | **71.4 %** | **98.9%** | **2.74%** | **98.9%** | **0.712** |
| **Herniation** | **-** | **99%** | **-** | **96.2%** | **0.003** |

The kappa value for each emergency cranial CT cases were calculated as it is seen in the above with the highest k of 0.869 (CI 95%) and lowest 0.003(CI 95%) for hydrocephalus and herniation respectively. The calculated average kappa is 0.5 (CI 95%)

***Table 4: The Miss-interpretations different CT cases by EMCC residents of AAU & St' Paul MMC, June 2019***

| Cases | Miss- interpretation |
|---|---|
| **Normal cranial CT** | **DAI, brain edema, ischemic change, sinus thrombosis, contusion, ring enhanced lesions** |
| **Meningeal Enhancement** | **DAI, SAH** |
| **DSF** | **Linear #, Basal skull #** |
| **Pneumocephalus** | **Normal** |
| **SDH** | **EDH, Hemorrhage** |
| **EDH** | **SDH, Contusion, hemorrhage** |
| **Ischemic stroke** | **Normal, Meningeal enhancement** |
| **Hemorrhage** | **Mass, tumor** |

Diffuse axonal injury (DIA) accounts for 40% of normal CT scan misinterpretation, Brain edema (25%), Ischemic change (15%), sinus thrombosis (10%), contusion (5%) and ring enhanced lesion (5%). Other common misinterpretations for different cases seen in this study has presented in table 5 above.

## Association

The author has also done the association of different independent variables with chi square and binary logistic regression. Variables; school where the residents attending their residency, year of residency, their level of confidence, sex of the residents, the frequency of CT they read per month, whether they took CT reading class in the residency, perception of difficulty of CT reading and also reading books regarding CT scan interpretation were analyzed.

Even though statistically significant difference has been demonstrated that females and EMCC residents who read books on emergency cranial CT scans interpreted emergency cranial scans cases more accurately with OR of 1.03 (95% CI, P: 0.037) and 1.21 (95% CI, P 0.04) respectively, the adjusted OR has shown no variable is statistically significantly associated.

*Table 5: The association of correct interpretation with different variables by EMCC residents of AAU & St' Paul MMC, June 2019*

| Variables | Answer | Correct | Incorrect | OR (CI 95%) | P value |
|---|---|---|---|---|---|
| School | AAU | 334 | 314 | 1.18 | 0.158 |
| | St Paul | 271 | 215 | | |
| Sex | Male | 446 | 418 | 1.34 | 0.037 |
| | Female | 159 | 111 | | |
| Year of residency | PGY1 | 275 | 238 | 0.99 | 0.913 |
| | PGY2 | 143 | 127 | | |
| | PGY3 | 187 | 164 | | |
| Level of confidence | Confident | 458 | 406 | 1.05 | 0.68 |
| | Not confident | 147 | 123 | | |
| Frequency of reading per month | = < 10 | 82 | 80 | 0.88 | 0.45 |
| | >10 | 523 | 449 | | |
| Post-graduation CT reading Class | Took | 367 | 308 | 1.01 | 0.404 |
| | Didn't take | 238 | 221 | | |
| Perception of difficulty | Yes | 348 | 300 | 1.03 | 0.783 |
| | No | 257 | 229 | | |
| Books | Always | 62 | 73 | 1.21 | 0.04 |
| | Sometimes | 479 | 385 | | |
| | Rarely | 64 | 71 | | |

*Table 6: The adjusted ODD ratio of correct interpretation of cranial CT scans by EMCC residents of AAU & St' Paul MMC with different variables, June 2019*

| Variables | P value | Adjusted ODD ratio | 95% C.I. for Adj. ODD ratio | |
|---|---|---|---|---|
| | | | Lower | Upper |
| School | 0.068 | 1.366 | 0.961 | 1.941 |
| Sex | 0.063 | 1.316 | 0.957 | 1.811 |
| Year | 0.537 | 1.034 | 0.856 | 1.248 |
| Postgrad | 0.754 | 0.942 | 0.679 | 1.307 |
| Difficult | 0.348 | 1.229 | 0.842 | 1.794 |
| Confident | 0.305 | 0.940 | 0.657 | 1.344 |
| Frequent | 0.862 | 0.934 | 0.639 | 1.365 |
| Self-learning | 0.972 | 1.139 | 0.873 | 1.485 |
| Books | 0.519 | 1.153 | 0.844 | 1.575 |

# Discussion

Cranial CT scans contribute important information to the medical decision making process occurring in the emergency department. Often CTs are initially interpreted by an emergency medicine physician and decisions are made on the basis of this initial interpretation. In many institutions, the radiologist subsequently interpret CTs with some means of resolving discrepancies that arise from this second interpretation.

There are several studies across different centres with a wide range of concordance rate between EMCC personnel and neuroradiologist reports on cranial CT scans. These findings range from 61.3% to 87%. In our study, the concordance rate is 57%, which is low as compare to the other studies. The low concordance rate in our study may be explained by the fact that only residents were involved in the study unlike most studies where emergency physicians were involved. The other is differences in the sample size, study methodology used, absence of clinical information and/or residents' level of training.Bearing in mind the aforementioned possible differences, the table below shows the summary of prior studies.

The AUROC show as how accurate the test is. The perfect test is the one with AUROC of 1 that is 100% sensitive and specific. This is rarely encountered practically, therefore, we consider the more close it is to 1, and the more accurate it is with ROC dragged more to the left. A result less than 0.5 indicate the test is not accurate at all, a value from 0.5 to 0.7 is considered to have low accuracy. Result above 0.7 has medium to high accuracy. In our study, the accuracy of EMCC residents in interpretation of cranial CT scans is 0.576, which is low accuracy

In this study, despite high specificity in most of the cases the sensitivity is very low. As it is known sensitivity tells us the diagnostic ability of the test form diseased individuals, and in this regard, the EMCC residents have shown a sensitivity of very low rate in cases like, herniation, meningeal enhancement (7.1%), SDH (34.5%), SAH (48.8%) and Pneumocephalus (38%). These are highly fatal cases that the emergency department of AAU and St' Paul frequently encounter. The EMCC resident in this regard shows unacceptable result and urgent measure has to be taken to improve this condition.

***Table 7: Different studies comparing the emergency staff and radiologist interpretation of Cranial CT scans***

| Author, Date and Country | Patient group | Study type (level of evidence) | Outcomes | Key results |
|---|---|---|---|---|
| Mucci, Brett, 2005 UK | 100 consecutive CT head scans requested by ED and reviewed by senior ED staff | Retrospective case series. Single center | Concordance between ED report and consensus opinion of 2 radiologists | 86.6% agreement. No findings missed that would change the overnight management of patient |
| Peron, Huff, 1998 USA | 83 Emergency Medicine residents at 5 institutions | Prospective multi-center study | Participants underwent exam of 12 CT scans. Then 2 hour course. Reexamined 3 months later. Comparison of pre and post test scores | Mean score in initial test was 60%. Retest 3 months later had mean score of 78% ($p<.001$ paired t test) |
| Mehta, 2005 UK | 212 emergency cranial CTs over 5 months reported by senior ED doctors | Prospective single center cohort study | Concordance between reports by senior ED staff and consultant neuroradiologist | Concordance between ED staff and neuroradiologist (78.3%). 6.6% of discordant ED reports could have had adverse clinical outcome |
| Alfaro, 1994 USA | 555 patients undergoing CT scanning in ED for trauma and non-trauma. Scans reported by 14 ED staff and result compared with radiology report | Prospective single center cohort study | Concordance between ED report and radiology report | Non-concordance rate 38.7% between radiology and emergency physician reports. Clinically significant misinterpretations found in 24.1% of scans |
| Arendts, 2003 Australia | 1282 patients undergoing non contrast CT head for trauma and non trauma. Reported by senior ED staff | Prospective blinded cohort study | Concordance between ED and consultant radiology report | 190 scans (14.8%) were misinterpreted. 78 (6%) of these had potential or actual consequences. No significant difference with varying level of experience or qualification of ED doctor reporting scan |
| Levitt, 1997 USA | 324 scans reported by 14 EMCC residents. Phase I (217 scans) then 1 hour educational session then phase II (89 scans) 10 days later | Prospective single center interventional study | Accuracy rate of reporting compared pre and post test | Concordance rate between ED and radiology report improved significantly from 61.3% pre-test to 88.6% post-test. Major missed findings decreased from 11.4% to 2.8% ($p<.0001$). No clinically significant mismanagement |
| Anas Khan Saudi Arabiya | 241 patients undergone CT scanning in ED and report from ED was compared with the radiologist | Prospective single center interventional study | Concordance between ED report and radiology report | Agreement was observed in 210 cases (87.14 %). disagreement (discordance) was noticed on 31 cases, whereas 15 cases reported |
| Perron, 1997 USA | 30 Emergency Medicine residents tested on interpretation of 10 CT scans. Then 2-hour educational session. Retested after 3 months | Prospective cohort study | Comparison of pre and post test scores | Pretest mean score 7, post test score 8. Scores significantly improved between pre and post tests |

Increased ICP is the leading cause of death from head trauma in patients who reach the hospital alive. [21] Midline shift is closely associate with intracranial pressure, leading to brain stem compression and eventually death if untreated. It is critical to manage ICP as quickly. Identifying midline shift, especially early or subtle onset, can significantly improve patient outcome. [22] The clinical skills of the physicians should be very sensitive in such situations and specificity may not be as important. In this study, the sensitivity of the residents to detect midline shift was 36.9 % with false positive rate of 63.1% and moderate agreement (k 0.372). Given that midline shift is a common encounter and needs urgent intervention. EMCC residents should have very high sensitivity to identify it even with physical examination alone before cranial CT scans are requested. Therefore, a moderate agreement and high false positive result is not acceptable. The skill needed to identify midline shift from cranial CT scans is not complex. Therefore, urgent strategies should be implemented to alleviate the problem.

The kappa value for each emergency cranial CT cases were calculated as it is seen in the above with the highest k of 0.869 (CI 95%) and lowest 0.003(CI 95%) for hydrocephalus and herniation respectively. The calculated average kappa is 0.5 (CI 95%). This kappa value signify that the agreement of the EMCC residents and neuroradiologist in interpreting cranial CT scan is moderate agreement and comparing to prior studies by Mucci et al and also Anas Khan et al showed agreement rate of 86% and 87.2 % respectively, the agreement rate of EMCC residents of this study is low.

According to the American heart association guidelines, cerebral CT scans may be interpreted by any specialty if the physician has acquired expertise in the field. The level of expertise is not defined, however, and kappa levels >0.8 are recommended as the minimal accepted agreement. In this study, the agreement of for hemorrhagic stroke is excellent (kappa 0.856) and ischemic stroke is substantial (kappa 0.712).

There is no statically significant difference between the year of residency and the reading level, this result tells us the residents don’t have any linear growth as they progress through the program and this might be due to absent of continuous teaching in this aspect.

Interventional studies from different centers as seen in the above table, shows that the performance of the EMCC residents improved significantly after teaching on CT scan reading was done. Based on this we can recommend that having continuous teachings or short course can improve the EMCC residence performance on the accuracy of cranial CT scan reading.

# Limitation of the study

- Patient's clinical data was not given for this study & effect of knowing clinical informatio n & clinical significance was not studied;
    - We chose not to provide clinical information because this was a study of how well trainees interpret important, common, unambiguous Cranial CT findings. Adding c linical information would make the results less clear as responses could reflect und erstanding of the clinical scenario more than ability to recognize CT abnormalities .
- All emergency cases cranial CT were not included; while these were representative of common conditions results may have been different with other CTs.
- The study was also done while the residents working hours which they might not devote their full attention in reading the scans.
- Emergency physicians were not included in this study.

# Conclusion

- The skills of residents in interpreting radiographic results are very low regardless of the prevalence of the condition in the ER or the relative clinical importance of the conditions.
- Poor sensitivity and high false positive results with misinterpretations are common. This can result in potentially dangerous patient mismanagement.
- EMCC has moderate agreement with the neuroradiologist in accurately interpreting emergency cranial CT scan.
- The residents are not confident enough on their interpretation of the radiographs
- All residents want a separate radiology attachment.
- Application of innovated education method.

# Recommendation

- Based on the observations we made in our study, we recommend the need for training of t he residents on Cranial CT scan results with particular emphasis given on emergency case s and commonly encountered cases on daily clinical practices.
- Radiology sessions should be more frequent & more on teaching how to read Cranial CT scans
- We should also develop a trend of writing official preliminary interpretation of residents o n patient's chart.
- Further wider studies including clinical significance should also be done based on these fi ndings.

# Annex

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# Questionnaires

**Part – I**

Directions: Please place a mark on the given spaces, encircle choices, and write comments accordingly. You can skip any questions that you feel are not applicable to you. Thank you!

1. School of residency…….
2. Age…….
3. Sex: A. Male B. Female
4. Year of residency training program
   A. PGY1 B. PGY2 C. PGY3
5. Did you had any Cranial CT scan reading class in your under graduate study?
   A. Yes B. No
6. Did you have any Cranial CT scan reading class in your residency training?
   A. Yes B. No
7. If "yes" to no 5, do you think the Cranial CT scan class was enough?
   A. Yes B. No
8. Did you took Cranial CT scan interpretation as part of your residency exam?
   A. Yes B. No
9. Do you think cranial CT scan reading is difficult?
   A. Yes B. No
10. How confident you are on interpretation of Cranial CT scan s
    a. Very confident
    b. Not confident
11. How frequently Cranial CT scan do you see per month?
    A. <5 B. 5-10 C. > 10 times D. Not at all
12. Where do you go to get help in difficulty of cranial CT scan readings? (more than one answer possible)
    A. radiologist
    B. Emergency physician

C. Emergency senior residents

D. my peers.

E. references

F. other…….

13. How frequently did you ask for help for interpretation of Cranial CT scan?

A. Rarely B. Sometimes C. Always D. Not at all

14. Did you use any self-learning methods for Cranial CT scan interpretations other than training and regular class?

A. Yes B. No

15. Do you believe there should be a separate radiology department attachment in the specialization training of Emergency Medicine?

A. Yes B. No.

16. How often do you read books regarding cranial CT scan interpretation?

A. Rarely B. Sometimes C. Always D. Not at all

## Part II

Cranial CT scans below mentioned cases that is confirmed by neuroradiologists of Tikur Anbessa hospital copied in Radiant viewer and all the slices of the scan will be given for the emergency medicine residents and blank paper will be given so each resident will describe what he/she see and finally write the conclusion of each scan.

1. Normal scan
2. SAH
3. DSF
4. EDH
5. Midline shift
6. Pneumocephalus
7. Hydrocephalus
8. Ischemic stroke
9. Hemorrhage
10. Meningeal Enhancement
11. Contusion
12. Herniation