# Carbon Nanotube Stationary Head CT Scanner Prototype Evaluation

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## INTRODUCTION

***Problem 1: Strokes***

- **Third leading cause of death ( ~750,000 yearly)**[2]
- Prevalence has **increased by 60%** from 1999-2019[3]
- **15 million people** effected globally[8]
- **1 in 16 Americans** will die **(~40 seconds)**[8]
- **Ischemic** strokes caused by occlusion (clot) of blood vessel supplying the brain[8]
- **Hemorrhagic** strokes caused by ruptured blood vessel in internal or external brain strutures[8]

***Problem 2: Traumatic Brain Injuries (TBIs)***

- **~ 470,000 TBIs** from 2000-2022[13]
- **Increase the risk for stroke by 69%**[13]
- Caused by sports/recreational events, military training/deployment, and explosions[13]

***Problem 3: Military Environment***

- **Unstable** due to **vibrations** from **explosions**, **extreme temperatures**, **humidity**, **air particles**, and **dangerous chemicals** and **machinery**

***Problem 4: CT Technical Limitations***

- **Heavy** and are unable to be mobilized[15]
- Only 2-5% of patients receive thrombolytic treatment due to **transportation delay** to the hospital[23]
- Struggle with producing **high quality** images due to **low resolution**, **noise**, **artifacts** that cause **streaking**, the inability to scan the entire subject due to **physiological limitations**, **long scan times**, **radiation exposure**, and **multiple moving parts**[15]

***Solution: CNT s-HCT***

- **Reduces scan time**, **decreases radiation exposure**, **maintains adequate image quality**, and **lowers the weight** of a clinical CT scanner[16]
- Eliminates need for **rotating gantry** by using a **fixed geometry** for **complete visualization**[16]
- **Durable and simple hardware** ensures functionality in austere environments[16]
- Utilizes a **fan-beam** and a **collimator** that reduces the effects of scattering for **improved image quality**[16]

## HYPOTHESIS

~ By utilizing a **multisource** and **multidetector carbon nanotube stationary head CT system**, the resulting picture should be of ***adequate*** quality and allow physicians to accurately **detect, diagnose, and treat strokes and traumatic brain injuries in harsh environments.**

## METHODS

***CNT s-HCT Features***

- Utilizes **ionizing radiation** to capture **2D images** from **multiple angles**
- **Reconstruction algorithm** generates **3D volume data** presented as **stack** of **cross-sectional images**
- **Three linear CNT x-ray source arrays** (tubes) and **nine x-ray detector panels** form **hexagonal tunnel**
- Acquires **135 projection images per slice**
- Scanning rate of **5 millimeters per second**
- **CTDI = 7 mGy** (10% of Ceretom®)
- Sample Size: **Five participants** who have undergone **head trauma**, **intracranial hemorrhage (subdural or intraparenchymal),** and/or **skull fractures**

***Requirement Criteria***

- Age/sex: 18 years or older and any sex
- **Stable** condition and provide written consent
- Must have **undergone CT head imaging** within the past **24 hours** or **will undergo** a CT of the head

***Main Goal***

- Compare clinical and CNT prototype CT images with **Fiji software (**realignment and resolution adjustment) for a fair comparison
- **IRB Number: NCT04495634**

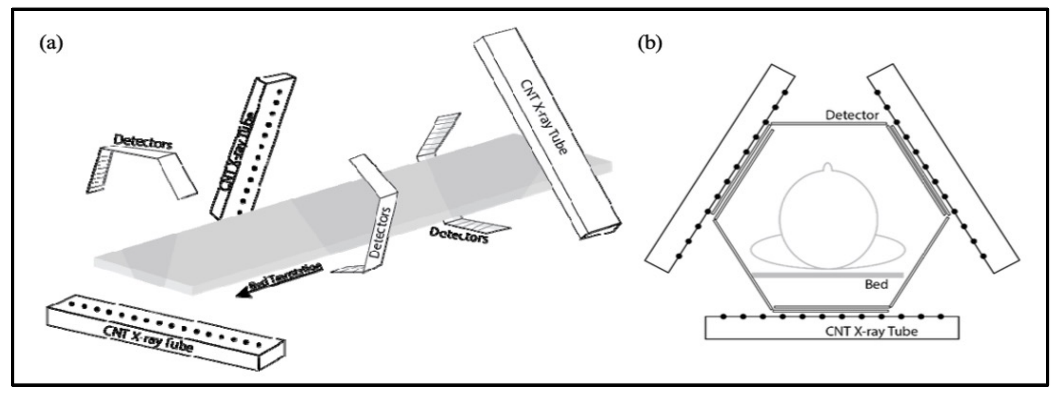


**Figure A.** Pictured above is a layout of the CNT prototype with its three linear CNT x-ray source arrays and nine x-ray detector panels that combine to form a hexagonal tunnel that the subject passes through while being scanned at a rate of 5mm per second.[16]

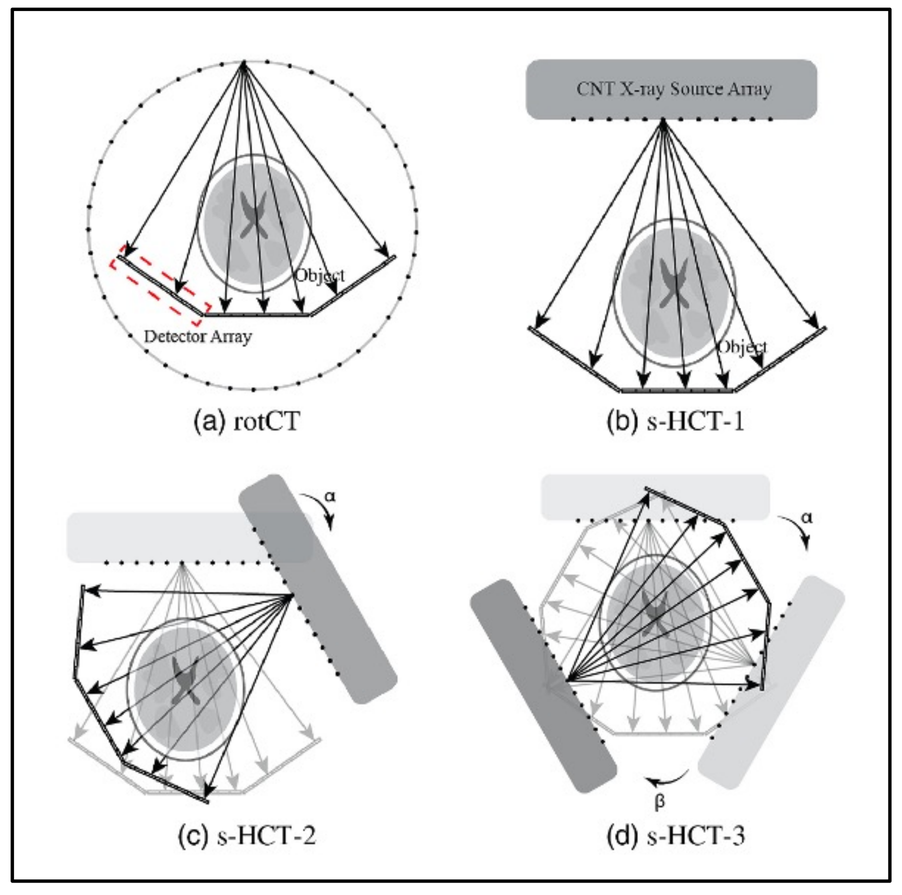


**Figure B.** Pictured above is a diagram that demonstrates the concept of the CNT x-ray multi-source array. The diagram shows how each of the three x-ray source arrays of the sHCT emits ionizing radiation at multiple angles to image each part of the subject's brain.[17]

## RESULTS

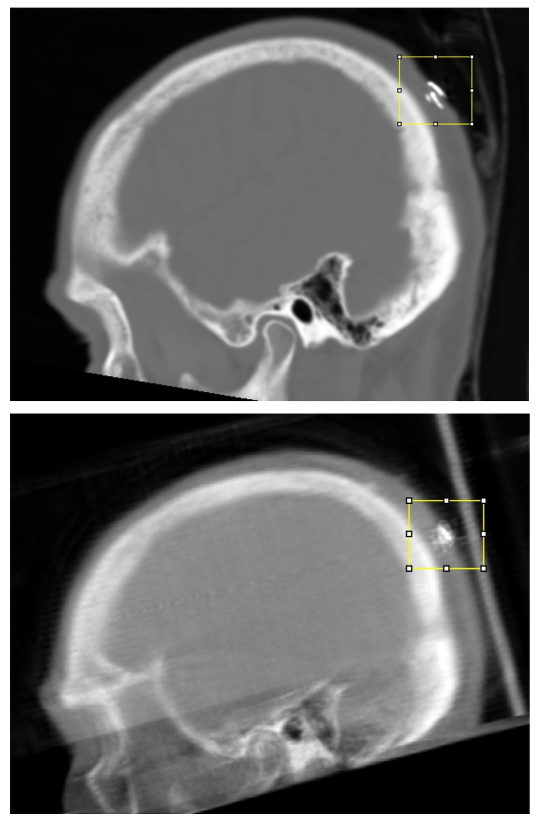

**Figure 1.** Metal staples presented in sagittal slice of both the SIEMENS clinical head CT (top) and the CNT s-HCT prototype (bottom) of Subject 1

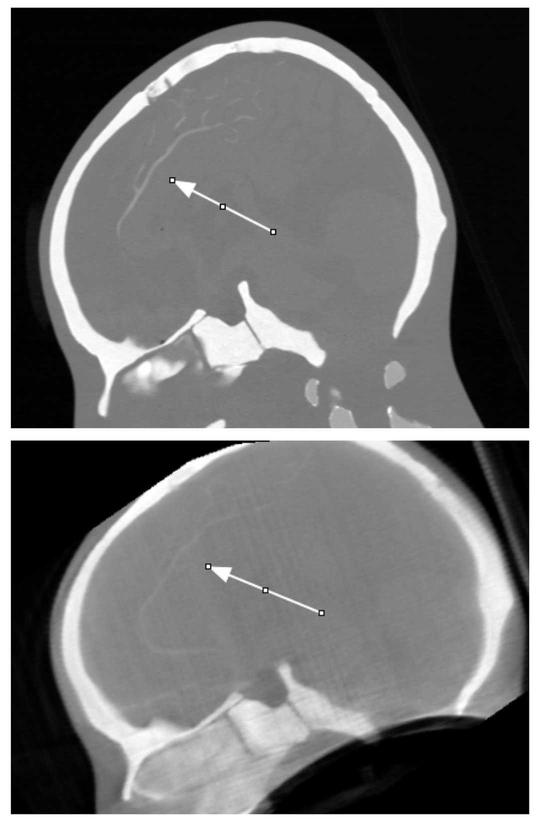

**Figure 2.** Anterior cerebral artery (ACA) presented in sagittal slice of both the SIEMENS clinical head CT (top) and the CNT s-HCT prototype (bottom) of Kyoto phantom

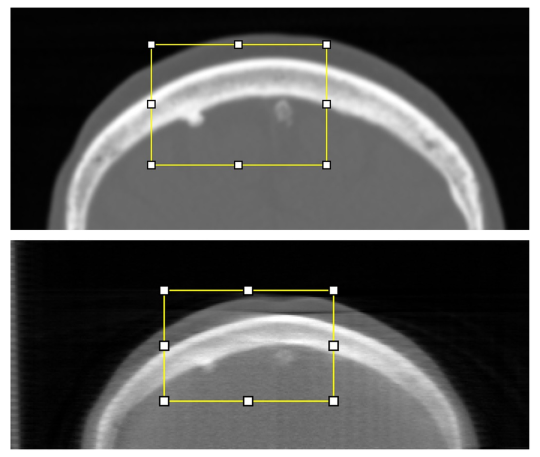

**Figure 3.** Calcifications in parietal lobe presented in coronal slice of both the SIEMENS clinical head CT (top) and the CNT s-HCT prototype (bottom) of Subject 5

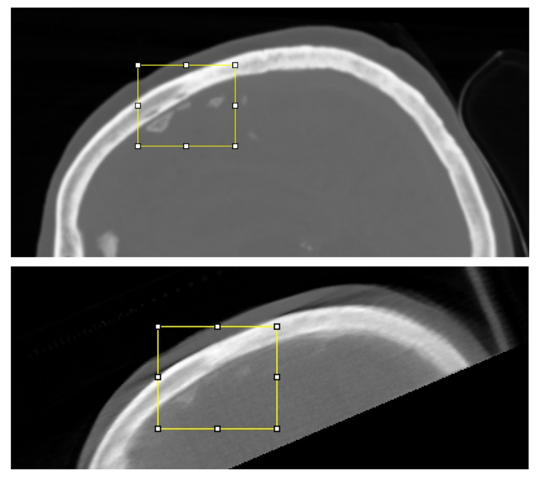

**Figure 4.** Calcifications in parietal lobe presented in sagittal slice of both the SIEMENS clinical head CT (top) and the CNT s-HCT prototype (bottom) of Subject 5

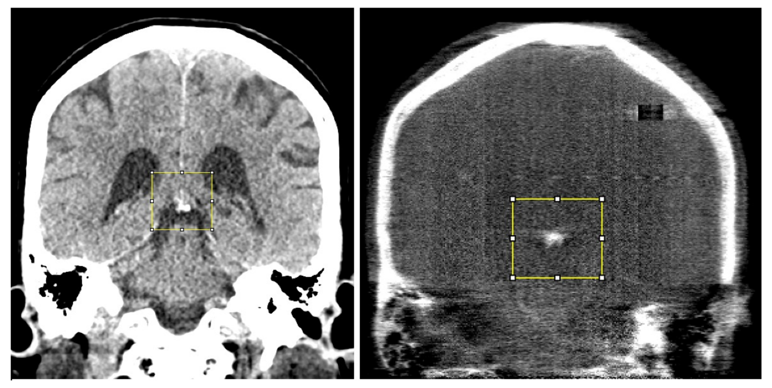

**Figure 5.** Pineal gland calcification presented in coronal slice of both the SIEMENS clinical head CT (left) and the CNT s-HCT prototype (right) of Subject 1

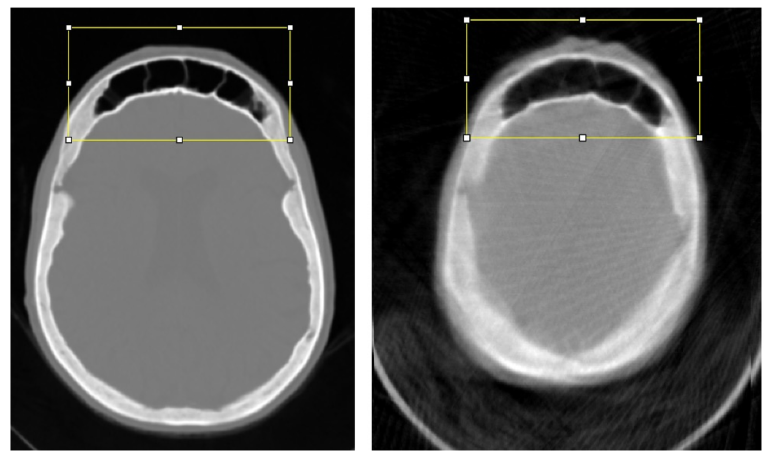

**Figure 6.** Frontal sinuses presented in transverse slice of both the SIEMENS clinical head CT (left) and the CNT s-HCT prototype (right) of Subject 4

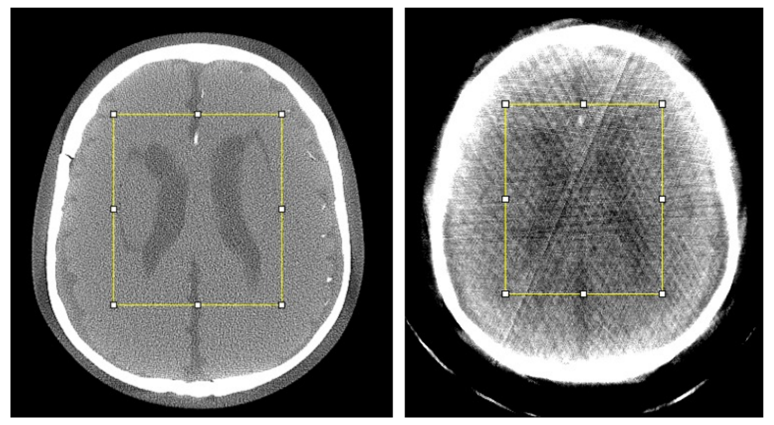

**Figure 7.** Lateral ventricles presented in transverse slice of both the SIEMENS clinical head CT (left) and the CNT s-HCT prototype (right) of Kyoto phantom

## DISCUSSION

***Limitations***

- **Under-sampling** and **beam hardening produced streaking artifacts**; however, this is **expected** and must be combatted against for adequate visualization
- **Timing** issues occur when the prototype's detectors fall off the timing scale and misregister, resulting in glitches that caused **data loss**
- **Limited brain volume visualization** due to prototype design limited coronal evaluation as subjects with shorter necks were blocked from being able to move through the entire gantry
- **IRB** paused study due to permission for increasing radiation dose

***Future Directions***

- The images produced demonstrated the prototype's ability to capture **bone**, **sinuses**, **airways**, and **calcifications** rather well; however, soft tissue was barely able to be visualized
- **Soft tissue visualization** will be corrected for by **increasing the radiation dose** without exceeding the CTDI of a clinical head CT
- **Noise effects** will be reduced by implementing additional **iterative reconstruction algorithms**
- **Full subject scanning** will be corrected through either **prototype redesign** or **physiological exclusion criteria** will be implemented
- **Increase population size** (approved for 50)

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