Review Article

ULTRASONOGRAPHY: MAXILLOFACIAL APPLICATIONS

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Abstract

Ultrasonography (US) is one among the more commonly used imaging modalities for dignosing maxillafacial diseases and disorders. It's an inexpansive, easy to use and non-invasive technique when we compare it with other maxillofacial imaging modalities like computed tomography, Magnetic resonance imaging, Positron emitting tomography etc. Use of US in maxillofacial region imaging has been explored much in recent years and found to be important in dignosing Solid and cystic swellings of head and neck region, space infections, intraosseous lesion of jaw etc. Development of high-resolution US and US-elastography has stretched its uses in diagnosis of TMJ disorders, carcinoma of tongue, cervical lymph node metastasis etc. Other than these US have also been of use for Guided fine needle aspiration. Though in present scenario US is being used to diagnose multiple numbers of maxillofacial diseases but it is yet to have its share in maxillofacial imaging as a routine diagnostic aid.

Key Words: - Guided-FNAB, Maxillofacial Applications, Maxillofacial imaging, Ultrasound, Ultrasonography.

Introduction

Imaging has an important role in diagnosis of maxillofacial diseases. Various modalities used for maxillofacial imaging is conventional radiography, computed tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasonography (US) etc. More advanced techniques include Nuclear Medicine, Positron Emitting Tomography (PET). Of these modalities, US is an easy to use technique for detection of non-invasive & superficial soft tissue related diseases in Oral and maxillofacial region.[1]

Ultrasonography is a technique based on sound waves that acquires images in real time and without the use of ionizing radiation. The phenomenon perceived as sound is the result of periodic changes in the pressure of air against the eardrum. The periodicity of these changes lies anywhere between 1500 and 20,000Hz.[2] By definition, ultrasound has a periodicity greater than the audible range. Diagnostic ultrasonography (sonography), the clinical application of ultrasound, uses vibratory frequencies in the range of 1 to 20MHz.

The ultrasound signal transmitted into a patient is attenuated by a combination of absorption, reflection, refraction and diffusion. Higher the frequency of the sound waves, higher the image resolution but the less the penetration of the sound through soft tissues. Fraction of the beam that is reflected to the transducer depends on the acoustic impedance of the tissues, which is a product of its density (and thus the velocity of sound through it) and the beam's angle of incidence. Because of its acoustic impedance, a tissue has a characteristic internal echo pattern.

Tissues that do not produce signals, such as fluid-filled cysts, are said to be anechoic and appear black. Tissues that produce a weak signal are hypoechoic, whereas tissues that produce intense signals such as ligament, skin, or needles or catheters are hyperechoic and appear bright.[2]

Diagnostic US has various modes namely A-mode, B-mode, M-mode and D-mode. A-mode or amplitude[3] mode is not used frequently. It is of historical use and rarely used only in ophthalmology now a days. B-mode or brightness mode is important in diagnostic US. It produces different scale of grey on the basis of different echogenecity of reflected waves. M-mode or motion mode is extremely valuable for accurate valuation of rapid movements.[3] It has excellent temporal resolution. D-mode or Doppler mode is based on the Doppler Effect i.e. change in frequency (Doppler shift) caused by reciprocal movement of sound generator and observer.[4]

US, as an imaging modality, has been extremely explored in recent years due to several advantages it provides. It is non-invasive, inexpensive, painless, well accepted by patient and unlike X-rays it does not expose patient to harmful ionizing radiations.[1]

Uses in Maxillofacial Region

Ultrasonography is used in the head and neck region for evaluating for neoplasm in the thyroid, parathyroid, or salivary glands or ducts, Sjogren's syndrome, and the vessels of the neck, including the carotid for atherosclerotic plaques.

Ultrasonography is an alternative diagnostic tool that is widely available, relatively inexpensive, non-invasive and easily reproducible. Recently, it has been used in maxillofacial imaging and has obtained wide acceptance as a diagnostic aid in evaluation of head and neck lesions. It is recognized as one of the most risk free methods of evaluating any disease of human body, but has still not found its place as a routine diagnostic aid.

The value of ultrasonography is well recognized in inflammatory soft tissue conditions of the head and neck region. Ultrasonography is an effective diagnostic tool to confirm abscess formation in the superficial facial spaces and is highly predictable in detecting the stage of infection.[5]

Many obstructive, inflammatory and tumourous lesions can be detected and differentiated by ultrasound. It can differentiate between cystic swellings, abscesses, benign and malignant lesions. Many researchers have also advised use of US in diagnosis of intra-osseous lesions.

Ultrasonography can provide accurate information on the content of intraosseous lesions of the jaws before any surgical procedure. Use of US along with CT and/or MRI is

advised in assessing solid and cystic component of intra-osseous lesions of the jaw. High-resolution ultrasound is also a reliable tool in evaluating tumor thickness and clearance of surgical margins of tumor.[6]

Main Indications for ultrasound in the Head & Neck Region

- Evaluation of swellings of the neck, particularly those involving the thyroid, cervical lymph nodes or the major salivary glands — ultrasound is now regarded as the investigation of choice for detecting solid and cystic soft tissue masses
- Detection of salivary gland and duct calculi
- Determination of the relationship of vascular structures and vascularity of masses with the addition of colour flow Doppler imaging
- Assessment of TMJ disorders
- Assessment of the Intraosseous lesions of the jaw
- Assessment of cervical lymph node metastasis
- Ultrasound-guided fine-needle aspiration (FNA) biopsy.
- Assessment of Maxillofacial space infections
- Assessment of Soft tissue lesions such as carcinoma of tongue

Recent advances include three-dimensional imaging to allow multiplanar reformatting, surface rendering (for example of a fetal face), and color Doppler sonography for evaluation of blood flow.

Clinical applications of US in dentistry are mainly in diagnosis of disorders of major salivary glands, diseases of facial musculature and superficial soft tissues. As high resolution US was developed it also became useful in imaging early tongue carcinomas, periapical lesions & temporo-mandibular disorders (TMD). A more recent addition to use of US in dentistry is diagnosis of cervical lymph node metastasis due to development of US-elastography.[6]

US can also be useful in guiding the exact site of biopsy of intra-osseous lesions of law, if necessary.[7]

US-Guided Fine Needle Aspiration

Normal and abnormal structures of oral and maxillofacial region can be visualized by using B-mode of US imaging. US can easily detect salivary gland disorder and is a useful tool for FNAB. For Guided-FNAB various imaging modalities such as US, CT, MRI may be used to complete the procedure without disturbing important blood vessels and other structures. Of these modalities US is least invasive, relatively inexpensive and easy to use technique. In addition, accuracy of US-guided FNAB has been relatively high.[6]

Alkhafaji et al found that needle aspiration of parotid masses has a sensitivity of 82%, a specificity of 86% and an overall diagnostic accuracy of 84%. Study have also supported US-guided FNAB by reporting that pathological diagnosis of lesions obtained by US-guided FNAB agreed with final histo-pathological diagnosis after surgical resection in about 90% of the cases.

Cervical Lymph Node (LN) Metastasis

The information regarding LN staging and localization of metastatic lymph node in patient with head and neck cancer is important and mandatory for the choice of therapy. Therefore imaging has an important role in staging the LN in patient with Oral Cancer. Other techniques used for the same purpose are CT, MRI, PET scan etc. US have found to have sensitivity varying from 63% to 97% and specificity varying from 69% to 100% in detection of cervical LN metastasis. Furthermore, US has been found to be only imaging technique that can be used for frequent routine follow-up.

In US examination of LN, a linear transducer with high frequency (10 MHz or more), is used. For delineation of shape and internal structure B-mode is used. Generally, US depicts LN as an oval to round structure with low echoegenecity. An echoegenic hilum containing vessels and fat is seen in a central area of high echogenicity.

For investigation of vessel structure and vasculature, a Doppler study, D-mode is used. Doppler US criteria (Avascular pattern, Scattered pattern, Peripheral vascularity) have been reported as important to differentiate between benign and metastatic LNs. In benign LN, in longitudinal section vessels in hilum are seen as linear structure which is dividing regularly.[6] The characteristics of metastatic LN delineated by US are an increased size of LN, a more round shape and cystic degeneration, keratinisation and tumor necrosis giving rise to a heterogenesity. Rounder shape is considered more suspicious of metastasis than oval and flat shape. Cystic degeneration is interpreted as a focal hypoechoic/anechoic area while tumor keratinisation as focal hyperechoic area, not in continuity with hilum.

US-elastography, a newly developed technique evaluates tissue elasticity by measuring the degree of tissue deformation in response to the application of an external force. This measurement of elasticity is used to differentiate between metastatic and reactive LN enlargement, as a hypothesis suggests that solid tumor cells differ in their consistency from adjacent normal cells.[6]

Carcinoma of Tongue

Carcinoma of tongue is relatively common, with 3% of all malignancies arising within the oral cavity. It is important to assess extent of carcinoma of tongue in order to predict the subsequent LN metastasis. Intraoral US is thought to be more easy and precise in the evaluation of tumor depth rather than more commonly used imaging modalities such as CT and MRI.

Tumor thickness on US can be considered as an objective parameter for depth of invasion within connective tissue which is a reliable parameter for predicting regional LN involvement. A study have shown that LN metastasis were not observed in patients with tumor thickness 5 mm or less on US findings whereas 64% of patients with tumor thickness 6mm or more were found to have subsequent metastasis.[6] Studies have also concluded that sonographic features of tongue carcinoma, demonstrated by intraoral US

are useful to estimate the depth of tumor invasion of superficial carcinoma of tongue because proximity of tumor to blood vessels and lymphatics, which enhances tumor's ability to metastasize, is determined by increasing depth of invasion. But it was also concluded that this technique of intraoral US provides incorrect result in assessing tumor thickness when US probe cannot contact the lesion appropriately such as when tumor is located at base of tongue.[8]

Space Infections

The ability to accurately locate pockets of pus in space infections of the head and neck is an important factor.

Clinical examination alone can only locate fairly large areas of fluctuation that are readily accessible. In the early stages of a head and neck infection, cellulitis is the principal clinical picture, and this is thought to be due to a predominance of aerobic organisms. Once the infection goes on to abscess and pus formation, anaerobic organisms appear to predominate, and this is of importance clinically from the standpoint of possible changes in antibiotic therapy as well as the need to surgically drain the abscess. As the authors state, there is little doubt that computed tomography (CT) scanning and magnetic resonance imaging (MRI) can greatly aid in the localization of pus deposits and, although these methods have their disadvantages.[5]

Both USG and MRI showed similar results in detection of superficial fascial space infections, including the buccal, canine, infraorbital, submandibular, submental, and submasseteric spaces. MRI demonstrated superiority in detecting extension of the infection into deeply located fascial spaces, which included the parapharyngeal, retropharyngeal, masticator, and sublingual spaces. USG didn't provide reliable data for detecting infections in the deeper fascial spaces, such as the deeper compartment of the parapharyngeal spaces.

USG with Doppler flow allowed for easy identification of a fluid-filled cavity, and at the same time it differentiated an abscess cavity from high and low-flow blood vessels. USG was helpful in localizing even small pockets of pus in the involved fascial spaces, which was used in guided needle aspiration and determining the exact location of surgical incision and drainage.

4 stages of infection have also been described according to ultrasonographic examination: [5]

Edematous changes: The echogenicities of the tissues were isoechoic, similar to the normal or uninfected side but with increase in the fluid contents.

Cellulitis: The echogenicities of the tissues were higher (hyperechoic) than normal because of massive inflammatory infiltration to the infected region.

Pre-abscess stage: The echogenicities of the tissues were mixed (hypoechoic and hyperechoic) at the end of cellulitis stage and the beginning of abscess formation stage.

Abscess stage: The echogenicities of the tissues were absent (anechoic) because of the abscess cavity, which can be solitary or multiple well defined foci of pus.

The main advantages of MRI over USG were its excellent tissue contrast, which permitted easily differentiation of lesions from the surrounding structures and depiction of all anatomic planes without having to move the patient.

The major disadvantage of MRI was the relatively prolonged time for image acquisition. As a result, the images may suffer from the effect of patient motion. The high static magnetic field also poses a danger to those individuals with cardiac pacemakers or neurostimulator units.

Intraosseous (IO) Lesions of Jaw

Radiology is the primary but not the only one imaging modality in diagnosis of intraosseous lesions of jaw. Intraosseous lesions of jaw are of wide variety including Cysts and tumors originating from various stages of tooth development, neoplastic and non-neoplastic reactive bony lesions etc. There are various imaging modalities such as Conventional Radiography, CT, MRI, PET scan, US recommended for diagnosis of intraosseous lesions of jaw. Use of US in addition to CT and/or MRI is of importance to evaluate solid and cystic component of jaw lesions.[7] Use of US in diagnosing soft tissue lesion is well recognized but it has limited use in diagnosing intraosseus lesions of bone due to amount of bone overlying the lesion. Well grown and expanding lesions of jaw have a very thin cortical bone making lesion more accessible to US waves that facilitates US study.

Lauria L *et al* has shown a correlation between US and histopathologic findings in 24 out of 26 cases of intraosseous lesions of jaw. These 24 lesions were all large and expansive lesions. Two cases in which diagnosis were wrong were very small and without expansion of vestibular cortex.[7] Another study showed that mixed (solid and cystic) lesions identification by US findings were in correlation with histopathological findings in 92.8% cases. Those mixed lesions were ameloblastomas and Calcifying Epethelial Odontogenic Tumor (CEOT). This study suggested that mixed lesions on US should be considered as neoplastic and should be biopsied for histopathological examination.

In keratocystic group US examination showed dense cystic content due to presence of keratin. Reasons for misinterpretation of cyst on US study can be thick remaining cortical bone, occurrence of infected cyst and solid areas within cystic lesions.

It was established that US cannot routinely used to establish definitive diagnosis of intraosseous lesions of jaw but it facilitate differential diagnosis between solid and cystic lesion. US is also recommended as excellent guide to biopsy in more representable area. US was also recommended as complimentary method for diagnosis of intraosseous lesions of jaw.

Lu L *et al* concluded that US can be used as an effective supplementary diagnostic method for mandibular

ameloblastomas. Color Doppler flow imaging (CDFI) can be used to predict tumor vascularity which can be a parameter to predict active tumor proliferation.[9]

TMJ Disorders

Imaging studies of the TMJ, are expected to provide the information of disk position, joint effusion and bone abnormalities for the evaluation of TMD.[6] Recent article[10] concluded that US is useful as an alternative imaging technique for monitoring TMD. The main disadvantage of US was inability of the ultrasound to penetrate bone, therefore it is difficult to visualize the articular disk due to its position i.e. between two hard tissues. According to a review article[10], diagnostic accuracy of US in detection of disk displacement ranged from 62% to 100%, sensitivity and specificity ranged from 31% to 100% and from 30% to 100%. Image interpretation was not standardized because the definition of the disk varied in different studies. In a study, the lateral capsule-condyle distance was proposed as a landmark of disk displacement. Manfredini D *et al* theorizes that a widened distance between the articular capsule and mandibular condyle in lateral portion of the TMJ might mainly result from the interposition of a displaced disk between them.[10] Most studies suggest to evaluate the antero-superior joint compartment in axial, coronal and oblique sagittal planes with the probe placed over the skin surface of the TMJ. The need to tilt the probe to achieve the best view and the lack of validated anatomical structure, which should help to improve the reproducibility of the examination, makes US an operator-dependent technique.

Use of US is well recognized to detect effusion in musculoskeletal areas by depicting the presence of intraarticular fluids in larger joints.[6] In TMJ, the presence of joint effusion may be detected by direct visualization of a hypoechoic area within the articular capsule or by an indirect measurement of the capsular distention, which was taken as the distance between lateral surface of the mandibular condyle and the articular capsule. According to the review article[10], diagnostic accuracy of US in assessing the presence of joint effusion compared with MRI ranged from 72% to 95%, sensitivity and specificity ranged from 71% to 85% and from 67% to 100%.

Many studies suggested that US assessment of bone pathologies is less accurate than that for soft tissues. In TMJ, US diagnosis of condylar erosion was commonly based on an interruption of the echogenity of the cortical surface. A report[10] accounts that diagnostic accuracy of US in assessing the presence of condylar abnormalities compared with MRI ranged from 56% to 94%, sensitivity and specificity ranged from 67% to 94% and from 26% to 100%.

Conclusion

Though US study is easy to perform, inexpensive, not harmful as CT and other imaging technique using ionizing radiations but still it has not made its place in routine imaging modalities of maxillofacial region. Its limited role in bony and intrabony diseases makes it less used and less appreciated imaging modality. But with continuing research and studies US may show tremendous result in maxillofacial imaging in near future.

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