International Journal of Medical and Health Research
ISSN: 2454-9142
Received: 28-05-2019; Accepted: 30-06-2019
www.medicalsciencejournal.com
Volume 5; Issue 7; July 2019; Page No. 213-217

Comparative evaluation of Ultrasonography and conventional radiography techniques for recognition of bone fractures in adult patients

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Abstract
High-spatial-resolution Ultrasonography (USG), however, may be an alternative imaging modality in patients with occult scaphoid fractures. Technical improvements in sonography have led to higher spatial resolution of this diagnostic tool, and, thus, high-spatial resolution US may depict subtle post-traumatic changes of the cortex and/or periosteum, which may already be present immediately after the injury but which are not depicted on conventional radiographs. Furthermore, high-spatial-resolution US, compared with MR imaging, is more readily accessible, less time-consuming, and considerably less expensive. Radiography is the use of x-rays to visualize the internal structures of a patient. X-Rays are a form of electromagnetic radiation, produced by an x-ray tube. The x-rays are passed through the body and captured behind the patient by a detector; film sensitive to x-rays or a digital detector. There is variance in absorption of the x-rays by different tissues within the body, dense bone absorbs more radiation, while soft tissue allows more to pass through. This variance produces contrast within the image to give a 2D representation of all the structures within the patient. Hence present study was planned for comparative evaluation of ultrasonography and conventional radiography techniques for recognition of bone fractures in adult patients.
The present study was planned in Department of Radio- Diagnosis, Lord Buddha Koshi Medical College & Hospital, Saharsa, Bihar. Total 25 cases of bony fractures referred to our hospital were evaluated in the present study. All the patients had undergone the USG and conventional radiography. The results of radiography and ultrasonography were compared to see their relative efficacy in the detection of fractures.
Ultrasonography is a very rapid, cost-effective, and radiation free imaging technique for detection of superficially situated bone fractures. USG can replace conventional radiography in cases of isolated uncomplicated fractures. In cases of doubtful fracture, combination of USG and conventional plain films may be considered to avoid unnecessary exposures from higher imaging like CT scan. It can be considered as the imaging of choice when CT or conventional radiography are not advised as in pregnant women.

Keywords: Ultrasonography, Conventional Radiography, Bone Fractures, etc

Introduction
A bone fracture (sometimes abbreviated FRX or Fx, Fx, or #) is a medical condition in which there is a partial or complete break in the continuity of the bone. In more severe cases, the bone may be broken into several pieces [1]. A bone fracture may be the result of high force impact or stress, or a minimal trauma injury as a result of certain medical conditions that weaken the bones, such as osteoporosis, osteopenia, bone cancer, or osteogenesis imperfecta, where the fracture is then properly termed a pathologic fracture [2].
Although bone tissue itself contains no nociceptors, bone fracture is painful for several reasons [3];

- Breaking in the continuity of the periosteum, with or without similar discontinuity in endosteum, as both contain multiple pain receptors.
- Edema and hematoma of nearby soft tissues caused by ruptured bone marrow evokes pressure pain.
- Involuntary muscle spasms trying to hold bone fragments in place.

Damage to adjacent structures such as nerves, muscles or blood vessels, spinal cord, and nerve roots (for spine fractures), or cranial contents (for skull fractures) may cause other specific signs and symptoms.
Some fractures may lead to serious complications including a condition known as compartment syndrome. If not treated, eventually, compartment syndrome may require amputation of the affected limb. Other complications may include non-union, where the fractured bone fails to heal or mal-union, where the fractured bone heals in a deformed manner. One form of malunion is the malrotation of a bone, which is especially common after femoral and tibial fractures. Complications of fractures may be classified into three broad groups, depending upon their time of occurrence. These are as follows – Immediate complications – occurs at the time of the fracture; Early complications – occurring in the initial few days after the fracture; Late complications – occurring a long time after the fracture.
The natural process of healing a fracture starts when the injured bone and surrounding tissues bleed, forming a fracture hematoma. The blood coagulates to form a blood clot situated between the broken fragments. Within a few days, blood vessels grow into the jelly-like matrix of the blood clot. The new blood vessels bring phagocytes to the area, which gradually removes the non-viable material. The blood vessels also bring fibroblasts in the walls of the vessels and these multiply and produce collagen fibres. In this way, the blood clot is replaced by a matrix of collagen. Collagen's rubbery consistency allows bone fragments to move only a small amount unless severe or persistent force

is applied.

At this stage, some of the fibroblasts begin to lay down bone matrix in the form of collagen monomers. These monomers spontaneously assemble to form the bone matrix, for which bone crystals (calcium hydroxyapatite) are deposited in amongst, in the form of insoluble crystals. This mineralization of the collagen matrix stiffens it and transforms it into bone. In fact, bone is a mineralized collagen matrix; if the mineral is dissolved out of bone, it becomes rubbery. Healing bone callus on average is sufficiently mineralized to show up on X-ray within 6 weeks in adults and less in children. This initial "woven" bone does not have the strong mechanical properties of mature bone. By a process of remodelling, the woven bone is replaced by mature "lamellar" bone. The whole process may take up to 18 months, but in adults, the strength of the healing bone is usually 80% of normal by 3 months after the injury.

Several factors may help or hinder the bone healing process. For example, tobacco smoking hinders the process of bone healing [4]. And adequate nutrition (including calcium intake) will help the bone healing process. Weight-bearing stress on bone, after the bone has healed sufficiently to bear the weight, also builds bone strength. Although there are theoretical concerns about NSAIDs slowing the rate of healing, there is not enough evidence to warrant withholding the use of this type analgesic in simple fractures [5].

Smokers generally have lower bone density than non-smokers, so they have a much higher risk of fractures. There is also evidence that smoking delays bone healing [6]. A bone fracture may be diagnosed based on the history given and the physical examination performed. Radiographic imaging often is performed to confirm the diagnosis. Under certain circumstances, radiographic examination of the nearby joints is indicated in order to exclude dislocations and fracture-dislocations. In situations where projectional radiography alone is insufficient, Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) may be indicated.

Both high- and low-force trauma can cause bone fracture injuries. Preventive efforts to reduce motor vehicle crashes, the most common cause of high-force trauma, include reducing distractions while driving. Common distractions are driving under the influence and texting or calling while driving, both of which lead to an approximate 6-fold increase in crashes. Wearing a seatbelt can also reduce the likelihood of injury in a collision [7].

A common cause of low-force trauma is an at-home fall. When considering preventative efforts, the National Institute of Health (NIH) examines ways to reduce the likelihood of falling, the force of the fall, and bone fragility. To prevent at-home falls they suggest keeping cords out of high-traffic areas where someone could trip, installing handrails and keeping stairways well-lit, and installing an assistive bar near the bathtub in the washroom for support. To reduce the impact of a fall the NIH recommends to try falling straight down on your buttocks or onto your hands. Finally, taking calcium vitamin D supplements can help strengthen your bones [8].

Treatment of bone fractures are broadly classified as surgical or conservative, the latter basically referring to any non-surgical procedure, such as pain management, immobilization or other non-surgical stabilization. A similar classification is open versus closed treatment, in which open treatment refers to any treatment in which the fracture site is opened surgically, regardless of whether the fracture is an open or closed fracture.

Since bone healing is a natural process that will occur most often, fracture treatment aims to ensure the best possible function of the injured part after healing. Bone fractures typically are treated by restoring the fractured pieces of bone to their natural positions (if necessary), and maintaining those positions while the bone heals. Often, aligning the bone, called reduction, in a good position and verifying the improved alignment with an X-ray is all that is needed. This process is extremely painful without anaesthesia, about as painful as breaking the bone itself. To this end, a fractured limb usually is immobilized with a plaster or fibreglass cast or splint that holds the bones in position and immobilizes the joints above and below the fracture. When the initial post-fracture oedema or swelling goes down, the fracture may be placed in a removable brace or orthosis. If being treated with surgery, surgical nails, screws, plates, and wires are used to hold the fractured bone together more directly. Alternatively, fractured bones may be treated by the Ilizarov method which is a form of an external fixator.

Occasionally smaller bones, such as phalanges of the toes and fingers, may be treated without the cast, by buddy wrapping them, which serves a similar function to making a cast. A device called a Suzuki frame may be used in cases of deep, complex intra-articular digit fractures [9]. By allowing only limited movement, immobilization helps preserve anatomical alignment while enabling callus formation, toward the target of achieving union. Splinting results in the same outcome as casting in children who have a distal radius fracture with little shifting [10].

Surgical methods of treating fractures have their own risks and benefits, but usually surgery is performed only if conservative treatment has failed, is very likely to fail, or likely to result in a poor functional outcome. With some fractures such as hip fractures (usually caused by osteoporosis), surgery is offered routinely because non-operative treatment results in prolonged immobilisation, which commonly results in complications including chest infections, pressure sores, deconditioning, deep vein thrombosis (DVT), and pulmonary embolism, which are more dangerous than surgery. When a joint surface is damaged by a fracture, surgery is also commonly recommended to make an accurate anatomical reduction and restore the smoothness of the joint.

Infection is especially dangerous in bones, due to the recrudescent nature of bone infections. Bone tissue is predominantly extracellular matrix, rather than living cells, and the few blood vessels needed to support this low metabolism are only able to bring a limited number of immune cells to an injury to fight infection. For this reason, open fractures and osteotomies call for very careful antiseptic procedures and prophylactic use of antibiotics. Occasionally, bone grafting is used to treat a fracture.

Sometimes bones are reinforced with metal. These implants must be designed and installed with care. Stress shielding occurs when plates or screws carry too large of a portion of the bone's load, causing atrophy. This problem is reduced, but not eliminated, by the use of low-modulus materials,

including titanium and its alloys. The heat generated by the friction of installing hardware can accumulate easily and damage bone tissue, reducing the strength of the connections. If dissimilar metals are installed in contact with one another (i.e., a titanium plate with cobalt-chromium alloy or stainless steel screws), galvanic corrosion will result. The metal ions produced can damage the bone locally and may cause systemic effects as well.

A Cochrane review of low-intensity pulsed ultrasound to speed healing in newly broken bones found insufficient evidence to justify routine use [11]. Other reviews have found tentative evidence of benefit [12]. It may be an alternative to surgery for established nonunions [13]. Vitamin D supplements combined with additional calcium marginally reduces the risk of hip fractures and other types of fracture in older adults; however, vitamin D supplementation alone did not reduce the risk of fractures [14].

High-spatial-resolution Ultrasonography (USG), however, may be an alternative imaging modality in patients with occult scaphoid fractures. Technical improvements in sonography have led to higher spatial resolution of this diagnostic tool, and, thus, high-spatialresolutionUS may depict subtle post-traumatic changes of the cortex and/or periosteum, which may already be present immediately after the injury but which are not depicted on conventional radiographs. Furthermore, high-spatial-resolution US, compared with MR imaging, is more readily accessible, less time-consuming, and considerably less expensive [15]. Radiography is the use of x-rays to visualize the internal structures of a patient. X-Rays are a form of electromagnetic radiation, produced by an x-ray tube. The x-rays are passed through the body and captured behind the patient by a detector; film sensitive to x-rays or a digital detector. There is variance in absorption of the x-rays by different tissues within the body, dense bone absorbs more radiation, while soft tissue allows more to pass through. This variance produces contrast within the image to give a 2D representation of all the structures within the patient [16].

Hence present study was planned for comparative evaluation of ultrasonography and conventional radiography techniques for recognition of bone fractures in adult patients.

Methodology

The present study was planned in Department of Radio-Diagnosis, Lord Buddha Koshi Medical College & Hospital, Saharsa Bihar. Total 25 cases of bony fractures referred to our hospital were evaluated in the present study. All the patients had undergone the USG and conventional radiography. The results of radiography and ultrasonography were compared to see their relative efficacy in the detection of fractures.

Ultrasound was done using a real time scanner (Philips Envisor C and Esaote) with a 5-12 MHz Broad Band linear array probe with musculoskeletal pre-set. Suspected site was examined patiently in both transverse and longitudinal planes. Care was taken to scan very lightly over the site. On USG, breech in the continuity of the cortex of the bone was used as the criterion to suggest a fracture as it is the most definitive and reliable factor in diagnosing a fracture on ultrasonography. A clear disruption of cortical bone as small as 1-2 mm was detected. Displacement of the fractured ends was also appreciated with the USG probe as step off deformity or avulsion of a bony segment. Limit of about 2 mm was taken as a criterion for deciding displacement to be present or absent.

All the patients were informed consents. The aim and the objective of the present study were conveyed to them. Approval of the institutional ethical committee was taken prior to conduct of this study.

Following was the inclusion and exclusion criteria for the present study.

Results and Discussion

Suspected fracture following trauma is a common reason for emergency room admission. X-ray is usually used to diagnose patients with suspected fracture and is the standard procedure. The use of ultrasound to diagnose fractures has been the subject of intense discussion over the last 20 years [17-20]. Viewing alterations to bone surfaces (discontinuities, displacement, subperiosteal hematomas) has been proven to be a reliable, manageable method of fracture diagnosis. One of the main advantages of ultrasound examination is the avoidance of radiation exposure; this is particularly true in children, who are more sensitive to radiation than adults [21]. Ultrasound diagnosis is also easy to teach, cheap, and available in emergency rooms and many medical practices [22]. All these are arguments in favor of the use of ultrasound in diagnostic algorithms for suspected fracture, which could reduce the number of x-ray examinations performed [23-24].

Fractures are diagnosed via ultrasonography based on observation of cortical bone disruption. In cases of small fractures, detection of this sign in sonogram and distinguishing it from other findings is highly dependent on the skills of the operator. The role of operator's skills in detection of injuries via ultrasonography was verified in the present study as well [25-28]. Ultrasonography by a radiologist has a higher sensitivity compared to emergency medicine specialist. The present study found that the specificity of this modality increased with frequencies of higher than 10MHz which might be due to the higher resolution obtained with higher frequencies [29]. Making it easier to detect the signs of fracture.

Some narrative review articles and qualitative systematic reviews are indicative of the potential benefit of ultrasonography in detection of chest wall fractures. In this regard, Chan, in his systematic review conducted on studies indexed in Medline, declares that ultrasonography has a higher sensitivity in detection of thoracic bone fractures compared to radiography [30]. Finding the diagnostic accuracy of ultrasonography to be two times the ability of radiography in fracture diagnosis, Dietrich *et al*. also referred to ultrasonography as a useful diagnostic tool for detection of rib fractures [31].

Table 1: Age & Sex of Patients

Age	No. of Cases
21 – 30 years	3
31 – 40 years	8
41 – 50 years	10
51 – 60 years	4
Sex	
Male	15
Female	10
Total	25

Table 2: Results of Radiography and USG

Type of Bone	Results of Radiography	Results of USG		Total
		Negative	Positive	
Long Bone	Negative	6	0	6
	Positive	0	10	10
	Total	6	10	16
Flat Bone	Negative	1	2	3
	Positive	0	2	2
	Total	1	4	5
Short Bone	Negative	1	1	2
	Positive	0	2	2
	Total	1	3	4

Table 3: Sensitivity and Specificity

	True Positive	False Positive	True Negative	False Negative	Total	Sensitivity	Specificity
Long Bone	10	0	6	0	16	100%	100%
Flat Bone	2	0	1	2	5	50%	100%
Short Bone	2	0	1	1	4	60%	100%

Ultrasonography is a quick, noninvasive diagnostic imaging modality with no risk of radiation exposure as it only uses sound waves. It was originally used for soft-tissue evaluation. A breakthrough was made by Ord *et al*. [32] In the imaging of maxillofacial fractures when they used USG for evaluation of orbital fractures. Gross swelling and tenderness over the fracture can make the procedure uncomfortable for the patient and can also make scanning of the bony outlines difficult, decreasing the accuracy of the process [33]. In this present study, there was not much difficulty in examination of patients with gross swelling and tenderness. Reduced tenderness may be because of the analgesic effect of medications taken by the patients. Moreover, it was also observed that isolated zygomatic arch or mandibular fractures were associated with minimal degree of swelling and tenderness. Unlike CT scan or conventional radiography, USG has a drawback of inability to relate a fractured site to surrounding normal anatomical landmarks.

The patients were examined based on evidence of subjective and objective findings with the study of history, inspection, palpation, percussion, and auscultation. The clinician must select the relevant imaging modalities to confirm the diagnosis based on signs and symptoms that indicate the presence of fracture in the facial bone. Though there are conventional imaging techniques for assessing the fracture but each has its own drawbacks which make it difficult to interpret. Conventional radiography requires special patient positioning and repeated exposures which may be challenging in a trauma room. CT on the other hand is invasive, not easily accessible and high cost which makes it usage option limited. Ultrasound is a high frequency sound wave that is transmitted in to the human body by a transducer and the echoes from tissue surface are detected and displayed on a screen. Initially USG Was limited only to soft tissues.

The high number of negative conventional radiography results is likely due to inappropriate indication for bone X-ray as well as due to the low sensitivity of this modality for certain types of fractures. It leads to unwanted exposure of the patients to harmful ionizing radiations, missed diagnosis and in appropriate treatment as well financial burden. This indicates the need for alternative methods for accurate detection of fractures, without risk of radiation exposure. Ultrasound may fill this role. Ultrasound shows promise as a diagnostic tool in detection of fractures. The development of handheld ultrasound systems may therefore enable a means of more quickly identifying clinically significant fractures, through more rapid image acquisition and simultaneous interpretation at the bed side. Because of their small size these are useful in locations where traditional radiography and experienced physicians are not available [34].

Conclusion

Ultrasonography is a very rapid, cost-effective, and radiation free imaging technique for detection of superficially situated bone fractures. USG can replace conventional radiography in cases of isolated uncomplicated fractures. In cases of doubtful fracture, combination of USG and conventional plain films may be considered to avoid unnecessary exposures from higher imaging like CT scan. It can be considered as the imaging of choice when CT or conventional radiography are not advised as in pregnant women.

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