Compact Navigation System Dedicated to Percutaneous Interventions Guided by CT: Advantages and Limits

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A. GANGI MD, PHD, S. GUTH MD, J.P. IMBERT MD, X. BUY MD, J.L. DIETEMANN MD, C. ROY MD.

Department of Radiology, University Louis Pasteur Strasbourg

Any questions or to submit cases please send us the mail at following addresses

E-mail : Afshin Gangi - E-mail : Stephane Guth

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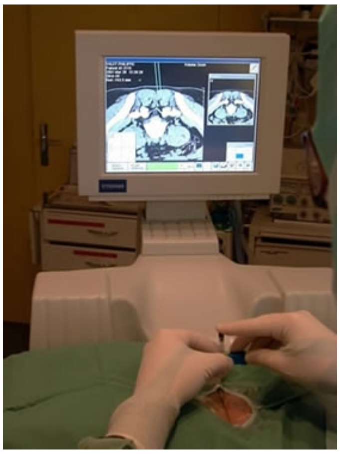
1) Introduction

This computer exhibit describes a compact and easy to use magnetic field navigation system dedicated to Computed tomography (CT) (FDA approved).

- In-vivo evaluation of free hand CT-based electronic targeting system
- Evaluation of accuracy of the targeting system for in-slice and cross-slice approaches

The accuracy and safety of imaging-guided percutaneous needle biopsy, aspiration, and drainage procedures have been well documented. Because percutaneous intervention is less invasive and more cost-effective than surgery, the number of radiologic procedures performed each year continues to increase. CT has remained the modality of choice for guidance in many interventional procedures. CT fluoroscopy has many potential advantages with real time guidance of the instruments. However, CT fluoroscopy has a greater potential for radiation injury to the patient than does conventional CT and also has the potential for considerable radiation exposure to personnel. CT Guide navigation system is the perfect illustration of tools that can help the operator to increase procedure efficiency with real time guidance and to decrease radiation exposure

CT-Guide navigation system and Multi-slice CT scanner (Volume Zoom)



CT-Guide screen with real time positioning of the needle

2) Principle

The system CT-Guide (UltraGuide, Tirat Hacarmel, Israel) consists in an image-based navigation tool using real-time magnetic tracker comprising a transmitter unit and magnetic sensors.

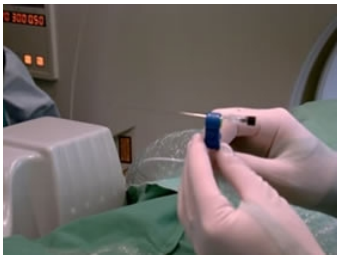
Magnetic Tracker

- The system consists in an image-based navigation tool using real-time magnetic tracker comprising a transmitter unit and magnetic sensors.
- The magnetic tracker includes two transmitters and two position sensor.
- The transmitter creates a magnetic field that is sensed by the position sensors enabling to measure their position with respect to the transmitter

Respiratory gating

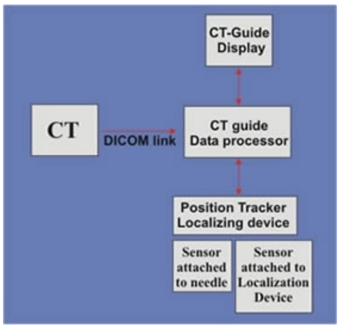
- Activated in procedures where body organs move due to respiration
- Respiratory phase of patient is monitored vs. respiratory phase during the scan

- Display of the relative respiratory phase is utilized during procedure
- Before starting the procedure Respiratory Gating is activated
- Patient's respiratory is learned for 10 sec. by measuring the position of the sensors on the body
- During procedure the position of the sensor on the body is measured, and a bar indicates the respiratory phase of patient relative to respiratory phase during scan



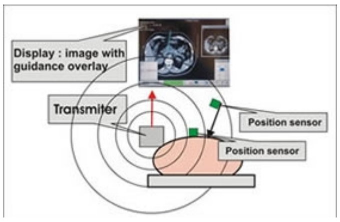
Magnetic sensor fixed sterilely to the needle

The localizing sensors are fixed to the patient body in the interest area



Navigation system protocol

The transmitter creates a magnetic field that is sensed by the position sensors enabling to measure their position with respect to the transmitter



Navigation system with the real time positioning control screen, transmitters, and sensors

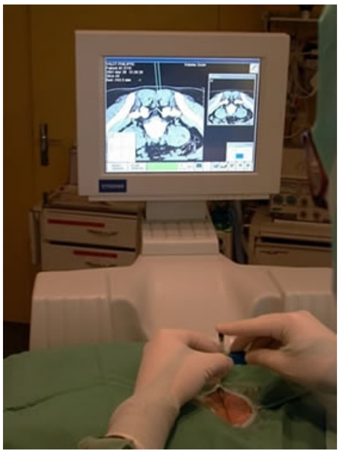
Patient in working position in front of CT-guide

3) Material

- Multi-detector CT scanner (Volume Zoom Siemens®)
- The sensors can be attached to needles of 9- to 22-gauge

- The CT guide placed in front of the operator in interventional room, connected by network to the CT scan. The sensors can be attached to needles of 9- to 22-gauge

Patient in working position and covered with sterile drapes

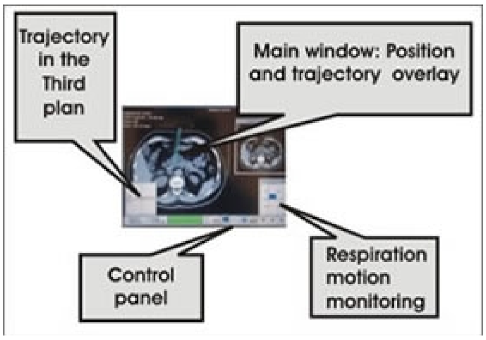


CT-guide monitor description

Features of the CT guide

- Real-time needle tracking
- Display of the needle's future trajectory
- Respiratory Gating
- Selectable pre-acquired target slices

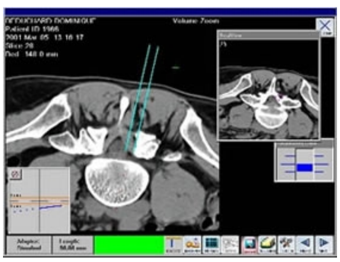
- Prospective Planning
- Real View window
- Top View window
- Electromagnetic technology
-



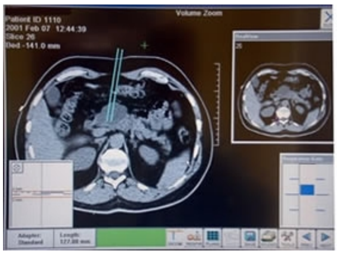
The position and the trajectory of the needle are projected in real time on the acquired CT images

4) Methods

125 interventional procedures were performed with a multi slice CT unit (Somatom Plus 4, volume Zoom, Siemens) associated with a compact navigation system (CT-Guide 2000, Ultraguide, Triate Hacarmel, Israel). The navigation system consists in an image-based navigation tool using real-time magnetic tracker comprising a transmitter unit and magnetic sensors. The localizing sensor is fixed to the patient body in the interest area. A spiral CT is performed and the data are transferred to the CT-guide navigator. Respiratory gating is provided to allow a continuous update of the needle position. The sensor is fixed to the needle. Then the patient is positioned in front of the CT-guide screen. The position and the trajectory of the needle are projected in real time on the acquired CT images. This enables real-time in-slice or out-of-slice tracking of the needle without radiation to the patient and to the operator.



The position and the trajectory of the needle are projected in real time on the acquired CT images



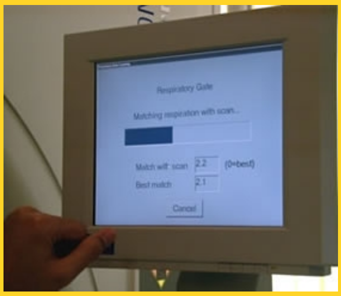
The position and the trajectory of the needle are projected in real time on the acquired CT images

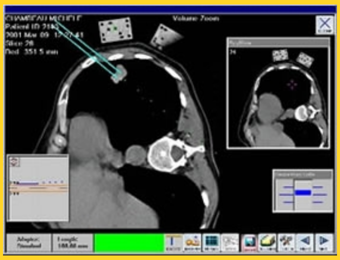
5) Technique

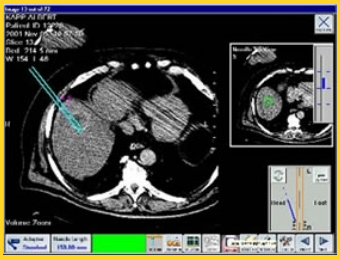
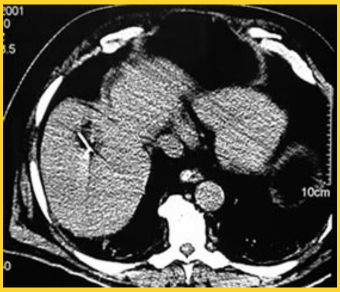
The localizing sensor is fixed to the patient body. A spiral CT is performed and the data are transferred to CT-guide navigator. The sensor is fixed to the needle. The position and the trajectory of the needle are projected in real time on the acquired CT images. This enables real-time in-plane or out-of-plane tracking of the needle without radiation to the patient and to the operator. Respiratory gating is provided to allow a continuous update of the needle position relative to the level of inspiration. The system can be adapted to all spiral CT scanners.

After insertion of the needle, the position of the needle tip is confirmed by a final CT control. With the multi-detector CT scan (Volume Zoom, Siemens Erlangen/ Germany) the intermittent mode was used. With the cluster scan mode, four contiguous sections were obtained with a single exposure of 0.5 second. The collimation depends on the size of the lesion. The multi-detector CT scan allows the use of various collimation 4x1 mm (4 mm exploration), 4x2.5 mm (10 mm exploration), or 4x5 mm (20 mm exploration). With this technique, the needle tip position was confirmed with only one intermittent control. Using the intermittent operational mode with a multi-detector CT scanner, the radiologist is able to step away from the gantry to obtain four CT sections per single exposures (single rotation of 0.5 second).

6) Procedure step by step

Procedure step by step	
Small localizing device is attached onto the patient to the target area before CT scan in the interest area	 The localization sensors are fixed to the patient body in the interest area
A spiral CT is performed in the interest area. Following CT scan of the area, CT images are transferred to the system by DICOM link	 Transmission of images to CT-Guide
Transferred CT study is automatically calibrated	 Activation of respiratory gating
One magnetic sensor is attached to the invasive tool and one to the localizing device	 Sensor attached sterilely to the needle

The magnetic sensor is connected to the invasive tool is connected to CT guide using a sterile cover	 Sterile covering
The length of the needle is selected	 Needle length selection
Position and trajectory of the tool are graphically in real time overlaid on CT images providing real time targeting information	 Real time guidance with respiratory gating
Then the patient and operator are positioned in front of the CT-guide screen . The position and the trajectory of the needle are projected in real time on the acquired CT images. At this stage CT guide is ready and fully configured for use. Freehand in-plane and out-plane interventions are enabled outside the gantry	 After insertion of the needle a confirmation CT-scan is performed

The out of plane mode	
The other important possibility of CT guide is the use of out of slice mode. In this mode, the operator can use the triangulation technique with the help of the device. The triangulation mode is performed with real time confirmation of the needle tip position on the monitor of the CT guide and visualization of the needle tract on each slice, which will be crossed by the needle.	 To avoid a pleural puncture, the out of plane mode is used
This out of plane mode is particularly useful during liver interventions (biopsy and Radio frequency ablation) with sub diaphragmatic localization of the lesion (VII, VIII segments). To control the position of the needle, only the intermittent operational mode was used with the CT because the needle manipulation was performed under the real time guidance of CT-Guide. After insertion of the needle, the position of the needle tip is confirmed by a final CT control. Success was defined as accurate placement of the needle or catheter in the desired site.	 Confirmations of the needle tip position

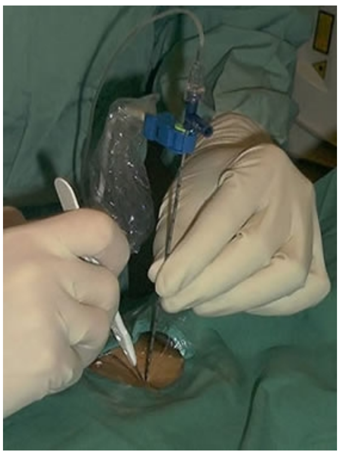
7) Results

In 59% of cases, successful positioning was achieved with the first insertion (deviation = 1 mm). In 32% of cases a deviation of the needle tip from the intended target was observed (mean deviation was 2.5 mm) and in 9% of cases the localization was impossible. Reasons for deviation were insufficient compliance in emphysematous patients, displacement of the lesion by the needle, bending of the needle, and interference of the magnetic sensors with the metallic scanner couch. Mean procedure-time for each probe-placement was 5.2 minutes. The use of thin needles (>20-gauge) was responsible of the major part of deviation of the needle tip (needle bending).

CT guide

8) Cases

Case 1



Radio frequency ablation of bone metastases with CT-guide control

Radio frequency ablation of bone metastases with CT-guide control

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Radio frequency ablation of bone metastases with CT-guide control

Case 2

Patient positioning for an epidural injection of steroid. Successful fast needle placement with CT-Guide

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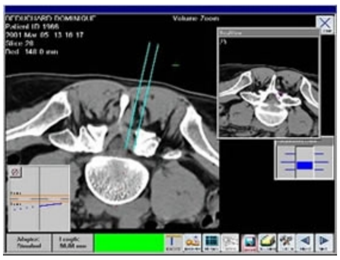

Patient positioning for an epidural injection of steroid. Successful fast needle placement with CT-Guide

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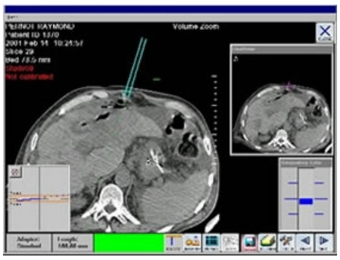
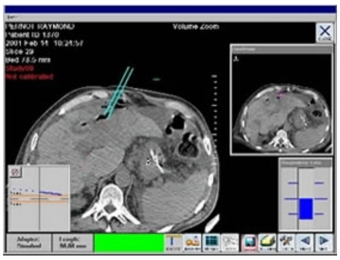
Case 3

Percutaneous drainage with CT-Guide monitoring

Percutaneous drainage with CT-Guide monitoring

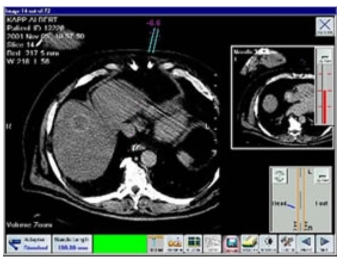


Percutaneous drainage with CT-Guide monitoring

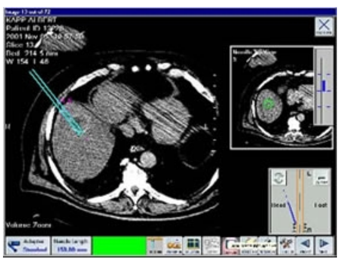


Percutaneous drainage with CT-Guide monitoring

Case 4



Out of plane technique. Radio-frequency ablation of the liver



Out of plane technique. Radio-frequency ablation of the liver

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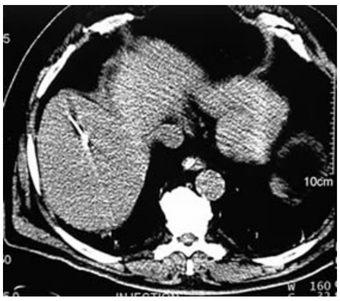

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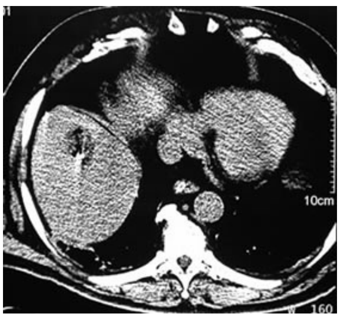

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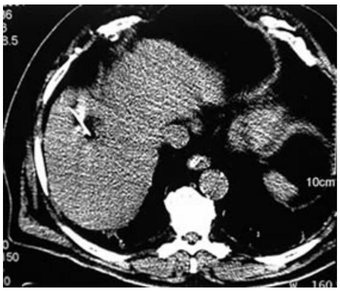
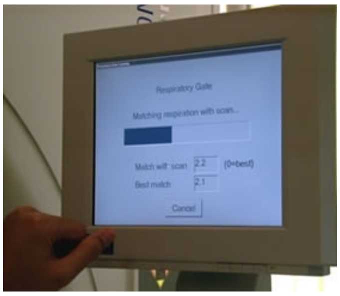


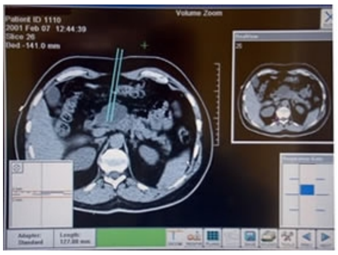
Out of plane technique. Radio-frequency ablation of the liver

Case 5

Pancreatic biopsy

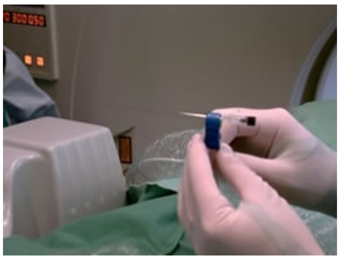


Pancreatic biopsy



Pancreatic biopsy

Case 6



Lung biopsy with respiratory gating

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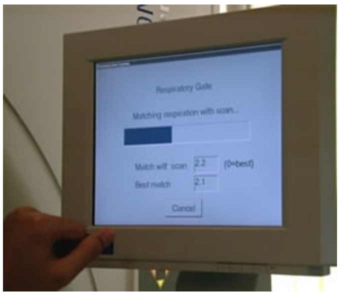

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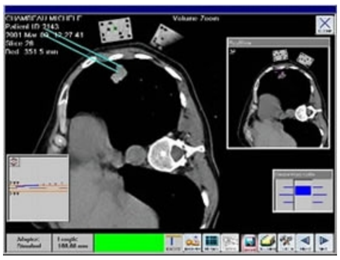

Lung biopsy with respiratory gating

Case 7

Foraminal radiofrequency neurolysis

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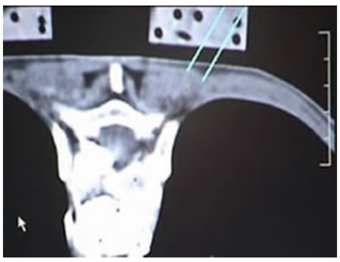
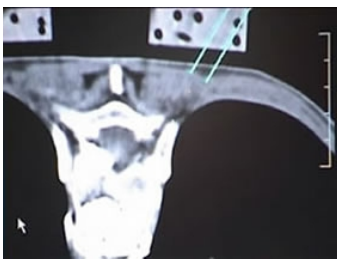


Foraminal radiofrequency neurolysis



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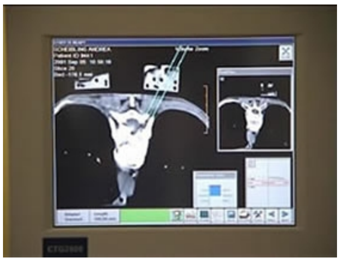

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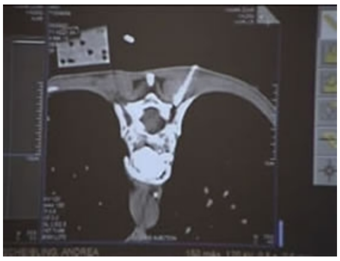
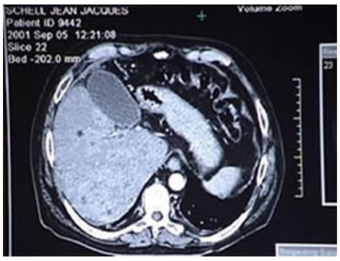


Foraminal radiofrequency neurolysis

Case 8



Respiratory gating is particularly useful in liver biopsy

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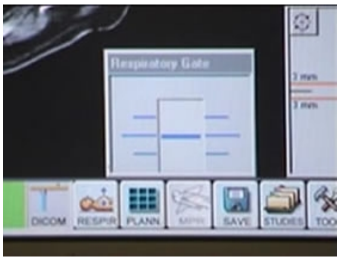

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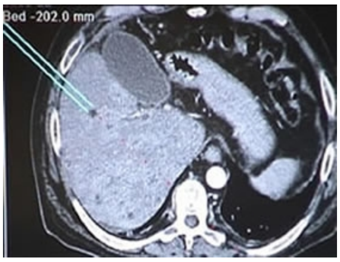

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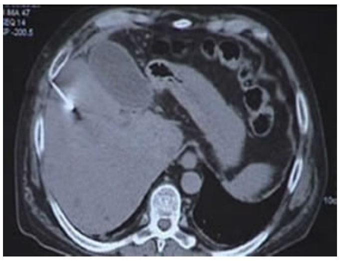


Respiratory gating is particularly useful in liver biopsy

Case 9

Laser photocoagulation of an osteoid osteoma

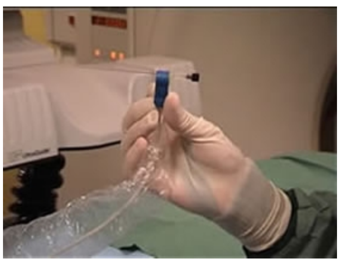
Laser photocoagulation of an osteoid osteoma

Laser photocoagulation of an osteoid osteoma

Laser photocoagulation of an osteoid osteoma

Case 10

Safe and fast needle placement in a retroperitoneal masse



Safe and fast needle placement in a retroperitoneal masse

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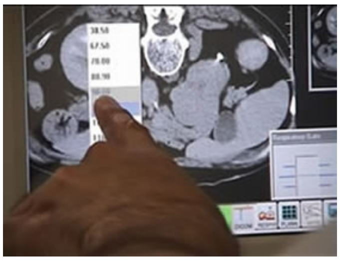
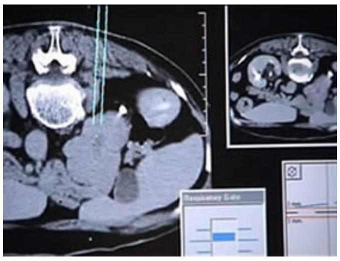
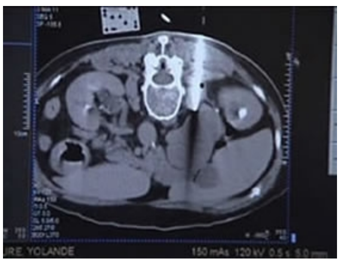


Safe and fast needle placement in a retroperitoneal masse



Safe and fast needle placement in a retroperitoneal masse



Safe and fast needle placement in a retroperitoneal masse

Safe and fast needle placement in a retroperitoneal masse

9) Conclusion

This compact electromagnetic navigation system is a safe, accurate and easy to use tool for CT guided interventions with substantial reduction of the radiation dose and real time guidance of the needle. The procedures were performed with use of only the intermittent operational cluster multi-detector CT mode. The fluoroscopy mode is used in during difficult interventions particularly the chest interventions with large respiratory motion and small nodule biopsy. CT-Guide is an accurate real-time guidance tool both for in-plane and out-of-plane minimally invasive procedures. This tool facilitates rapid single-pass needle placement and eliminates intra-procedural physician irradiation. CT-Guide is not constrained to paths in the CT gantry plane, thus allowing target approach from any direction.

Benefits of CT-Guide:

- Easier, faster and more accurate freehand procedures
- Ensures alignment prior to insertion
- Overcomes inaccuracies due to breathing Enables usage of optimal contrast phase images
- Assists in avoiding vital organs and anatomy
- Aligns the needle within the slice
- Provides dynamic 3-D position of needle tip
- Radiation-free guidance

Limits of CT-Guide:

- needle bending (>20 gauge)
- Large patient with more than 40 cm distance between the device and the needle
- Chest biopsy with small mobile lesion