INTRODUCTION

Osteoid osteomas are benign tumors of the bone typically seen in children and young adults. They cause inflammation, local effects on normal tissue from tumor expansion, and secondary effects and complications (e.g., scoliosis, osteoarthritis) ***(Hayes, 2015).***

The disease is self-limiting and pain may disappear after several years of conservative medical treatment, with an average time of pain resolution of 5–6 years. This treatment usually includes aspirin or other non-steroidal anti-inflammatory agents. However, long-term medical therapy may be unacceptable because of refractory pain and complications of chronic anti-inflammatory agents. In addition, osteoid osteoma may occur in articular or peri-articular areas of bone; in such cases, medical therapy may be inadequate and more aggressive interventions are necessary ***(Anthony et al., 2014).***

Several methods of treatment plan have been utilized as treatment options other than medical management. These options include open surgical resection with intra-lesional, marginal, or wide surgical margins, CT-guided burr ablation and, most recently, CT-guided radiofrequency (RF) ablation. There is general agreement that in open procedures complete removal of the nidus is needed for cure and resolution of symptoms. Fail to do so is usually associated with incomplete relief of symptoms, and an increased risk of local recurrence.

Since intra-operative localization of these small lesions can be very difficult, open surgical removal often necessitates considerable resection of bone, and consequently internal fixation and/or bone grafting may be required.

Although various localization techniques have been developed to ensure complete removal, the nidus may even be missed at surgery ***(Anthony et al., 2014).***

Radiofrequency ablation (RFA) is a minimally invasive procedure where cancerous or diseased cells are destroyed using heat produced by high-frequency radio waves ***(Hayes, 2015).***

Rosenthal et al. (1995) have reported the use of RF ablation for treatment of osteoid osteomas. ***Dupuy et al. (2008)*** together with European and American researches have reported that treatment with percutaneous image-guided radiofrequency ablation can result in significant palliation of painful bone tumors ***(Goetz et al., 2014)***.

Regardless of the method of treatment chosen, success is highly dependent on pre-procedural localization of the nidus. CT-guided procedures may reduce morbidity and complications when compared with traditional open surgical resection. ***(Lindner et al., 2011)***

AIM OF THE WORK

To determine the safety and efficacy of CT guided radiofrequency ablation (RFA) of the osteoid osteoma located at the upper extremity.

ANATOMY OF THE UPPER EXTREMITY

Understanding the anatomy of the arm and the human body as a whole assists in identifying the location of the lesion during patient encounters. In fact; knowledge of anatomy is of the utmost importance in medicine ***(Eovaldi et al. 2018).***

The upper extremity or arm is a functional unit of the upper body. It consists of three sections, the upper arm, forearm, and hand. It extends from the shoulder joint to the fingers and contains 30 bones. It also consists of many nerves, blood vessels and muscles. The nerves of the arm are supplied by one of the two major nerve plexus of the human body, the brachial plexus. ***(Eovaldi et al., 2018)***

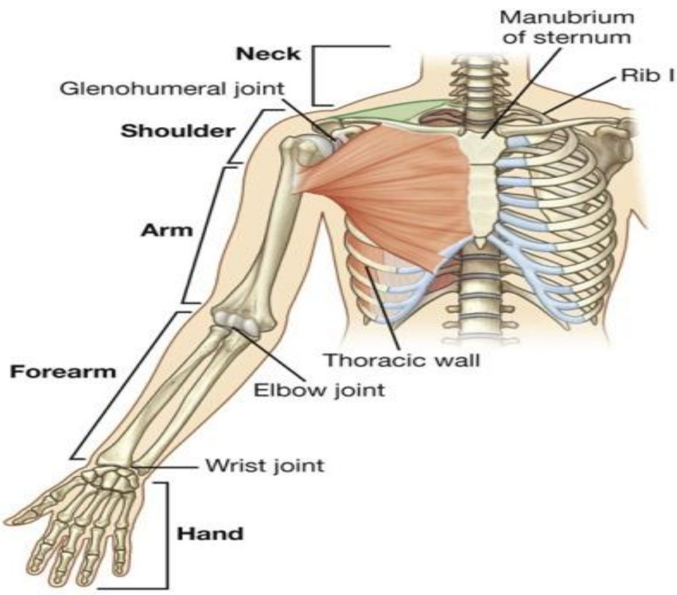

Figure (1): Upper limb structure

Bone & joints' structure

The upper extremity begins at the shoulder joint, where the humerus bone articulates with the scapular glenoid (ball-and-saucer joint). The elbow joint is where the humerus articulates with the ulna and the radius (hinge joint). While the wrist joint when the radius and the ulna articulates with the carpal bones (ellipsoidal or condyloid joint). In turn the carpal bones articulate with each other and the metacarpal bones (synovial joints) with the latter are seen articulating with the phalanges via basic hinge joints. ***(Eovaldi et al., 2018)***

Arterial supply:

The arterial supply of the upper extremity starts with the subclavian artery. The subclavian has a complicated course through the axilla, changing names twice before it gets to the upper arm. As it passes the one rib, it becomes the axillary artery. In the axilla, it passes deep to the pectoralis minor muscle toward the humerus. It gives off the anterior and posterior circumflex humeral arteries, before coursing posteriorly around the humeral head, giving rise to its largest branch, the subscapular artery. As it passes the teres minor, it becomes the brachial artery. At this point, it gives off the profundal brachii, which supplies the deep structures of the arm. It then travels along the humerus in the radial groove, along with the radial nerve. As it passes into the elbow, near the median nerve, it courses deep to the brachialis and splits into 2 branches, the radial (lateral branch) and ulnar (medial branch). ***(Varacallo et al. 2018).***

The radial artery courses down the arm and supplies the deep palmar arch, while the ulnar artery supplies the superficial palmar arch. Due to its many anastomosing arteries, there are not many clinical correlates to the arterial injury of the upper extremity.

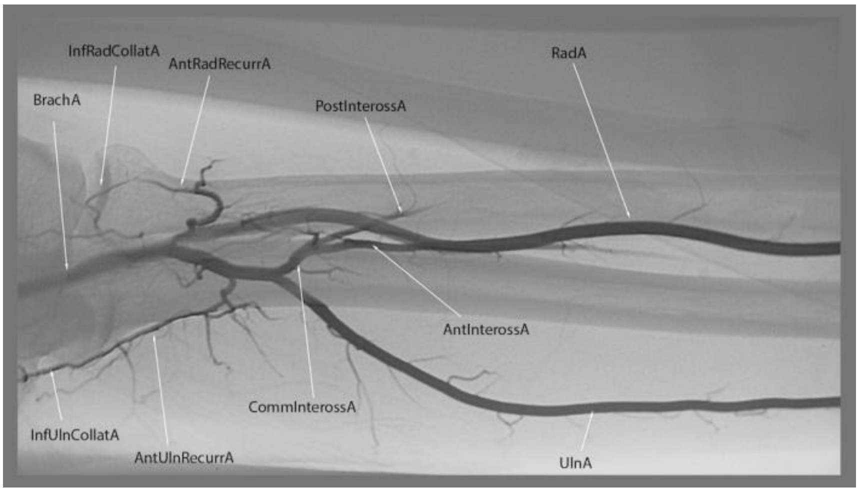

Figure (2): Arterial supply at the forearm

Venous drainage:

The venous drainage of the upper extremity is accomplished via two large veins. The first, the basilic vein, is formed by the radial and ulnar veins. It courses along the medial side of the arm where it meets with the brachial veins, forming the axillary vein. The cephalic vein arises around the hand and transverses the anterior-lateral area of the upper limb. It eventually courses between the pectoral and deltoid muscles, dumping into the axillary vein. The median cubital vein is a vein that is commonly used as a venipuncture site. It is a branch connecting the cephalic and basilic vein ***(Varacallo et al., 2018).***

<u>Nervous supply:</u>

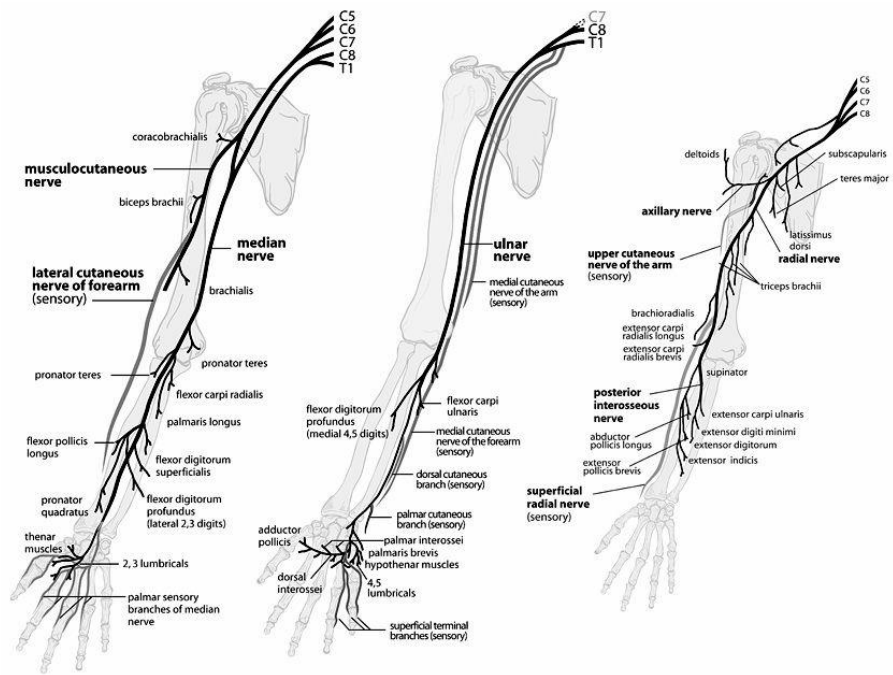

Figure (3): Nerve supply of the upper limb

The brachial plexus supplies all the nerves in the upper extremity. It is formed by the anterior rami of spinal nerve levels C5 through T1. The five major branches of the plexus are the musculocutaneous, axillary, median, radial, and ulnar nerve.

Nerve roots C5 to C7 supplies the musculocutaneous nerve. As it moves distally down the upper arm, it pierces the coracobrachialis from deep to superior. It courses between the biceps brachii and brachialis muscle, eventually turning into the lateral cutaneous nerve as it passes lateral to the biceps tendon. In total, it provides motor innervation to the three muscles of the anterior arm, the biceps brachii, brachialis, and coracobrachialis, as well as sensory innervation to the radial side of the forearm. Although lesions of this nerve are rare in clinical practice, they would theoretically result in weakened flexion and supination at the elbow joint, although it would not be absent due to the actions of the brachioradialis and supinator muscles. There would also be a sensory loss over the radial side of the forearm ***(Varacallo et al., 2018).***

Nerve roots of C5 and C6 supply the axillary nerve. As it courses through the axilla, it transverses between the axillary artery posteriorly and the subscapularis muscles anteriorly. It then exits posteriorly through the quadrangular space, accompanied by the posterior circumflex humeral artery. The axillary nerve supplies the deltoid muscle, as well as one of the four rotator cuff muscles, the teres minor. It also provides sensory innervation via the upper lateral cutaneous nerve of the arm. Injury results in failure of abduction of the arm as well as atrophy of the deltoid and loss of sensation in the upper lateral arm.

The median nerve is derived from nerve roots C6 through T1. It innervates the flexor muscles of the anterior forearm. A major exception to this rule is the flexor digitorum profundus, which is the only muscle in the anterior compartment innervated by the ulnar nerve. The median nerve courses from the axilla down the anterior arm, lateral to the brachial artery. Midway down the arm, it crosses the artery anteriorly, entering the anterior forearm through the cubital fossa. In the forearm, the nerve course between the flexor digitorum superficialis and profundus muscles, giving rise to two branches: the anterior interosseous nerve, which supplies the deep compartment of the anterior forearm, and the palmar cutaneous nerve, which innervates the skin over the radial surface of the palm. It then continues distally through the carpal tunnel where it splits into two more branches: the recurrent branch, which supplies the thenar muscles, and the palmar digital branch, which supplies sensory innervation to the radial 3.5 digits and the palmar surface as well as motor innervation to the two radial lumbricals. Median nerve injury may mimic carpal tunnel syndrome; results in tingling, pain, and numbness in the distribution of the median nerve distally to the wrist. This can be treated, conservatively in most cases, with splinting of the wrist. Corticosteroid injections can also manage it.

The radial nerve has supply from every root of the brachial plexus, C5 through TI. It arises from the axillary region and courses with the axillary artery, exiting posteriorly. It travels down the posterior surface of the humerus in the radial groove. It then wraps laterally around the arm where it meets and courses near the brachial artery. It then courses over the lateral epicondyle where it splits into the deep and superficial branch. The deep branch supplies motor innervation to most of the muscles in the posterior compartment of the forearm, which the superficial branch supplies sensory innervation to the posterior surface of the hand and fingers. In the course of the radial nerve down the arm, it also supplies cutaneous innervation via the lower lateral cutaneous nerve of the arm, the posterior cutaneous nerve of the arm, and the posterior cutaneous nerve of the forearm, besides the superficial branch. When the radial nerve is injured, it results in motor deficits to the triceps and extensor muscles of the forearm and wrist-drop.

The ulnar nerve contains fibers from spinal roots C8 and T1. It courses down the humerus and over the medial epicondyle. It then pierces the flexor carpi ulnaris and gives way to three branches in the forearm, the muscular branch and the palmar and dorsal cutaneous branches. As it courses down the forearm, it innervates the ulnar half of the flexor digitorum profundus muscle and the flexor carpi ulnaris. As it transverses the wrist, it travels superficial to the flexor retinaculum, into the hand, where it innervates the hypothenar muscles, the ulnar two lumbricals, and the interossei muscle. The cutaneous branches given off also supply the sensation to the ulnar 1/5 fingers. There are various presentations of ulnar nerve injury, depending on the location of the injury ***(Varacallo et al., 2018).***

Muscles of the upper limb

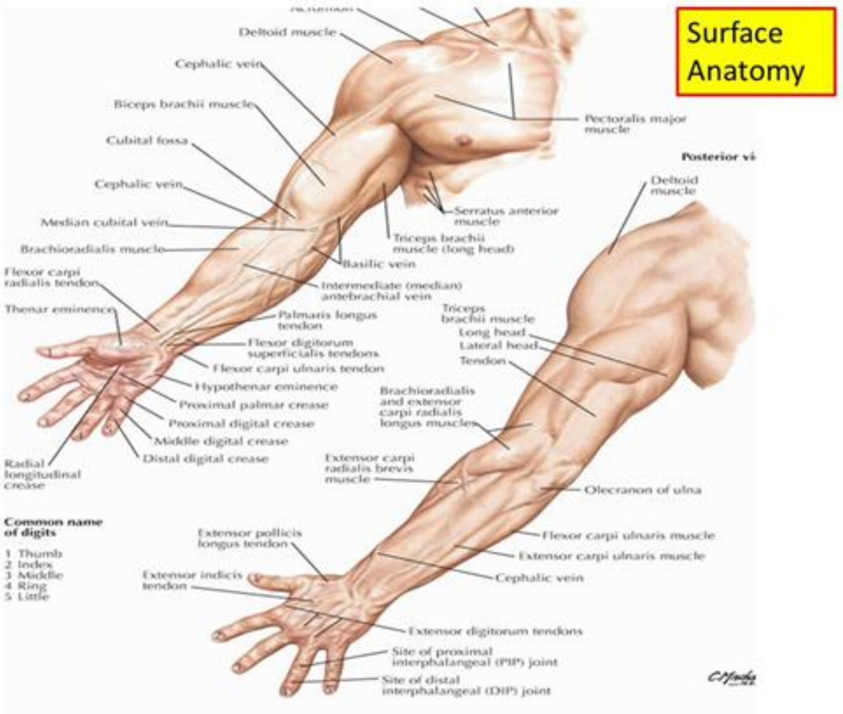

Figure (4): Surface anatomy of the upper limb

The musculature of the upper limb is quite vast. The upper arm contains three muscles in the anterior compartment. The long and short head of the biceps brachii are located superiorly while the coracobrachialis and brachialis are deep to the biceps. The posterior compartment contains only one muscle, the triceps brachii. The forearm consists of 20 muscles, separated into five compartments ***(Eovaldi et al., 2018)***

The anterior forearm consists of four muscles in the superficial group: flexor carpi radialis, flexor carpi ulnaris, palmaris longus, and pronator teres. The lone muscle in the intermediate/middle compartment is the flexor digitorum superficialis.

The deep layer of the anterior compartment contains three muscles: flexor digitorum profundus, flexor pollicus longus, and pronator quadratus. These muscles consist of mainly flexor and pronator muscles, and most of the superficial muscles arise from a common flexor tendon on the medial epicondyle of the humerus.

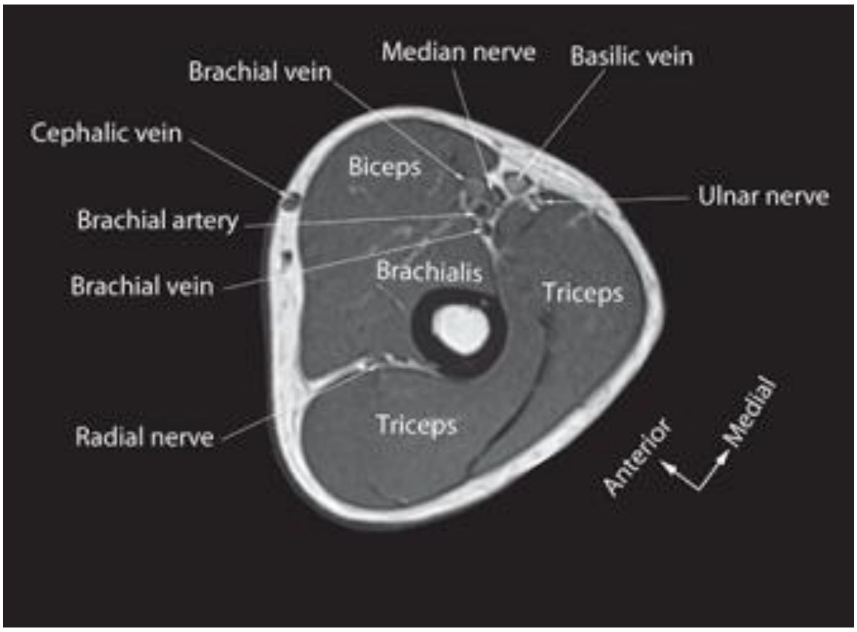

Figure (5): Axial CT cut at the distal third of the arm

The posterior forearm is separated into two compartments, superficial and deep, with seven and five muscles, respectively. The superficial compartment consists of anconeus, brachioradialis, extensor carpi radialis longus and brevis, extensor carpi ulnaris, extensor digitorum, and extensor digiti minimi. The deep compartment contains abductor pollicis longus, extensor indicis, extensor pollicis longus and brevis, and supinator. As with the anterior superficial compartment, the majority of the superficial muscles of the posterior compartment arise from a common extensor tendon; this time arising from the lateral epicondyle. The main actions of the muscles in the posterior forearm are extension and supination ***(Eovaldi et al., 2018).***

The muscles of the hand can be subdivided into three groups, which are muscles of the palm, thenar muscles, and hypothenar muscles. The thenar muscles are located at the thumb, and consist of abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis. The median nerve innervates all three of these muscles. The hypothenar muscles are located at the ulnar side of the hand, near the five digit, or pinky finger. They are the abductor digiti minimi, flexor digiti minimi brevis, and opponens digiti minimi. The ulnar nerve innervates them all. The third group of muscles consists of two single muscles and three groups of muscles. The single muscles are palmaris brevis and adductor pollicis. The first group is the dorsal interossei, which consists of four muscles attaching to the metacarpals, which are responsible for abduction of the fingers. The second group, the palmar interossei, are three (some anatomy texts report four) muscles located on the anterior surface of the metacarpals. They are responsible for adduction of the fingers. The ulnar nerve innervates both the palmar and dorsal interossei. There are also four lumbrical muscles in the hand. Each of these muscles originates from the tendon of the flexor digitorum profundus and is responsible for flexion of the finger at the metacarpal-phalangeal joint and extension of the interphalangeal joints. The radial two lumbricals are innervated by the median nerve, while the ulnar nerve innervates the two on the ulnar side. There are no lumbricals associated with the thumb ***(Eovaldi et al.,2018)***

PATHOLOGY OF OSTEOID OSTEOMA

Osteoid osteoma is a non-malignant skeletal tumor of unclear etiology; it is composed of osteoid and woven bone. The lesion is typically of diameter less than 15mm. Osteoid osteoma can occur at any bone, yet, in nearly 2/3 of the patients; the appendicular skeleton is involved. While the facial bones and the skull are exceptionally involved ***(Nawaz-Khan, 2015)***.

Osteoid osteoma is a common lesion, accounting for about twelve percent of benign bone tumors. They present clinically by local pain that is described as knife-like boring, that become worse at night, and typically alleviated by aspirin. ***(Afshin et al., 2017)***

Osteoid osteoma tend to occur more frequently in males (M: F ratio = 3:1). It is frequently seen at the age group between five to thirty five years with second decade peak incidence. The majority (65 to 80%) of them occur at the lower extremity (proximal femur and femoral neck) with less frequently seen at the upper extremity and the spines ***(Berquist, 2017)***