Human to Artificial Intelligence, and Back---
A Teleradiology Perspective

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PRESENTER FINANCIAL DISCLOSURE

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Background: Challenges in Emergency Radiology

- Europe--- 1.2:10,000
- US – 1: 10,000
- Singapore – 1: 20,000
- India - 1: 100,000
- Nepal– 1: 200,000
- Bangladesh – 1: 1,000,000

- Shortage of radiologists
- Demand-supply mismatch
- Increasing expectations

Chong ST, Robinson JD, et al. Emergency Radiology: Current challenges and preparing for continued growth. JACR2019
Levin DC, Parker L, et al. Recent trends in imaging use in hospital settings: implications for future planning. JACR2017
Kalyanpur A. Commentary—Radiology in India: the next decade. Indian J Radiol Imag 18(3):191–192
Agrawal A, Khandelwal N. Commentary--Nucleating emergency radiology specialization in India. Emerg Radiol 2016

Background- Intracranial hemorrhage in our workflow

- ICH in a small proportion of scans

- Rapid and accurate diagnosis critical for management. 50% mortality within 24 hours**. Earlier treatment improves outcomes#

- Automation of radiology workflow triage should have an overall positive impact in the busy emergency settings

**Elliott J, et al. The acute management of intracerebral hemorrhage: a clinical review. Anesth. Analg.110, 2010
#Fujitsu K, et al. Indications for surgical treatment of putaminal hemorrhage: comparative study based on serial CT and time course analysis. J Neurosurg. 73, 1990

Background: Assisted Intelligence

A DL algorithm for ICH detection was developed with image segmentation & hemorrhage classification properties.

Detection of different types of hemorrhage by the ICH detection algorithm (below).

IPH

SDH

SAH

IVH

EDH

Hemorrhage model architecture
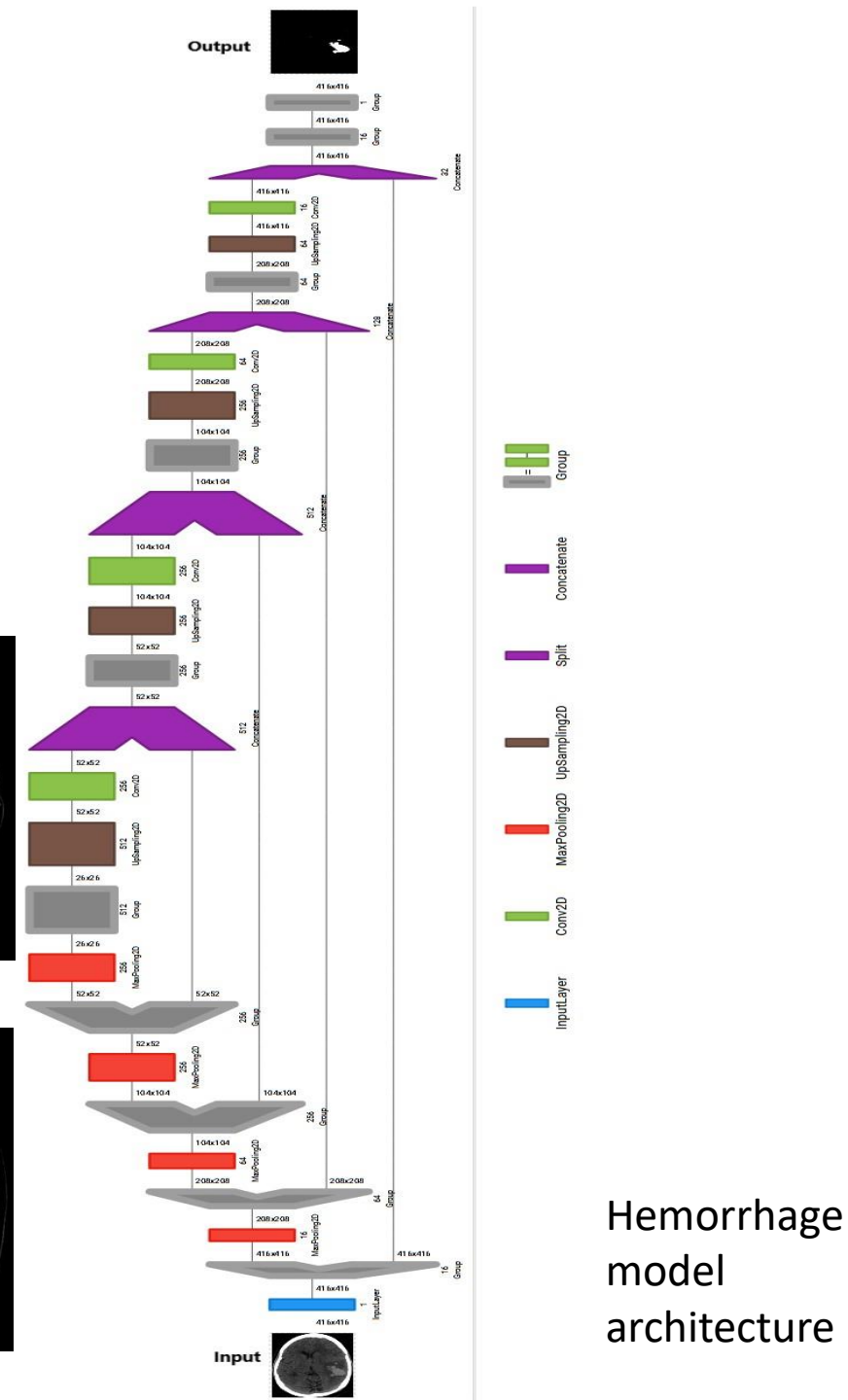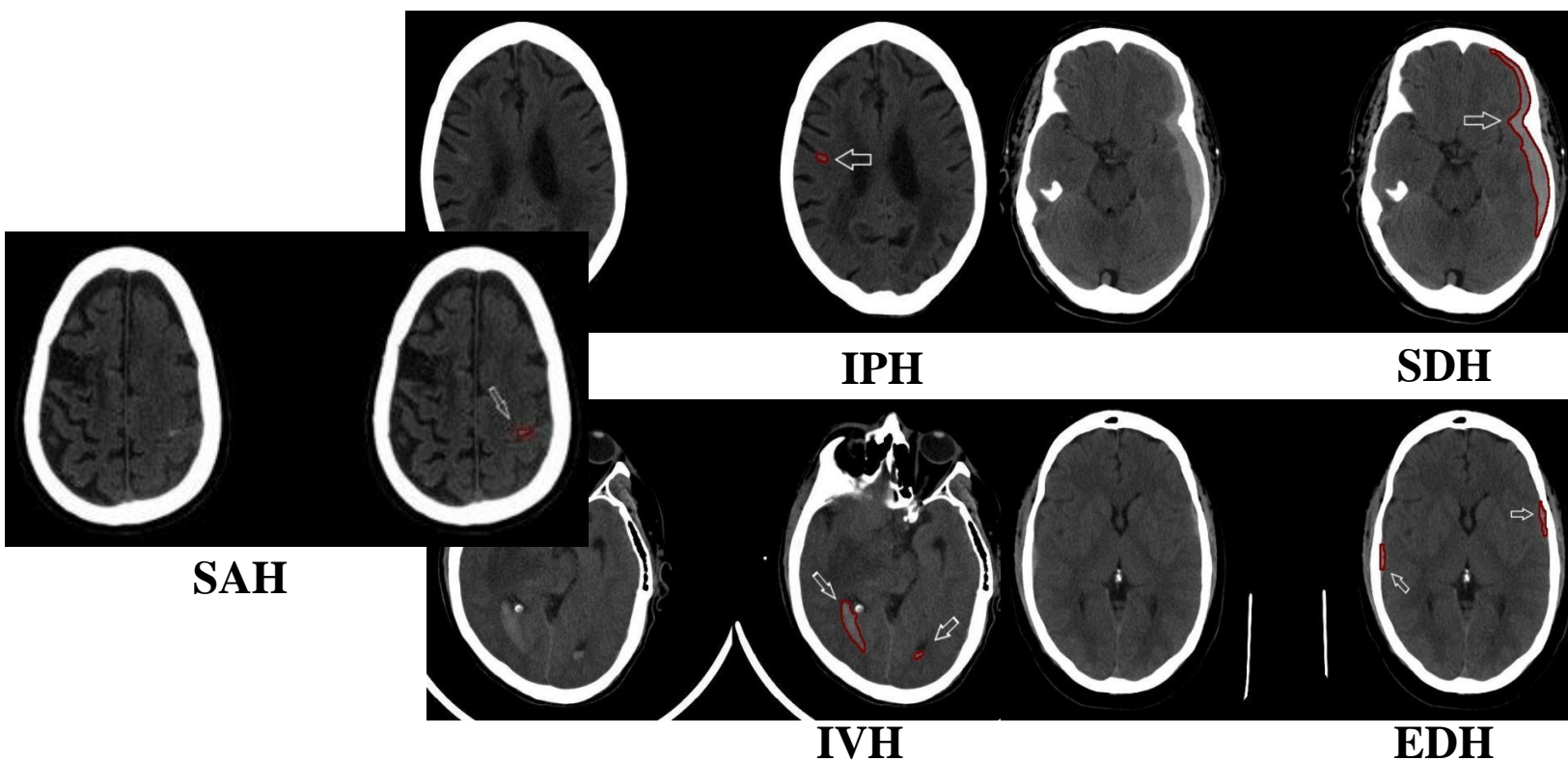
Assisted Intelligence - Our Experience

- The tool was developed as a triage tool for a busy teleradiology workflow

- Improved sensitivity at each slice by location-based clustering of predictions on consecutive slices, with greater weightage on predicting positives at the cost of increasing FPs

- Such a tool may have several pitfalls, as encountered by our team*

*Deep learning algorithm in detecting intracranial hemorrhages on emergency computed tomographies. Kundisch A, Hönning A, Mutze S, Kreissl L, Spohn F, Lemcke J, Sitz M, Sparenberg P, Goelz L.PLoS One. 2021 Nov 29;16(11):e0260560. doi: 10.1371/journal.pone.0260560. eCollection 2021.PMID: 34843559 Free PMC article. Clinical Trial.

Assisted Intelligence - Our Experience

| Result	Cases
True Positive	159
False Negative	5
False Positive	20
True Negative	116
Total	300

| Parameter	Value
Sensitivity (True Positive)	96.95%
Specificity (True Negative)	85.29%
Positive Likelihood Ratio	6.59
Negative Likelihood Ratio	0.04
Accuracy	91.67%
Time Per Case	15 Sec – 45 sec

False Negative Analysis

- Microbleeds
- Epidural Hemorrhage
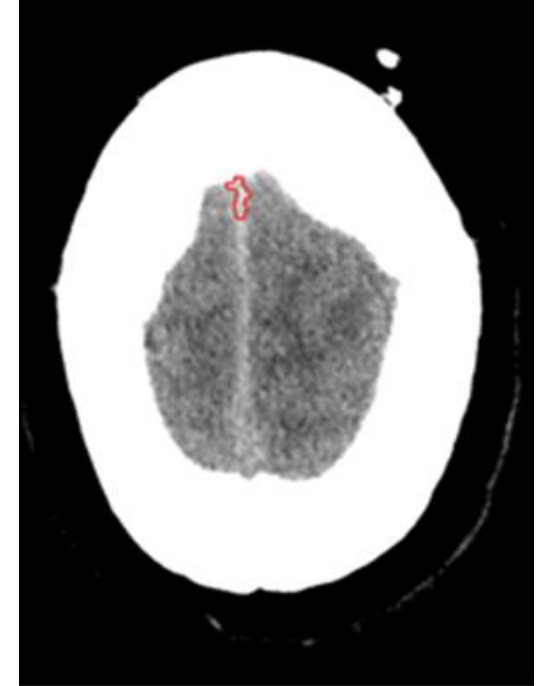- Subdural Hemorrhage

False Positive Analysis

- Intracranial calcifications involving basal ganglia, falx, tentorium, pineal region, choroid plexus, hyperdense dural venous sinuses, volume averaging artifacts, motion artifacts, and dense bones
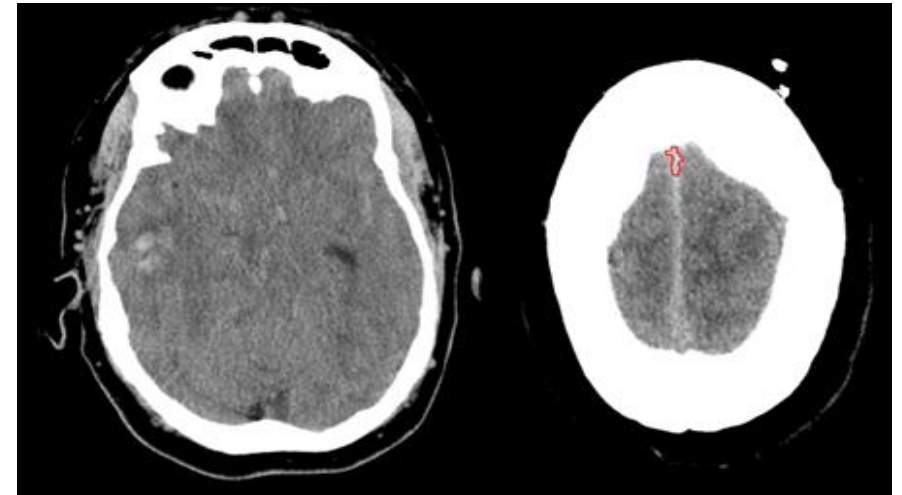
Proposed Workflow Integration
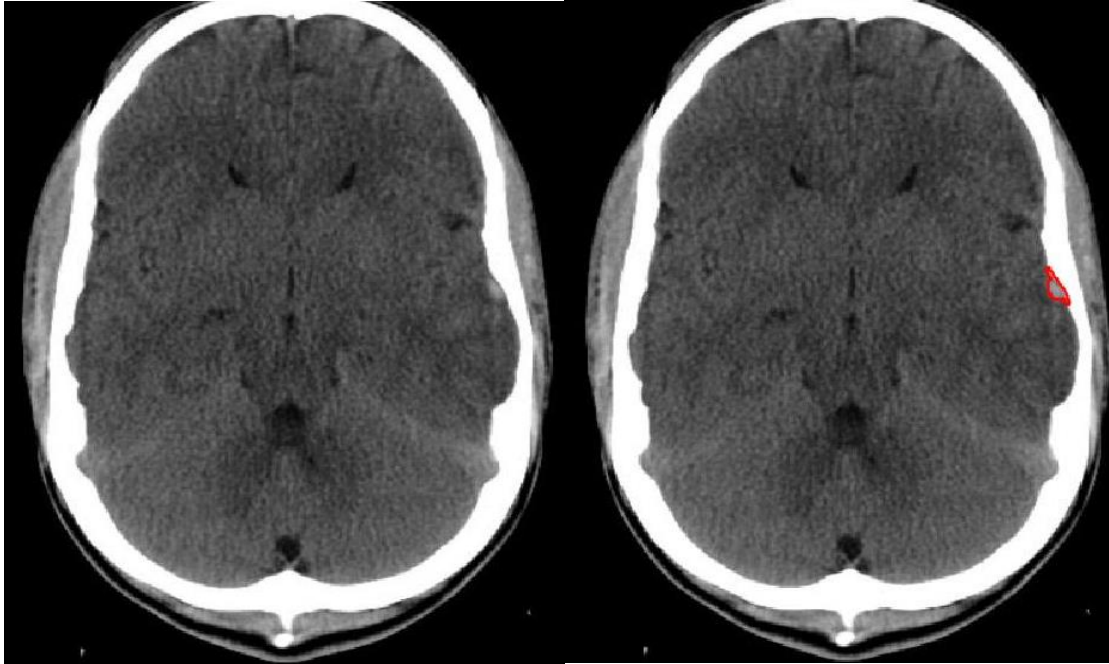
Subtle extra-axial hemorrhage missed by radiologist and detected by AI tool

False positive rate of 15% high for direct clinical use, but probably acceptable for radiological triage

Workflow integration---- a different story

AI Integrated with RIS PACS Workflow

|	ID ⬍	Status ⬍	Pat ⬍	Hosp ⬍	MRN ⬍	Crit ▲	Img # ⬍	Mo ⬍	Proc ⬍
		Select ⬍		Select ⬍		Select ▼		Select ⬍	Select
ⓘ .P 🖥 ⠿ 📖 AI ❌ ↻ 👥	14835	Read in Progress	ANONYMIZE.13	AHRA AI Hospital	MRN-PAT012	Stat	0/107	CT	CT Head
ⓘ 🖥 ⠿ 📖 AI ❌ ↻ 👥	14836	Read in Progress	ANONYMIZE.14	AHRA AI Hospital	MRN-PAT013	Stat	0/135	CT	CT Head
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ⓘ 🖥 ⠿ 📖 AI				Hospital	MRN-PAT018	Stat	0/146	CT	CT Head
ⓘ 🖥 ⠿ 📖 AI				Hospital	MRN-PAT019	Stat	0/343	CT	CT Head
ⓘ 🖥 ⠿ 📖 AI 👥 ❌	14844	Unassigned	ANONYMIZE.21	AHRA AI Hospital	MRN-PAT020	Stat	0/170	CT	CT Head

> Detection from Telerad Tech : CT Brain
> -----------------------
> Status - Positive
> Type of Hemorrhage- Intracranial Hemorrhage, Subarchnoid
> Hemorrhage
> No of Hemorrhage slices-2
> Midline shift towards and by / no of slices-2mm shift towards left/8
> -----------------------

Critical findings highlighted with color code and with tooltip summary

False Positive results were counterproductive on integration into the emergency workflow as normal studies were flagged as positive, resulting in the need for their additional analysis and subsequent delay in turnaround time

Aim of the Study:

- To study the feasibility and usefulness of trained Radiology Assistants (RA) in lieu of artificial intelligence in a busy emergency Teleradiology practice

RA training

Diploma in Medical Imaging Technology, Bachelor's and Master's degrees in the same field, completed at least 6 months of internship training in performing scans using X-ray, CT, and MR equipment.
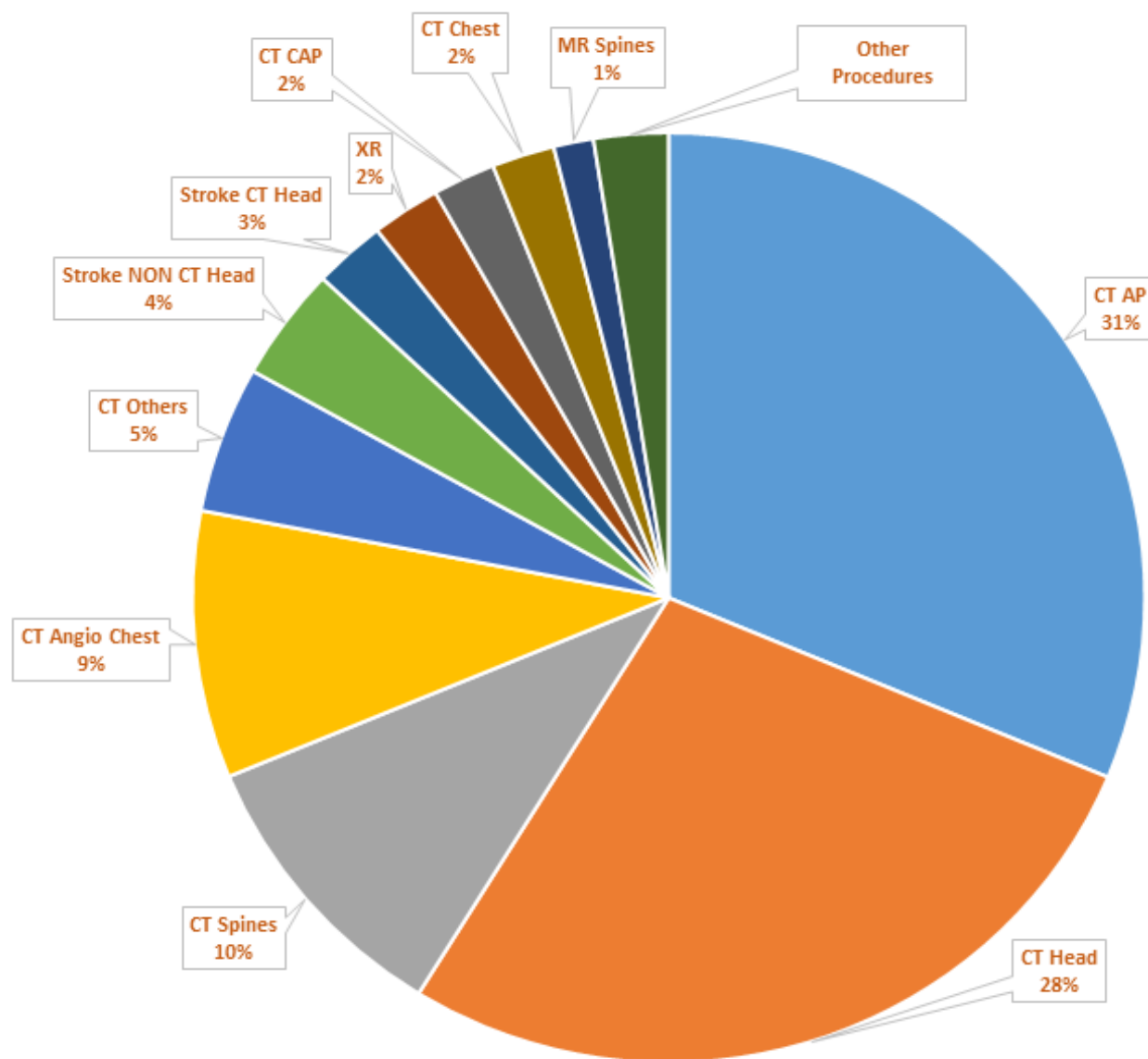
Knowledge of radiology and the procedures involved in performing scans, skill in identifying specific anatomical features, and ability to identify significant findings such as fractures and bleed

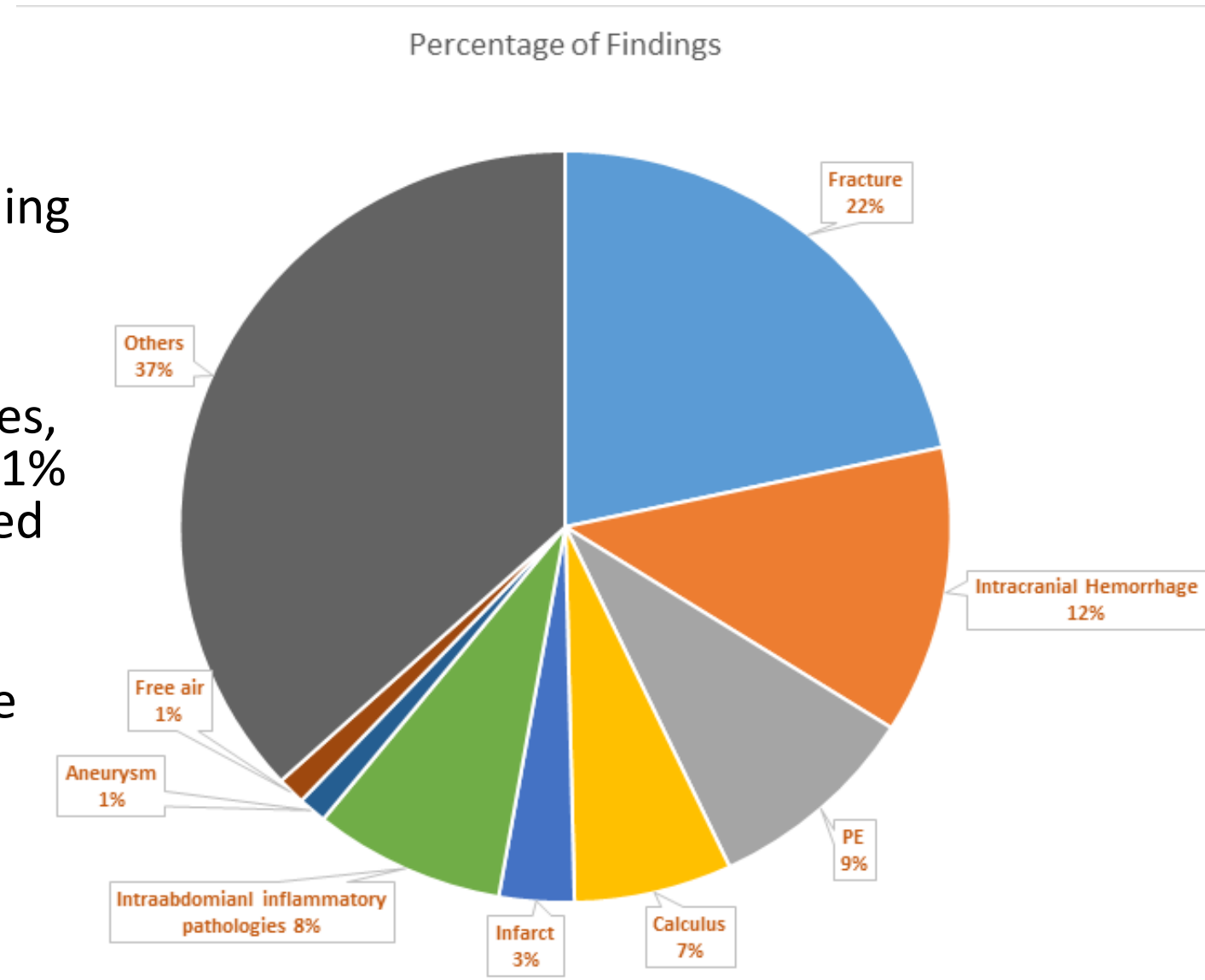| Proficiency Level	Duration	Program details
L1 - Junior Level Learning Initial Technical skills	0-3 months	• Orientation of technologist to existing workflow process and reporting guidelines • Moodle platform - Training and Quiz • ***Training on X-ray (chest, spine and extremities)*** • ***Training on CT Head, Spine, and CT Maxillofacial*** • QA Test for Proficiency; Evaluation and approval • Followed by On the floor observation and training for peer review and first read
L2 – Intermediate Level Contributing to the team productivity	3-5 months	• Tech to be proficient to Peer Review: x rays, CT head and spine (L1) • QA Test for Proficiency; Evaluation and approval • Followed by On the floor observation and training for peer review and first read • ***Training on CT Chest PE, CT Chest, Abdomen and Pelvis [CAP]***
L3 – Senior Level All Technical skills developed and key contributor to the team productivity	5-6 months	• Tech to be proficient to Peer Review: CT Maxillofacial and CT Angio studies (L1 + L2) • ***Training on MR Head and Spine, CT Angio Head and Neck*** • ***Peer review*** • QA Test for Proficiency; Evaluation and approval • Followed by On the floor observation and training for peer review and first read
L4 – Mentor/Asst. Supervisor Can mentor others and drive development and productivity **Testing and practical**	6 -8 months	• Trainings Juniors (Buddy Training) • Mentoring junior techs • Presentations (QA, Interesting cases) • Exam on Peer review reporting – External QA cases • Examination – Theory and Practical

Methods:

- Retrospective descriptive study over 12 months, January 2021-December 2021

- A total of **376095** cases including all imaging modalities were read in our emergency teleradiology practice

- Of these **135876 (36%)** were **peer reviewed** by **radiology assistants (RA)** with the goal of identifying any significant missed pathology such as intracranial hemorrhage, fracture, pulmonary thromboembolism, free air, urolithiasis

- Peer reviews were done in tandem with the radiologist's initial reads by radiology assistants trained to detect specific findings

- Missed findings were brought to the attention of the radiologist for approval and further decision to communicate to the referring facility and addend the initial report

- External feedback on the peer-reviewed cases was used as a surrogate for findings missed by RAs

Percentage of Second Read

- CT CAP 2%
- CT Chest 2%
- MR Spines 1%
- Other Procedures
- XR 2%
- Stroke CT Head 3%
- Stroke NON CT Head 4%
- CT Others 5%
- CT Angio Chest 9%
- CT Spines 10%
- CT Head 28%
- CT AP 31%

Results:

- Second read by RAs detected missed pathology in 1115 studies (0.8%), including but not limited to fracture, intracranial hemorrhage, pulmonary thromboembolism, urolithiasis, infarct, intraabdominal inflammatory pathologies, free air, aneurysm and others. Of these 1% were high grade missed findings detected by RAs and 0.1% were missed based on external feedback from referring clients

- The missed findings were brought to the attention of the radiologist, who **disagreed** with 194 cases (**17%)** and **agreed** with 921 cases (**83%**)

Percentage of Findings

Fracture 22%
Intracranial Hemorrhage 12%
PE 9%
Calculus 7%
Infarct 3%
Intraabdomianl inflammatory pathologies 8%
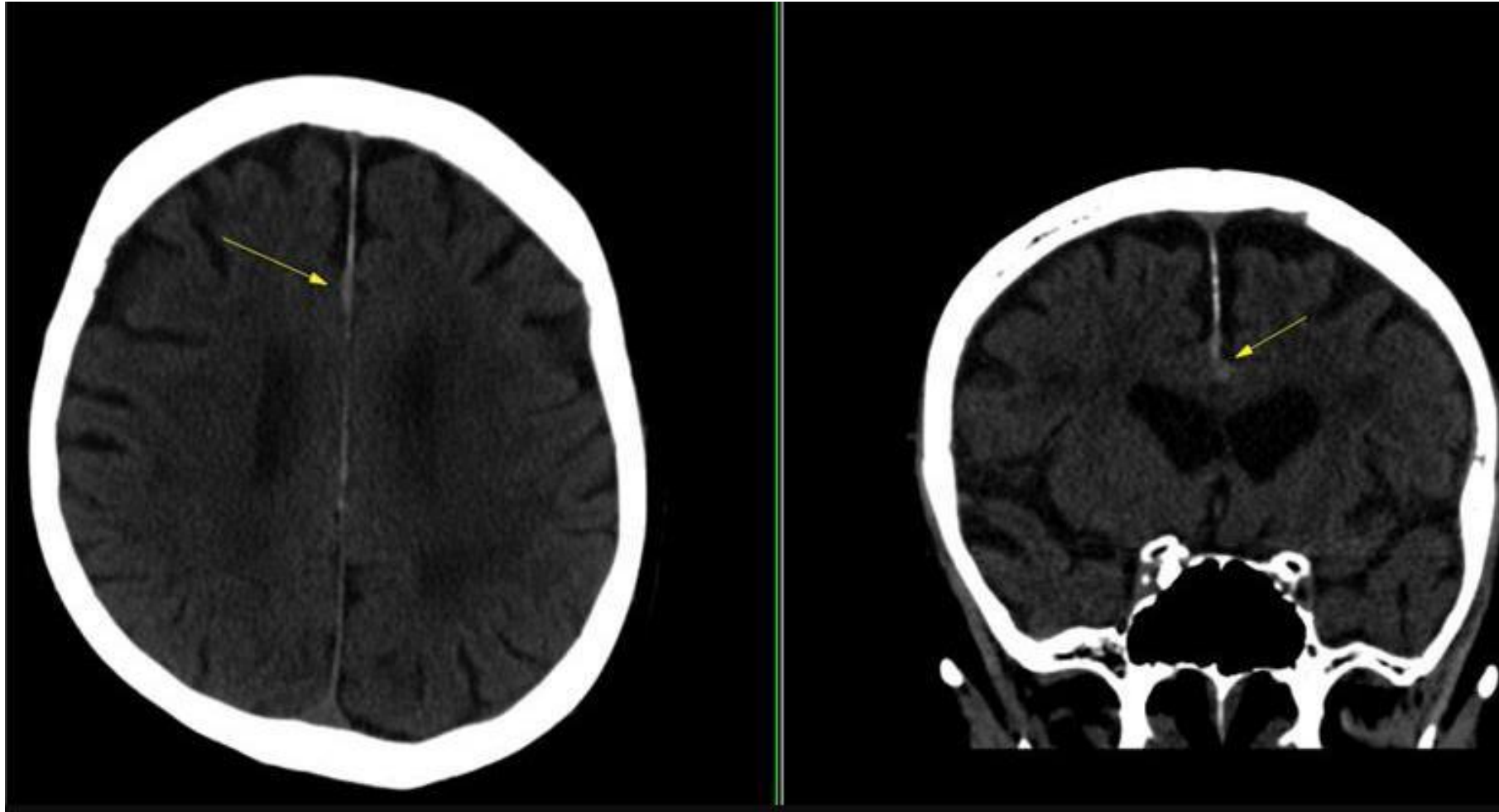Aneurysm 1%
Free air 1%
Others 37%

Head CT for Intracranial Hemorrhage by RAs

- Number of cases where RAs made the diagnosis of intracranial hemorrhage - **114**

- Number of such discrepant cases that were then confirmed by the radiologists – **106**

- False positive rate **7%**

- Mean turn-around-time **90.8 min**

CASE 1
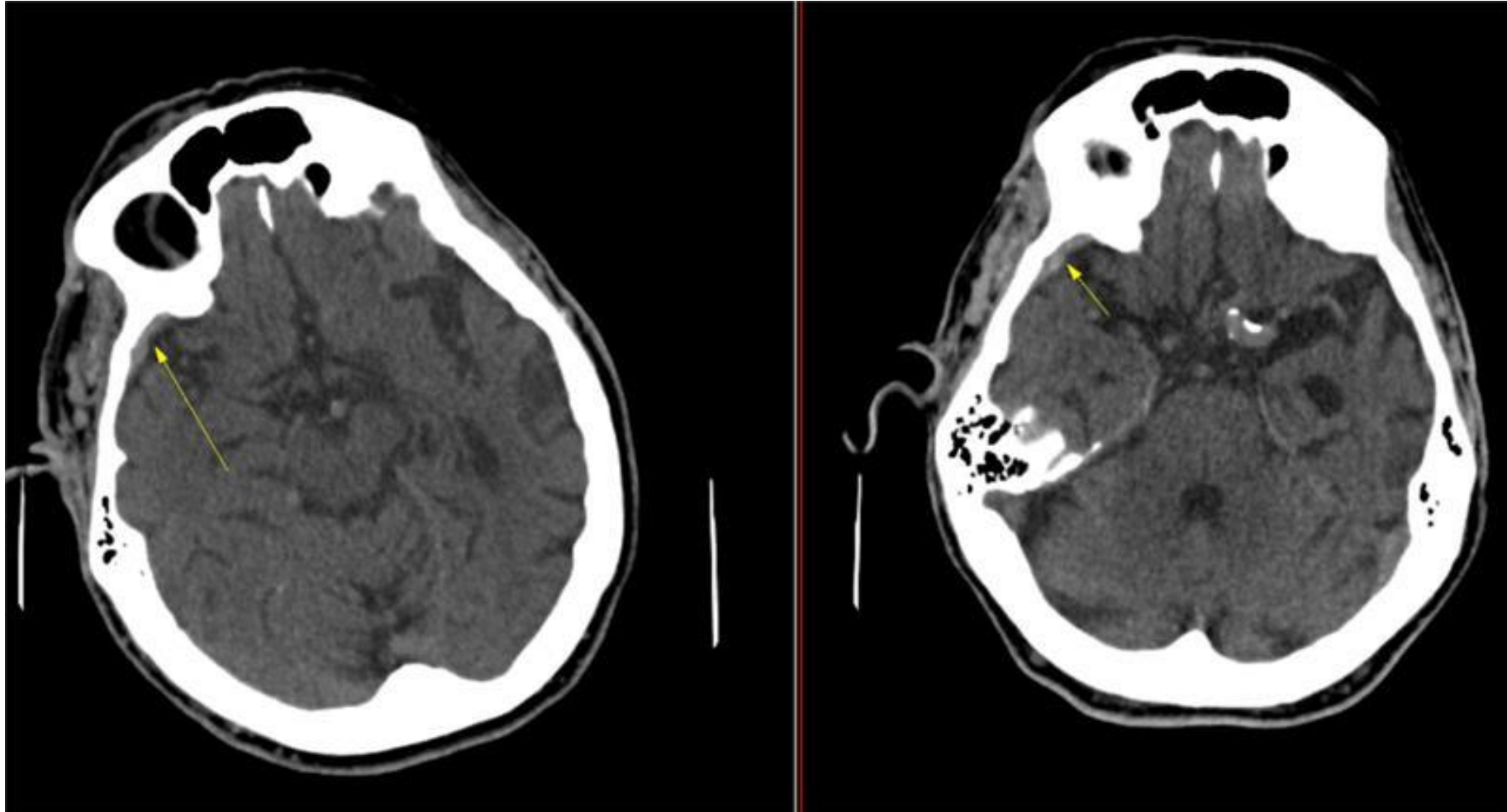
CASE 2

CASE 3

Overcall by RA

Discussion

- In our previous study, double reporting identified missed findings in 3.8% cases. 50% of the high-grade errors were more commonly seen in CT abdomen and pelvis and radiographs*

- In this study 41% of the high-grade errors were more commonly seen in CT abdomen and pelvis and radiographs

- 0.8% significant missed findings were seen on head CTs on second read by a radiologist *

- The RAs detected ICH in 0.3% of the head CT examinations

- False positive rate for ICH detection by RAs is 7% compared to 15% for AI tool

*Agrawal A, Koundinya DB, et al.(2017) Utility of contemporaneous dual read in the setting of emergency teleradiology reporting. Emerg Radiol 24:157-164

Conclusions:

- Trained radiology assistants can provide value to the peer review program of a busy teleradiology practice and decrease errors

- Useful concept to meet the ongoing radiologist shortages and the prevalent gaps in the real-life performance of AI tools

- The human RA model versus AI

- Turn-around-time metrics favor AI

- Studies focused on a human centered design of improved AI tools should be the way forward

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