International Journal of Research in Medical Sciences
Mehta NN et al. Int J Res Med Sci. 2019 Jun;7(6):2127-2131
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20192485

Original Research Article

Role of robotic arm assistance in computed tomography guided bone biopsy

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Received: 18 February 2019
Revised: 05 April 2019
Accepted: 11 April 2019

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ABSTRACT

Background: Use of robotic assistance technique has significant benefits over conventional techniques. The present study looks at the recent technological developments in image guidance for bone biopsy procedures.
Methods: Patients who were referred to the department of radiodiagnosis, Bharti Hospital and Dot3d scanning center, Sangli, Maharashtra, India from July 2017 till December 2018 with suspected bone lesions were included in the study. These patients underwent robotic arm CT guided bone biopsy of their lesions.
Results: In the present study, 47 patients were included. Authors observed that 93.6% had a positive diagnosis based on CT guided bone biopsy. Metastatic lesions were diagnosed in 8 cases. Inflammatory lesions and tuberculosis were other commonly observed diagnosis.
Conclusions: Further growth and development of medical imaging devices have allowed more interventional procedures to be performed and more patients to benefit from them. Radiologists needs to develop a thorough understanding of the anatomical structure involved and need to acquire both solid grounding in technology and the practical skills to visualize a nerve structure.

Keywords: Computed tomography, FNAC, Robotic arm

INTRODUCTION

Computed tomographic (CT) fluoroscopy offers much advantage for performance of Interventional procedures. With CT fluoroscopy the trajectory of a needle can be tracked in real time which allows the radiologist to make necessary adjustments. Major limitation of CT fluoroscopy is high radiation exposure to patient and physician.[1] Radiologists hand exposure has been theoretically and empirically determined to be approximately 2mGY per procedure it has been calculated that on basis of annual dose limit of 500msv of continuous hand exposure would be limited to performing only 4 CT fluoroscopic procedures per year.[2] Experience and training may lead to minimize reduction in exposure.[3] Paulson et al, recently reported reducing radiation exposure by lowering the milliampere setting and acquiring intermittent spot images during the procedure. Intermittent spot check images have gained greater acceptance, as it generally can allow successful completion of the intervention with a substantial reduction of radiation exposure.[4] Rabio robotic arm, a next generation platform of robotic targeting system for biopsy and procedures comes with an array of advanced targeting features making robot the hands of a radiologist making it possible for radiologists to perform complex procedures with high degree of accuracy, minimizing unwanted organ damage and with significantly high patient comfort. This study looks at the recent technological developments in image guidance for interventional procedures. It also describes the new techniques and unconventional approaches that help provide safe access to difficult to reach lesions.

METHODS

The present study was conducted in the department of radiodiagnosis, Bharati Hospital, Sangli, Maharashtra, India and Dot3d Scanning Centre, Sangli, Maharashtra, India.

Patients who were referred to our department with suspected bone lesions from July 2017 till December 2018 were included in the study. The study was approved by the institutional ethics committee.

Procedure for intervention with help of robotic arm

The patient is placed in predetermined position suitable for intervention (supine, prone or lateral). The system is prepositional and firmly attached to the table with clamps. Based on the pre-interventional images and the anatomical region of interest the Table is moved using the laser vizier from the CT gantry. The CT version comprises laser light sensors at the upper part of the application module for automated registration. The arm moves back and forth; It returns so that the light detectors area lightened with laser (within ±0.5mm) The laser light is switched off and the table can be moved into gantry until the position of the laser line matches with the zero position of the z axis of the scanner.

If planning for MRI interventions, then it is performed using fast gradient echo sequences in transverse sagittal or coronal oriented. Suitable slices are selected and sent via the network in DICOM format to the computer of the robotic assistant system. The insertion site and a target point are selected on the graphical user's interface and the corresponding coordinates are sent to the control unit. The drives are activated, and the application module is moved with the tool center point to the insertion site on skin. The cannula can then be inserted through a guiding sleeve or along an open angle.

Registration

Active needle driver, at for a robot to target the anatomy based on the images, the coordinate system of the robot must be registered to the coordinate system of the imaging device. If the robot is permanently attached to the patient table of the imaging device, this registration can be done once through a calibration procedure. If the robot is designed to be moved from one imaging device to another or to be placed on the table for certain procedures, fast and accurate registration techniques are required.

Patient movement and respiration

A limiting problem in some interventional techniques is organ movement due to respiration. High power robotic systems can avoid this problem.

Mode of control

The best user interface for an interventional robot has yet to be determined. For many procedures, joystick control seems well-suited and keeps the radiologists firmly in control. However, there are procedures such as biopsy where a straight-line trajectory needs to be followed and some degree of autonomy seems appropriate if robustness can be achieved.

Imager compatibility

On the cannula existing force feedback devices are too bulky for the clinical environment. In addition, friction forces and tissue during insertion are high, which compromises the accuracy of force feedback measurements. Therefore, this topic must be considered a research issue at this time. For MRI systems, compatibility can be achieved by using nonmagnetic and nonconductive materials. For CT systems, radiolucency of the end-effector is important so that it can hold the instrument on the scan plane. The robot system must also be easily interfaced with the imaging system and allow quick access to the patient in emergency situations. When the robot system is actuated it should not interfere with the imaging system. The kinematic structure of the robot must allow it to reach inside the gantry, which is one reason why specially designed robots are needed for these procedures.

Statistical analysis

Patient related data were obtained from the medical records using a pre-designed case report form. Patient data were tabulated and analyzed.

RESULTS

In the present study, 47 patients were included. The characteristics of these 47 patients have been described in (Table 1), which includes information like specimen obtained and the diagnosis obtained. Non-representative and non-specific samples were reported as negative. The most common lesions for which CT guided biopsy was done were in the vertebral bodies (n=21). Paraspinal lesions were the next most common lesions (n=11). Biopsy sample was greyish white material in majority of the patients (n=23). Seven cases had light to dark brown aspirated material. Rest of the cases had firm to hard colorless aspirate, hemorrhagic fluid and scattered marrow cells. Authors observed that 93.6% had a positive diagnosis based on CT guided bone biopsy (Table 2).

Table 1: Characteristics of the patients included in the study.

Speciman		Report	Result
Bone	Soft tissue		
Rib left	Fibronoid material and fibro-adipose tissue only	Non representative	Negative
Sacral area	tiny bits of greyish white soft tissue	Non hodgkins lymphoma	Positive
L4Vetebral body	firm to hard tissue pieces	Bony trabaculea marrow cells	Positive
T7 Vertebral body	firm to hard tissue	Negative malignancy	Positive
T7 Vertebral body	firm to hard tissue	Negative malignancy	Positive
S1 Vertebral body	firm to hard tissue	Negative malignancy	Positive
T11Verebral body	firm to hard tissue	normal bone tissue	positive
D10 vertebral body	Elongated piece of greyish white soft tissue	Fibrous tissue with inflammation	Positive
L2 vertebral body	Elongated piece of greyish white soft tissue	Fibrofatty and fibrous granulation tissue with focal mononuclear leucocytic infiltration	Positive
SI Joint left	three tiny species of light brown soft tissue	No evidence of Koch's	Positive
D7 vertebral body	single elongated piece of greyish white soft tissue	No evidence of Malignancy and tubrculosis.	Positive
L4-L5 with araspinal abscess	single elongated piece of greyish white soft tissue	Nonspecific granulation tissue.	Positive
Bone marrow	scattered bone marrow cells in a background of abundant red blood cells.	Scanty bone marrow	Positive
Rt. Iliac bone lytic lesion with abscess	Haemorrhagic fluid	Bone abscess	Positive
Bone marrow	Tiny pieces of dark brown soft tissue	Multiple myloma	Positive
Left paraspinal	greyish white soft tissue	Inflammation	positive
D9-D10	greyish white soft tissue	Granulomatous inflammation	Positive
D10 vertebral body	greyish white soft tissue	Normal bone tissue	Positive
Left Iliac bone	Elongated piece of light brown soft tissue	Metastasis adenocarcinoma	Positive
Spine and ribs	Greyish white soft tissue	Metastasis poorly differentiated Carcinoma	Positive
L2paraspinal mass	Elongated piece of light brown soft tissue	Malignant	Positive
Left Iliac bone	Tiny bits of light brown soft tissue	Bone marrow within normal limits.	Positive
L2 vertebral body	Grey white soft tissue	Inflammatory lesion	Positive
L5 vertebral body	Grey white soft tissue	Metastasis adenocarcinoma	Positive
Rt. Iliac bone and acetabulum	Grey white soft tissue	Metastatic adenocarcinoma	Positive
D10 -D11 vertebral body	Grey white soft tissue	Tuberculosis	Positive
L3	Reddish white thick	Metastasis carcinoma	Positive
L1-L2-L3 Para spinal	grey white soft tissue	Paraspinal abscess	Positive
L5-S1 vertebral body	Tiny bits of brown white soft tissue	plasmacytoma	Positive
Paraspinal	Grey white soft tissue	Nonspecific Inflammation	Positive
Paraspinal	grey white soft tissue	Tuberculosis	Positive
Paraspinal	Grey white soft tissue	Inflammatory lesion	Positive
Sacral area	Tiny bites	Tuberculosis	Positive
Right iliac crest	Grey white soft tissue	plasmacytoma	Positive
Right foot	Grey white soft tissue	Nonspecific granulation tissue	Positive
L4Vetebral body	Grey white soft tissue	Non representative	Negative
L5 vertebral body	Grey white soft tissue	Metastatic adenocarcinoma	Positive
L2-L3 Vertebral body	Grey white soft tissue	Nonspecific granulation tissue	Positive
L2 vertebral body	7 smears	non diagnostic	Positive
L4 vertebral body	Two pieces of grey white soft tissue	Negative malignancy	Positive
Paraspinal abscess	Two pieces of grey white soft tissue	Nonspecific	Negative
L1Vertebral body	Two smears	Metastatic adenocarcinoma	Positive
D10-D11para spinal	Single piece grey white soft tissue	Tuberculosis	Positive
D7-D8 paraspinal	D7-D8 para spinal	Tuberculosis	Positive
L4-L4	L3-L4 paraspinal area	Tuberculosis	Positive
D4	Bone marrow aspiration	Plasma cell dyscrasia	Positive
D9	Para spinal D9	Inflammatory lesion.	Positive

Table 2: Results of bone biopsy in our patients.

Results obtained	Positive	Negative
Total number out of 47	44	3
Percentage	93.6%	6.4%

Among three cases, diagnosis could not be obtained. One of these three cases was from left rib from which fibrinoid material was obtained, one was from L4 vertebral body and the last one from the paraspinal abscess. No evidence of malignancy or tuberculosis was found in 13 cases. Metastatic lesions were diagnosed in 8 cases, tuberculosis in 6 patients and inflammatory lesions were diagnosed in five patients (Table 3). Other less common diagnoses were bony abscess, leucocytic infiltration, lymphoma and paraspinal abscess. Figure 1 describes the positioning of the CT guided bone biopsy needle in various lesions in the vertebral body and iliac crest with the help of robotic arm Figure 2 illustrates axial CT scans showing bone biopsy needle position in various paraspinal lesions with the help of robotic arm.

Table 3: Distribution of diagnosis among our patient population.

Diagnosis	N
Bony abscess	1
Bone marrow within normal limits	2
Focal mononuclear leucocytic infiltration	1
Inflammation	5
Malignant	1
Metastasis	8
No evidence of malignancy or tuberculosis	13
Non-hodgkins lymphoma	1
Non-representative	3
Non-specific granulation tissue	3
Normal tissue	2
Paraspinal abscess	1
Tuberculosis	6

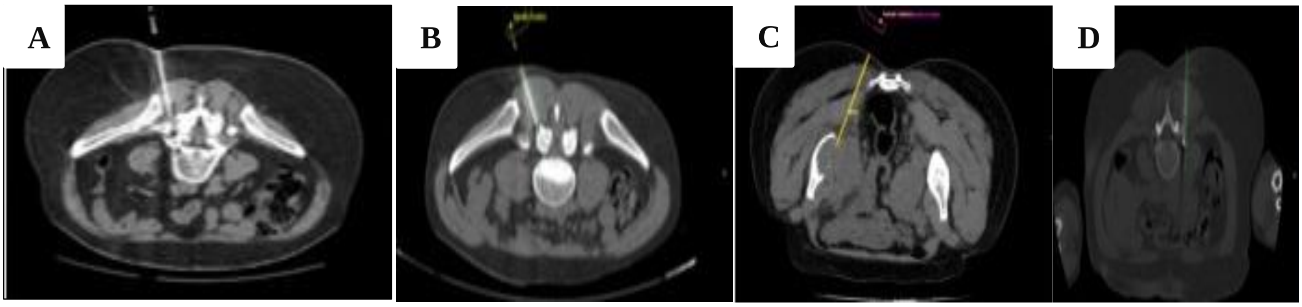

Figure 1: Axial CT scans showing bone biopsy needle positioning in various vertebral body lesions with the help of robotic arm. (A) L5-S1 lesion, (B) L5-S1 lesion, (C) Right iliac bone lytic lesion with abscess, (D) L4 lesion.

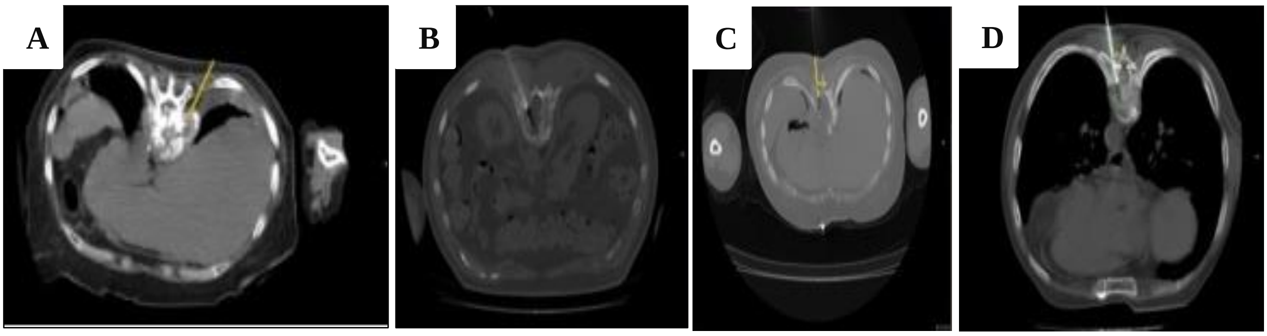

Figure 2: Axial CT scans showing bone biopsy needle positioning in various paraspinal lesions with the help of robotic arm. (A): T12 paraspinal lesion. (B): L2 paraspinal lesion. (C): Biopsy needle near paraspinal lesions. T12(D): T9 paraspinal lesion.

DISCUSSION

In general diagnostic and therapeutic radiology requires the highest quality images for perfection, this high-quality imaging may require more imaging time and more radiation dose. Because of robotic arms imaging can be restricted to the region of interest.[6] Computed tomography provides a very good representation of the skeletal structures and are therefore first choice of mapping of skeletal injuries in conjunction with severe trauma or for detailing skeletal structures. It is still a golden method of imaging for oncology patients.[7] Robotic arms have been introduced to hold and move instrument precisely. Robotic arms allow greater precision and accuracy and lack tremors when compared with humans. The use of robotic arm reduces complications which may occur during the procedure. Robotic arm can provide excellent guidance for localizing a lesion, tracing the pathway to guide the needle to reach up to the pathology and the depth of intervention needed from the desired site to take the biopsy. Similar to percutaneous procedures with cannulae and probes reconstructive procedures have also developed. Robots have some potential advantages over the human operator in certain applications. Examples include working in hazardous environments such as imaging rooms where radiation is used.[8] During fluoroscopic or CT guided procedures the operator frequently advances the cannula with the imaging beam off and then acquires additional images to identify the current position of the tip. Options to overcome the limitation of intermittent imaging include stand-off devices to keep the operator ‘s hands out of the direct x-ray beam.[9] These devices are clumsy, and still force the operator to be too close to the radiation. During percutaneous radiotherapy procedures radioactive seeds or probes are inserted into the patient. These are dangerous to have close to the operator. Other potential uses are to integrate robots with image guidance, including multimodality integration, and the integration of tracking technologies such as optical or mechanical trackers.[10] The robots can perform active guidance in procedures where path planning and execution are difficult or provide a zone of constraint to keep the operator out of dangerous areas. A robot can also be integrated with active control to compensate for motion such as respiration. By compensating for patient motion the target can be made to appear static.[11] To be accepted in clinical practice, however, a robot must be intuitive and require minimal operator training. It must also be quick and easy to set up and not significantly increase the length of procedures. Robots must also be cost effective. The possibility of performing procedures that the human cannot perform but that are clinically necessary remains an ultimate goal for medical robotics. Engineers and radiologists should work together to create and validate these systems for the benefits of patients everywhere.

CONCLUSION

As research and development in medical imaging focuses on interventional needs, it is likely that the role of medical imaging in interventions will become more integral and more widely applied. Further growth and development of medical imaging devices have allowed more interventional procedures to be performed and more patients to benefit from them. 3D reconstruction of CT scan is useful advance in the understanding of anatomy of the body and its pathologies and robotic arm attachment further makes the procedure more precise. It is just that the radiologists need to develop a thorough understanding of the anatomical structure involved and need to acquire both solid grounding in technology and the practical skills to visualize a nerve structure.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Mehta NN, Mehta N, Gorde N. Role of robotic arm assistance in computed tomography guided bone biopsy. Int J Res Med Sci 2019;7:2127-31.