Chapter-5

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POINT OF CARE IMAGING WITH MOBILE COMPUTED TOMOGRAPHY

Adithya G Rao

Assistant Professor, Yenepoya School of Allied Health Sciences, Mudipu, Dakshina Kannada, Karnataka, India

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Introduction

This chapter discusses how Point of Care Imaging with Mobile Computed Tomography, a notable advancement in Medical Imaging is enhancing healthcare delivery and improving patient outcomes. It is important to remember that fixed CT scanners are huge, the equipment weighs up to almost 2,500 to 4,000 kg, and they rely on high-voltage capacities and cooling machinery. In certain cases, such as the early care of stroke patients, or in medical emergency rooms, in ICUs where it is difficult to move the patients, fixed CT scanners are simply too inconvenient to be used effectively. So, instead of taking the patient to radiology, the mobile CT scanner may now be wheeled right into the patient's room for bedside operations. These machines are specially built to accommodate patients of all sizes and to enable CT imaging wherever it is required, such as the operating room, the intensive care unit, radiation oncology suites, and the emergency department [1] [2].

History

The discovery of X-rays revolutionized medical diagnostics in 1895. But X-rays had limitations. Two-dimensional projections helped to visualize bones and tumors and other soft tissues were obscured in shadows and made it difficult to locate pathologies/objects located behind the bones. Tomographic" techniques were developed between the 1910s and 1960s which then created cross-sectional images of the body from multiple X-ray projections. In 1963, Allan Cormack, a Physicist first proposed a process to improve tomographic imaging in an article in the "Journal of Applied Physics. Cormack recommended measuring X-rays subsequently they pass through a body to see the quantity of radiation that had been absorbed. He also provided mathematical formulas for creating images of specific cross-sections by the measurements.

Five years later, Godfrey Hounsfield, an engineer at the British entertainment giant - Electrical and Musical Industries (EMI) anticipated a device that would work like how Cormack had described. He thought about using computers to identify and display patterns of numerical data and use that capacity to improve tomographic X-ray images. Hounsfield proposed to build a scanner based on these ideas and, in 1968, the board approved Hounsfield's proposal, facilitating him to build an experimental prototype [3]. The prototype CT brain scanner was set up at Atkinson-Morley's Hospital. The processing time for the image was about 20 minutes. Later, it was reduced to 4.5 minutes after the introduction of minicomputers. The first patient was scanned in 1972 by this machine. Dr. Hounsfield's research lead to the development of a clinically beneficial CT scanner for imaging [4].

Basic principle: The term "computed" in Computed tomography means calculated or reconstructed, and "tomography" is a complex word consisting of the terms "tomo" which means to "cut" / "section" in the Greek language, and "graphy" that means "to describe" in Greek. X-rays form the basis of Computed Tomography scanner operations. In CT, energy is typically applied between 80 and 150 kV. A CT scanner's gantry has an X-ray tube that revolves around an object, while detectors detecting X-rays that pass through it on the other side. When the Patient is exposed to X-ray a portion of the X-ray photons are absorbed and some are sent to the detector when the X-rays travel through the sample. The data collection system receives the detections obtained at various angles. This offer projection information for creating tomographic pictures [5].

Components: A CT scanner consists of high-voltage generator, filters, collimators, detector arrays, DAS, couch (patient table), operational console, and image reconstruction computer are all part of the gantry. The X-ray tube receives enormous voltages, typically between 120 and 140 kV, from an incredibly steady three-phase generator. Together, the detector and x-ray tube are aligned. When an X-ray is produced, it travels through an object and ends up at a detector, which records a lot of transmission measurements. A filter is placed in amid the X-ray tube and the object which would absorb the low energy X-rays that do not contribute to the image formation but also increase the radiation dose to the patient. The collimator is a device that is positioned between the filter and the patient. It reduces the radiation dose by giving the X-ray beam a definite shape and restricting the scattered X-rays. CT detectors capture the incoming radiation. Gas-filled detectors, and scintillation detectors, were a few of the detectors. CT scanners use scintillation crystals of sodium iodide (NaI) coupled with a photomultiplier tube.

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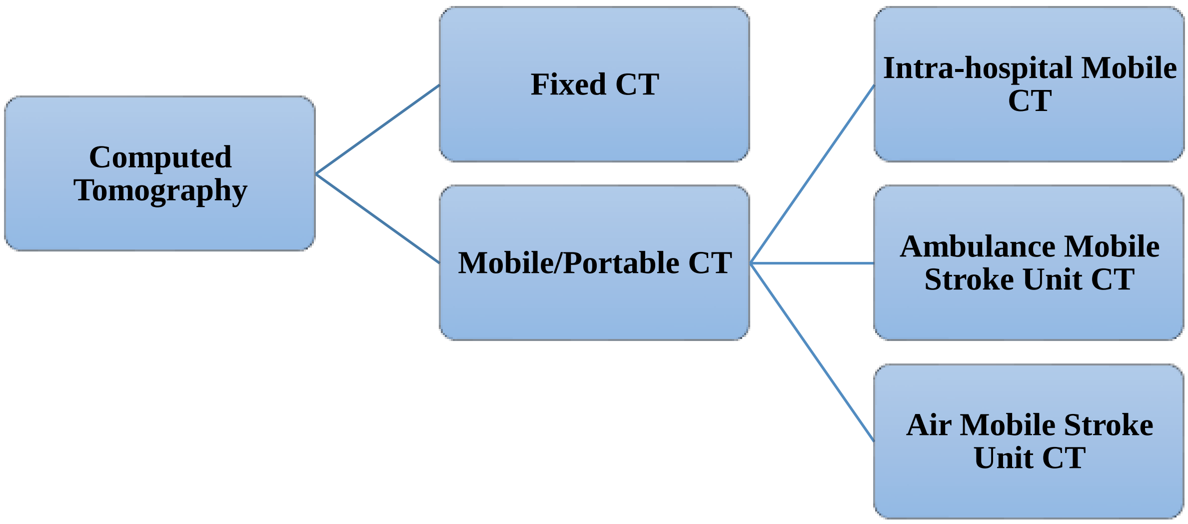
It's the most frequently used solid-state detectors that transform the X-rays into light photons, which then are converted into electrical signals through photodiodes. A photodiode alters the scintillation lights to electrical signal.

The patient couch is made of carbon fibers, which will not interfere with X-rays due to their property of low-photon absorption. It is tough and rigid and supports weight up to 204 kg. To establish the scanning position and regulate the patient's movements, the patients recline on the couch and are moved through the gantry aperture. The CT scan's control center is the operating console. It comprises of computers, displays, and a keyboard that are used to regulate the scanner, get data from the DAS, and create 3-dimensional images [4] [5] [6].

Classifications of the CT scanner

According to the data acquisition method, the scanner is categorized into axial and spiral (helical). A fan beam is used in conventional CT scanners, which acquire one slice image before moving on to the following slice scan location. Utilizing a Data Acquisition System, the fan-shaped X-ray beam and detector follow a helical route in relation to the target in the spiral (helical) CT scanner. In certainty, the scanned object on the CT couch is moved to the bore of the scanner as the gantry revolves [6]



Mobile Computed Tomography

A mobile CT scanner, also known as a portable CT scanner, is a compact and maneuverable imaging modality designed for point-of-care imaging within hospitals or for pre-hospital use [1]. Traditional CT scanners are stationary, requiring patients to travel to a dedicated CT suite for imaging. These suites are equipped with high-voltage power sources, lead or concrete-shielded walls and ceilings, and a control room operated by technologists. However, transporting critically ill patients, particularly those admitted to intensive care units (ICUs), to a fixed scanner can be challenging. To address these challenges, portable or mobile CT scanners were developed. These devices can be easily moved within the hospital, enabling bedside imaging for patient [2]. Additionally, mobile stroke units represent a revolutionary advancement, integrating imaging capabilities and a dedicated stroke care team directly into hospital ICUs. Beyond hospital settings, CT scanners installed in ambulances or air ambulances have transformed acute stroke management by facilitating pre-hospital diagnosis and treatment, significantly enhancing patient care [2].

Challenges leading to the procurement of Mobile CT:

1. High demand - Head CT is in high demand, especially for clinically ill patients with acute stroke and trauma [7].

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2. Staffing and Logistical Challenges: To address the concerns related to the safety of the patients, Doctors, and nursing staff routinely accompany the patients to the Imaging and Radiology department, increasing the cost and time. Even with such aid, the risks involved in the transfer of the patients are significant [8].
3. Patient transfer – a risky game with the patient's health status: The intra-hospital transfer of critically ill patients especially in ICUs and triage leads to a substantial number of adverse effects on the patient's health [9].
4. Complications in Pre-Determined Radiology Schedule: A sudden allotment of emergency cases with acute and critical conditions ties up the CT scanner causing a delay in the schedule [7]

Components: The mobile CT scanners are not different from the fixed CT scanners except that they are smaller, compact, and weighs very less. The total weight of the mobile unit is the weight of the mobile unit after all the components are assembled together. Hence it becomes important to reduce the weight of the unit which can be achieved by determining if the particular component is necessary or can be removed or can be replaced or modified, which could further reduce the weight [10]. A mobile CT consists of following component:

1. The scanner frame
2. The console

Components of Mobile CT Scanner

1. Gantry - Compartment for X-ray tube, detectors and other components
2. Head rest/ holder
3. Caster Wheels
4. Hand holder
5. LED Control panel
6. Lower compartment for battery and processing units

Fig-5.1 Mobile CT scanner

The imaging unit consisting of X-ray tube, detectors, pre and post collimators, filters, generator and other hardware is mounted on the frame which is adapted to scan the anatomical area to produce 3 dimensional images [11]. **X-ray tube:** Mono-block technology is used which reduces the size of the X-ray tube by combining the high-voltage generator and the tube into a single housing [12]. It reduces the cost and size of X-ray tube and generator configuration, while removing the high voltage cable that normally connects the two components. As a result, Monoblock is more compact, cost-effective and reliable than traditional X-ray tube design [13]. For the movement of the unit, the frame is mounted on wheels equipped with pulleys for movement. It is a fine movement mechanism which moves the unit precisely relative to the patient. A networking unit will be mounted on the frame, which connects the CT with the Hospital and Radiology information system and other IT network, hence eradicating the requirement of conventional cables [10].

An LED control panel is provided at the end which would help in the selection of patients, selection of protocols, adjusting the exposure factors and other acquisition parameters, image acquisition, image reconstruction and sending the acquired images for post-processing and PACS. Electric supply: The CT unit can be powered by single phase AC power. A regular power supply output socket is capable of starting the CT scanner. It is generally provided with battery backup which would provide the electric supply in cases of power failure [11].

Technical specifications: To achieve a compact, moveable CT scan unit, certain trade-offs or compromises has to be made in the technical specifications and hardware compared to a fixed conventional CT scanner.

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A few technical specifications of major mobile CT scan in the market are specified in table 1.

Table 1: Technical specifications of 4 major Mobile CT scanners

CT Scanner parameters	**Value**
Gantry Bore (Brain stroke CT units) (cm)	35
Detector coverage (mm)	24
Collimation (mm)	32 X 0.75
Rotation time (sec)	1
Pitch (mm)	0.55
Tube voltage (kV)	80 - 120
Tube current	25
Slices	Up to 32
Height (cm)	153 - 170
Width (cm)	134 – 160
Depth (cm)	73 - 81
Weight (kg)	236 - 998

Even though certain trade-offs are made, the mobility, good image quality and less radiation dose is given upmost importance. And the Scanner parameters will change frequently with continuous innovation and development.

Mobile CT Vs Conventional Fixed CT: Technological Trade-offs

Understanding the technological differences and similarities between mobile and fixed CT becomes very important to illustrate its strength and weaknesses. Mobile CT takes an upper hand due to its portability, its ability to work with the battery, significantly lower weight. But to achieve this, certain trade-offs has to be made like small reduction in the quality of images, capability of the scanner and smaller FOV. Table 2 illustrate the differences between Mobile CT and Conventional CT of major scanners in the market [2] [15].

Table 2: Differences between Conventional and Mobile CT scanners

Parameters	**Conventional fixed CT**	**Mobile CT**
Gantry	Large and heavy	Small and lighter
Weight	Around 2.7 metric ton	236 – 998 kg
Electric supply	High voltage power supply	At least 110V outlet
Battery	NA	Rechargeable battery powered
Gantry tilt	Yes	NA
Tube current	ATCM	Fixed
Shielding	General room shielding	0.5 mm thick gantry casing and 0.5 mm lead curtains

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Radiation dose	Comparable to mobile CT	Comparable to fixed CT
Detector coverage (mm)	12 – 40	24
Rotation time (sec)	1	0.4
Image quality	Good	Small reduction in image quality

Radiation Safety: All the mobile CT unit comes with a self-shielded scanner design. They do not allow the scattered and leakage radiation to pass through them. The scanners are also equipped with detachable radiation shield which covers the bore of the gantry from the front and back thus protecting the neighbouring patients and staffs from the ionising radiation [7]

Primary Applications

- **ICUs:** Arguably, one of a mobile scanner's most significant uses is in intensive care units. In situations where a patient's life is in danger, imaging can be done sooner and many of the hazards that come with transporting critically sick patients—such as line displacement, disruption of medication titration, and difficulties related to ventilator use—can be avoided.
- **Operation theatres:** Intraoperative applications are the second most popular usage for a portable CT scanner. The most frequent uses of the scanner are for trauma, tumor removal, and ventricular reservoir or shunt implantation. The benefit is that the scanner can validate intra-operative catheter location or the degree of resection in addition to doing a localizing scan for neuro-navigation right before surgery [16].
- **Acute stroke units:** Mobile stroke units (MSUs) are specialty ambulances that have the staff, tools, and imaging capacity necessary to diagnose and manage acute stroke in a pre-hospital environment. The mobile CT is attached to the Ambulance or air ambulance [17]. These units are also capable of being used in rural and remote populations to improve the quality of care provided for patients with acute stroke [18].

Advantages over conventional CT:

- **Faster Diagnosis:** Reduced patient waiting as the scan delay that could have occurred due to pile-up of prescheduled scan at the centre following emergency cases is reduced.
- **Improved Patient Treatment:** Transferring a critically ill patient to radiology department may cause further complications. Hence bringing the CT unit to the patient's bedside can avoid the same.
- **Infection control:** Reduced chances of spread of infection and catching the infection due to non-transfer of critically ill patient's outside ICU/triage/Wards [19].
- **Optimized staff deployment:** Generally, where 3 to 4 staff is required to transfer the patient from ICU to Radiology department is reduced since there is no transfer is required. Hence the workforce can be utilized elsewhere [7].
- **Reduced down time:** Conventional CT scanners use direct electricity. Hence loss of power can have impact on services. But mobile CT scanners allow continuation of scan even after power outage due to battery backup specification [20].
- **Application of Mobile CT in Acute Stroke Unit**: In patients suspected with acute stroke, its diagnosis and management requires immediate attention. Hence to provide immediate diagnosis, mobile CT plays an essential role especially in CT equipped Ambulance and Air-ambulance [18].
- **Swift Response to Emergencies**: Emergencies such as disease outbreaks, natural disasters, and conflicts frequently need for immediate medical attention. In emergency situations, where prompt access to diagnostic services can make a life-saving difference, mobile CT scanners have shown to be invaluable. These scanners allow medical teams to quickly evaluate the severity of injuries or illnesses, triage patients, and prioritize treatment plans at temporary hospitals or relief centers. These devices are incredibly portable, making it simple to take them to disaster-affected areas even isolated locations without access to traditional medical facilities [21].

Pitfalls:

- Image quality may be compromised because of the mobile environment [22].
- Even though there is no significant rise in radiation dose, the quantity of noise is comparatively high [1].
- Smaller bore of the gantry limits the types of scans as larger parts of body may not be visualized.

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- Potential truncation artifact when the patient is positioned off the isocenter due to small bore [2].
- Frequent maintenance including quality assurance checks.
- Increased downtime for site travel when the system is elsewhere.
- Restricted interior space and increased claustrophobia events [23].

Present and Future of Mobile CT: The major challenge persist in finding an optimal balance between minimizing the weight while maximizing the structural integrity. There is a requirement for next generation CT scanners which not only deliver better image quality but also maintain the portability.

Artificial Intelligence:

- **Improved Image Quality and Reconstruction:** Patient mobility and inadequate data capture are two common causes of artifacts and noise in traditional CT image reconstruction methods. AI algorithms that use sophisticated image processing techniques, such deep learning-based methods, can handle these problems. Large datasets are used to train these algorithms, which improves image quality by helping them comprehend and recreate the underlying structures. AI technologies let radiologists see minute details and minor abnormalities more clearly by decreasing noise and artifacts. Improved diagnosis and treatment planning can result from this improvement in image quality, which will eventually benefit patients.
- **Automated Image Analysis and Interpretation:** In mobile CT scanning, artificial intelligence (AI) is essential to automate picture analysis and interpretation. Artificial intelligence (AI) algorithms can evaluate CT images and carry out activities that radiologists typically do by utilizing machine learning and computer vision techniques. AI systems can be trained on big datasets to identify particular patterns linked to illnesses or ailments, allowing for the automatic identification of anomalies. Furthermore, automatic segmentation of anatomical structures in CT scans, such as blood arteries or organs, can be accomplished using AI algorithms [24].
- **Reduction in Radiation dose:** The optimization of radiation dose in mobile CT scanning is also facilitated by AI algorithms. However, it's a difficult trade-off because lowering radiation dose can affect image quality. The AI algorithms aid in balancing radiation exposure with image quality. Through pre- or post-reconstruction, image noise reduction can be accomplished by utilizing several deep learning techniques. Less radiation is used in low-dose CT, which may have a negative impact on the image quality, particularly in cases when noise levels are higher [25].
- **Workflow Optimization and Efficiency:** The workload for radiologists and other medical imaging specialists has significantly increased. This increase may cause burnout, which could affect the long-term viability of healthcare delivery, increase patient waits times, and possibly necessitate that patients travel farther in order to receive necessary medical care. Mobile CT scanning workflow optimization and efficiency are enhanced by AI-based automation. AI algorithms lighten the workload for technicians and radiologists by automating time-consuming and repetitive activities. This frees them up to concentrate on more important work and complex interpretations. AI systems, for example, can automatically identify and label anatomical features in CT images, making precise scanner alignment and positioning possible. This expedites the imaging process by lowering the need for manual repositioning and modifications [26].

Hardware developments:

Bore: The smaller bore which are currently being used do not permit imaging of many of the structure. They are particularly designed to accommodate head and proximal part of the neck. Designing the CT unit with bigger bore may allow variety of cases that could be accommodated, hence improving the productivity. **Detector technology:** The Ultrafast Ceramic detector technology helps to keep the electronic noise very low. It improves the efficiency and also increases the spatial resolution [27].

Teleradiology solutions: Teleradiology is the digital transfer of radiographic images of patients between several institutions for the purpose of primary data interpretation, expert consultation, or clinical assessment. Images are uploaded via Digital Imaging and Communications in Medicine (DICOM), which are shown on desktops and downloaded by providers. After that, they are encrypted, compressed, and transported to virtual clouds, where they are received by radiologists, who analyze them and provide the report to the source [28]. It is evident that teleradiology has spread across the medical community and a wide range of radiology specialties. It's also likely

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to stay the norm for many locations where onsite radiology is either severely weak or nonexistent, especially when it comes to transportable CT units [29]. By integrating these advancements into the wider healthcare environment, the idea of a more responsive and integrated treatment system becomes clear. The smooth amalgamation of mobile CT scanners, telemedicine, and advanced diagnostic instruments might potentially result in an environment for quick and precise but also easily accessible healthcare especially for individuals residing in isolated or underprivileged regions [30].

Conclusion

Mobile CT is an important development in CT technology as it provides a better way to acquire diagnostic images in critically ill patients. The small reduction is imaging quality was noted but from the recent developments in CT technology, it can be reduced. Portable CT scanner can play a vital role in management of critically ill patients with high risk in transfer to radiology department. Artificial intelligence algorithms have demonstrated their worth in enhancing image quality and reconstruction in mobile CT scanning. By lowering noise and artifacts, these algorithms can improve the raw data that the CT scanner collects and create images that are more precise and clear. The identification and classification of anomalies and diseases is one of the important uses of AI in image analysis. AI systems can be trained on big datasets to identify particular patterns linked to illnesses or ailments, allowing for the automatic identification of anomalies which would be of great help while working remotely [24]. With this, Computed Tomography is becoming more and more mature as it applications are becoming more widespread. We can see and hope for new breakthrough technologies in Computed Tomography thus improving the diagnosis and healthcare.

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