FACTORS INFLUENCING THE OUTCOME OF ACUTE LATERAL HUMERAL CONDYLAR FRACTURE IN CHILDREN AND ITS RELATED COMPLICATIONS

BY

DR WARITH MUHAMMAD BIN SYAFREIN EFFENDI

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DR WARITH MUHAMMAD BIN SYAFREIN EFFENDI

Department of Orthopedic,

School of Medical Sciences, Universiti Sains Malaysia

Health Campus, 16150 Kelantan, Malaysia.

Introduction : Lateral condylar of humerus fractures are among the commonest fracture in children. Open reduction and internal fixation (ORIF) is the preferred option as it prevents complications caused by inaccurate reduction, however the outcomes remain variable.

Objective : The purpose of this study is to determine factors influencing the overall functional outcome following lateral condylar fractures of humerus in children and to describe the complications that arise.

Methods: There were children until the age of 14 years old for the girls and 16 years old for the boys were involved in this study. All of them were treated for lateral condyle humeral fracture for at least 1 year. They were selected and contacted after reviewing their radiological and treatment records and were asked to come to HUSM for further evaluation. During evaluation, the functional ability of the involved elbow was assessed. A radiological assessment of affected limb was also performed through a proper antero-posterior radiograph. The functional outcome was assessed based on activity of daily living, range of motion and carrying angle of the affected elbow with the normal elbow and graded using Dhillon scoring system into excellent, good, fair and poor outcome. The amounts of residual displacement after treatment were documented. Data were statistically analysed using SPSS version 20.

Result: Twenty-seven male and six female patients were involved in this study. The age at time of fracture was within 2 to12 years old with the mean of 6.3 years old. Thirteen patients had medial residual displacement between 3mm to 5mm and 20 patients had 2mm or less medial residual displacement. A large numbers of patients attained good functional outcome scoring (42.4%) followed by excellent score (27.3%). This is followed by fair score (24.2%). Only a small numbers of patient had poor scoring system (6.1%). Both residual medial intraarticular displacement and residual lateral cortex displacement post fracture treatment (both $\leq$2mm and 3mm-5mm) did not significantly affect the early functional outcome (Dhillon score) .(Multiple logistic regression, β = -0.19; 95% CI=-1.09, 0.40; *p*-value= 0.034) (Multiple logistic regression, β= -0.12,CI= -

0.67,0.63, p-value 0.94). Age of fracture, type of treatment and method of surgical fixation are not statistically correlated with Dhillon score. In term of complications, only one patient (3.0%) had persistent pain, 14 (42.4%) patients clinically had lateral condyle prominence, 4 (12%),with cubitus varus deformity, 2 (6.1%) had fishtail deformity, 19 (57.6%) had osteophytes and there was no incidence of AVN and non union. All of these complications are not statistically associated with Dhillon scoring.

Conclusion: This study shows that children who sustained lateral condyle of humerus fracture have excellent-good outcome (69.7%) after at least 1 year of follow up. The amount of medial and lateral residual displacement of lateral humeral condyle fracture did not affect the early functional outcome as long as it is within 5mm. The most common complications encountered are osteophytes (57.6%) and lateral condyle overgrowth (42.4%).

ABSTRAK

Latar- belakang: Kepatahan sisi luar tulang siku (humerus)adalah antara patah yang lazim pada kanak-kanak . Pembedahan (Open reduction Internal Fixation)untuk memperbetulkan tulang yang patah dan teranjak adalah pilihan yang lebih popular kerana ia dapat mengelakkan komplikasi yang disebabkan oleh teknik pembedahan yang tidak tepat, namun hasil akhir dari rawatan ini adalah tidak sama dan sering berubah-ubah.

Objektif : Tujuan kajian ini adalah untuk menilai hasil akhir fungsi bagi patah sisi luar tulang siku (humerus)di kalangan kanak-kanak yang menjalani operasi atau rawatan konservatif dan juga komplikasi-komplikasi yang biasa terjadi. Ia juga bertujuan untuk mengkaji sama ada tahap anjakan serpihan tulang patah (displacement) dan kualiti redusi pembedahan dapat mempengaruhi hasil akhir fungsi atau tidak.

Metodologi: Tiga puluh tiga kanak-kanak yang belum mencapai kematangan usia iaitu 14 tahun untuk kanak-kanak perempuan dan 16 tahun untuk kanak-kanak lelaki , terlibat dalam kajian ini. Kesemua mereka telah dirawat selepas mengalami patah sisi luar di siku (humerus) untuk sekurang-kurangnya 1 tahun. Mereka telah dipilih dan dihubungi selepas kajian semula rekod radiologi dijalankan selepas rawatan dan telah diminta untuk datang ke HUSM untuk penilaian lanjut. Pada masa yang sama , keupayaan hasil akhir fungsi tangan yang terlibat telah dinilai dan dimarkahkan . Satu penilaian radiologi dari

siku yang terlibat juga dilakukan dengan kaedah radiografi . Hasil akhir fungsi dinilai berdasarkan aktiviti seharian, sudut dan darjah pergerakan sendi yang terlibat .Pemarkahan ini dinilai menggunakan kaedah Dhillon Scoring ke dalam kumpulan yang sangat baik, baik, sederhana dan teruk. Anjakan serpihan yang patah dan kualiti redusi pembedahan didokumentasikan . Data dianalisis secara statistik menggunakan SPSS versi 20.

Keputusan: Dua puluh tujuh kanak-kanak lelaki dan 6 perempuan terlibat dalam kajian ini. Usia pada masa kepatahan adalah puratanya berusia 6.3 tahun merangkumi usia dari 2 tahun sampai 12 tahun. Tiga belas pesakit mengalami anjakan kepatahan antara 3mm-5mm manakala 20 lagi pesakit mengalami anjakan kurang dari 2mm. 14 pesakit mencapai skor yang bagus (42.4 %) diikuti dengan 9 pesakit skor sangat baik (27.3 %). Ini diikuti dengan 8 pesakit skor sederhana (24.2 %). Hanya sejumlah kecil pesakit iaitu 2 orang dikategorikan sebagai teruk (2 (6.1 %). Kajian kami menunjukkan bahawa anjakan serpihan tulang sebaik selepas rawatan , secara statistiknya tidak mempengaruhi hasil awal fungsi skor Dhillon bagi anjakan tulang sisi dalam (residual medial intraarticular displacement) (Multiple regresi logistik , β= -0.12,CI= -0.67,0.63, p-value 0.94) dan anjakan tulang sisi luar (residual lateral cortex displacement) (Multiple regresi logistik, β= -0.12,CI= -0.67,0.63, p-value 0.94). Juga tidak ada perbezaan yang signifikan di antara jenis rawatan dan skor Dhillon (CI: -2.23,0.86 , p-value _0.37). Dalam konteks komplikasi pula , hanya satu pesakit (3.0 %) mempunyai kesakitan yang berkekalan, 14 (42.4 %) pesakit secara klinikal mempunyai tonjolan tulang , empat pesakit dengan kebengkokan tulang (Cubitus varus) (12%) , dua (6.1 %) pesakit mempunyai kecacatan fishtail , unjuran tulang (osteophytes) sekitar sembilan belas (57.6 %) dan tidak ada kejadian AVN dan tulang tidak bercantum (non union). Semua komplikasi ini tidak ada kaitan statistik dengan pemarkahan Dhillon .

Kesimpulan: Kajian ini telah menunjukkan bahawa kebanyakan kanak-kanak yang mengalami kepatahan tulang sisi luar di siku (humerus) akan mempunyai hasil yang Cemerlang-Bagus (69.7 %) selepas sekurang-kurangnya 1 tahun rawatan susulan. Jumlah anjakan kepatahan samada dari sisi dalam atau sisi luar tulang tidak menunjukkan prebezaan dari segi fungsi awal Dhillon selagi anjakan masih dalam lingkungan 5mm. Komplikasi yang paling biasa dihadapi adalah unjuran tulang (osteophtyes (57.6 %) dan tonjolan tulang (lateral prominence) (42.4 %). Tiada sebarang kejadian AVN dan tulang tidak bercantum ditemukan. Walau bagaimanapun, kami mendapati bahawa tahap anjakan kepatahan selepas pembedahan dan jenis rawatan tidak mempengaruhi skor Dhillon.

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II. ACKNOWLEDGEMENT

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V ABSTRACT

Back ground: Lateral condylar of humerus fractures are among the commonest fracture in children. Open reduction and internal fixation (ORIF) is the preferred option as it prevents complications caused by inaccurate reduction, however the outcomes remain variable. The purpose of this study is to determine factors influencing the overall functional outcome following lateral condylar fractures of humerus in children and to describe the complications that arise.

Methods: There were children until the age of 14 years old for the girls and 16 years old for the boys were involved in this study. All of them were treated for lateral condyle humeral fracture for at least 1 year. They were selected and contacted after reviewing their radiological and treatment records and were asked to come to HUSM for further evaluation. During evaluation, the functional ability of the involved elbow was assessed. A radiological assessment of affected limb was also performed through a proper antero-posterior radiograph. The functional outcome was assessed based on activity of daily living, range of motion and carrying angle of the affected elbow with the normal elbow and graded using Dhillon scoring system into excellent, good, fair and poor outcome. The amounts of residual displacement after treatment were documented. Data were statistically analysed using SPSS version 20.

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Conclusion: This study shows that children who sustained lateral condyle of humerus fracture have excellent-good outcome (69.7%) after at least 1 year of follow up. The amount of medial and lateral residual displacement of lateral humeral condyle fracture did not affect the early functional outcome as long as it is within 5mm. The most common complications encountered are osteophytes (57.6%) and lateral condyle overgrowth (42.4%).

VI ABBREVIATION

AVN : Avascular necrosis

LCH : Lateral condyle humerus

LCOG : Lateral condyle overgrowth

RMD : Residual medial displacement

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1. INTRODUCTION

Lateral condylar fracture of humerus is the second most common fracture of the elbow in children. Majority of them are injuries of growth plate with a Salter-Harris IV fracture pattern, and they are common in children between 2-14 years of age.(Wilkins.,1996) Open reduction and internal fixation (ORIF) is the preferred option for most lateral condylar fractures because it prevents complications caused by inaccurate reduction, although long arm cast immobilization, closed reduction, and internal fixation (CRIF) can provide effective treatment for the undisplaced or minimally displaced fractures. The treatment goal in lateral condylar fracture is union without residual deformity. (Landin et al.,1986)

However, complications such as nonunion, avascular necrosis (AVN), premature epiphyseal fusion, lateral condylar overgrowth, stiffness, cubitus varus or cubitus valgus, and fishtail deformity have been reported after the operative treatment of lateral condylar fractures, despite initial anatomic reduction and fixation.(Song et al.,2008)

One of method to assess the success of the treatment is by measuring the functional outcome during follow up (Dhillon et al.,1988). Dhillon scoring system has been widely used to assess the functional outcome after lateral condyle fracture. There are multiple factors that could influence the functional outcome. Kyong et al (2010) made a study of an association between Jakob type of classifications and functional outcome of lateral humeral condyle fracture in children and showed no differences in functional results between fracture types. Wattenbarger et al (2002) study on lateral humeral condyle in children, and measured the fracture displacement based on lateral metaphyseal site of the fragments which is from non articulating surface of the elbow joint rather than from medial intraarticular metaphyseal fragments**.** There was lack of literature studying the associations between functional outcome and residual medial intraarticular displacement which is more crucial to reflect articular incongruency. Weiss et al (2009) also concluded from his study that fracture displacement and articular incongruency predict complications.

Therefore, the current study is designed to determine factors influencing the functional outcome of acute lateral condyle fracture of humerus particularly the amount of residual medial displacement at minimum 1 year follow up. Apart from that, this study also highlights the related complications encountered during follow up.

2 LITERATURE REVIEW

2.1 BONE

Bone is a specialized mineralized connective tissue. It is dynamic , well structured and one of the hardest substances in the body and constantly changes shape in relation to the stresses placed on it. It is the primary structural framework for support and protection of all organs in the body. (Sinnathamby.,2006) Bone also gives the necessary rigidity to function as attachment and lever for muscles and supports the body against gravity. Bone is a reservoir for several minerals in the body and stores about ninety percent of body's calcium. (Brinker, Miller.,1999)

All of the bones have two basic structural components which are compact and cancellous bone. Compact or cortical bone is the solid, dense bone that is presence in the walls of bone shafts and on external bone surfaces. Cancellous or trabecular bone is more porous, lightweight and has honeycomb structure. It consists of delicate bars and sheet of bone, with thin bony spicules (trabeculae) branch and intersects to form a sponge like network. This bone is found where tendons are attached, in vertebra bodies, in the ends of long bones and within flat bones. (Kaplan et al.,1996)

The molecular and cellular compositions of compact and cancellous bone tissue are identical and only difference in porosity that separates these gross anatomical bones types. Immature bone or woven bone is the first kind of bone to develop in prenatal life. Existence of this immature bone usually temporary as it is replaced with mature bone as growth continues which largely absent from normal bone after age of four years. Immature bone is usually formed rapidly and characterized the embryonic skeleton, sites of fracture repair and variety of bone tumours. Mature or lamellar bone composed of parallel or concentric lamellae, 3 to 7 micrometer thick. Osteocytes within their lacunae are dispersed at regular interval between or within lamellae. (Brinker, Miller.,1999)

Canaliculi, connect neighboring lacunae with each other which form a network or channels that facilitate the flow of nutrients, hormones and waste products of osteocytes, permitting these cells to communicate with each other. (Sinnathamby.2006) The bulk of compact bone is composed of an abundance of larger longitudinal canals system (approximately 50 micrometer in diameter), each constitute of cylinders of lamellae, concentrically arranged around a vascular space known as the Haversian canals. (Miller.,2008)

The canals and the surrounding lamellae are called a Haversian system or an osteon and connected to each other by Volkmann's canal. This second systems of canals, penetrates the bone more or less perpendicular to its surface. These canals establish connections with the inner and outer surfaces of the bone. (Miller.,2008)

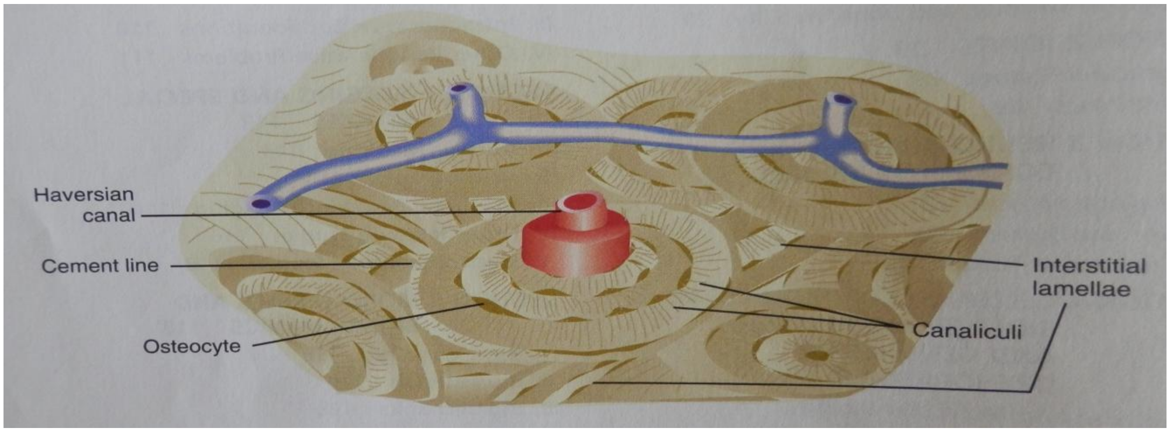

Fig. 1 Illustration of cortical bone (adapted from Miller, M. D., Review of Orthopedics, 6th Edition, Page 2)

2.1.1 CELLULAR BIOLOGY

Bone is an essential and complex biological tissue. It consists of important cells for its formation, repair, maintenance and mineral homeostasis. The predominant bone cells are osteoblasts, osteocytes and osteoclasts. (Miller.,2008)

2.1.1 (a) OSTEOBLASTS

Derived from undifferentiated mesenchymal stems cells, the osteoblasts responsible for the formation and organization of the cellular matrix of bone and its subsequent mineralization. These cells are also responsible for the synthesis of collagen and other bone proteins. Osteoblasts have more Golgi apparatus, endoplasmic retinaculum and mitochondria compared to other cells, in view of its function. (Miller.,2008)

Osteoblasts have parathyroid hormone (PTH) receptors on their cell membranes and these allow them to respond to the PTH and produce alkaline phosphatase, type 1 collagen, osteocalcin and bone sialoprotein. When PTHs bind to these receptors, it stimulates osteoblasts to release a secondary messenger to stimulate osteoclastic resorption of bone and elevate the serum calcium in the body. Osteoblasts also have receptor for 1,25-dihydroxyvitamin D that stimulates matrix alkaline phosphatase synthesis and production of bone specific proteins such as osteocalcin. Osteoblasts respond to glucocorticoids which then inhibit the synthesis of Deoxyribonucleic acid (DNA), osteoblastic proteins and collagen production. (Miller.,2008)

2.1.1 (b) OSTEOCYTES

Originating from osteoblasts, osteocytes are mature bone cells that are surrounded by calcified bony matrix which not as active in matrix production as osteoblasts and secrete substances for bone maintenance. They have long interconnecting cytoplasmic channel known as canaliculli that connect them to each other and to the surface of the bone. Ninety percent of the mature skeleton cells are constituted of osteocytes. Osteocytes have a high nucleus/ cytoplasmic ratio, which flattened nucleus and poor in organelles such as endoplasmic retinaculum and Golgi apparatus. Osteocytes are directly stimulated by calcitonin and inhibited by parathyroid hormones. (Brinker, Miller.,1999)

2.1.1 (c) OSTEOCLASTS

Osteoclasts are responsible for bone resorption. These irregular shaped giant cells are originated from multiple macrophages that consolidated and bound to the surfaces of the bone via cell attachment proteins called integrins. Morphologically, osteoclasts are motile multinucleated cells that have ruffled border that increases its surface area which important in bone resorption. Bone resorption occur in shallow depression called Howship's lacunae, region that been occupied by osteoclast. Osteoblasts stimulate the differentiation of macrophages to mature osteoclasts via expression of the receptor activator of NF-kβ ligand that binds to the receptors on osteoclasts and increase bone resorption. The bone resorption activity of osteoclasts is also regulated by parathyroid hormones and calcitonin which secreted by parathyroid and thyroid glands, respectively. (Brinker, Miller.,1999)

2.1.2 BONE MATRIX

Bone matrix has organic and inorganic components. The organic component of the bone matrix constitutes about 40 percent of dry weight of the bone. It composed of collagen, proteoglycans, non-collagenous matrix proteins, growth factors and cytokines. The inorganic component of the bone matrix constitutes about 60 percent of dry weight of the bone. It composed mainly calcium hydroxyapatite which provides compressive strength to the bone and calcium phosphate which makes up the remaining inorganic matrix. (Kaplan et al.,1996)

Main collagen in the bone is type 1 collagen, which makes up 90 percent of the organic component of the bone. It provides tensile strength to the bone. Proteoglycans are composed of subunits known as Glycosaminoglycan proteins complexes which responsible for compressive strength of the bone. Non-collagenous matrix proteins such as osteocalcin, osteonectin and osteopontin are responsible to promote bone formation and mineralization. (Miller.,2008)

Growth factors and cytokines as, for example Transforming Growth Factor-β, Insulin- like Growth Factor, Interleukin-1 and 6 and Bone Morphogenetic proteins aid in bone cell differentiation, activation, growth and turnover. (Kaplan et al.,1996)

2.1.3 BLOOD SUPPLY OF THE BONE

Bone as a complex biological tissue receives 5 to 10 percent of the cardiac output. Long bones obtain blood supply from nutrient artery, metaphyseal- epiphyseal arterial system and perosteal system. The nutrient arteries derive from the major arteries of systemic circulation. The nutrient arteries enter the diaphyseal cortex through the nutrient foramen and enter the medullary canal. In the medullary canal, arteries branches into arterioles in the endosteal cortex. This high pressure system supply at least the inner two third of the mature diaphyseal cortex through the Haversian system. (Sinnathamby.,2006)

The metaphyseal- epipphyseal arterial system originates from the periarticular vascular plexus. This arterial system mainly supplies the cancellous bone of the proximal and distal metaphyseal and anastomoses with the medullary system.The perosteal source which the low pressure system formed by the vessels in the periosteum, especially in the area of tendinous and fascial attachments. These vessels penetrate and supply the outer third of mature diaphyseal cortex. It absent especially in the joint where the surface of the area is covered with articular cartilage. (Miller.,2008)

In normal physiology of bone, the direction of the arterial flow in mature bone is from the endosteum to the periosteum or centrifugal pattern. In a complete displaced fracture bone, the nutrient artery will be disrupted and the periosteal system pressure will be dominant which the flow will be reverse as a result of changes in pressure gradient (centripetal pattern). The metaphyseal or periosteal system will play a major role in vascularisation of the callous formation in the bone healing process. In this case it is very important to preserve and respect as much as possible the periosteum and soft tissue surrounding while reducing and fixating the fracture in operative procedure. (Miller.,2008)

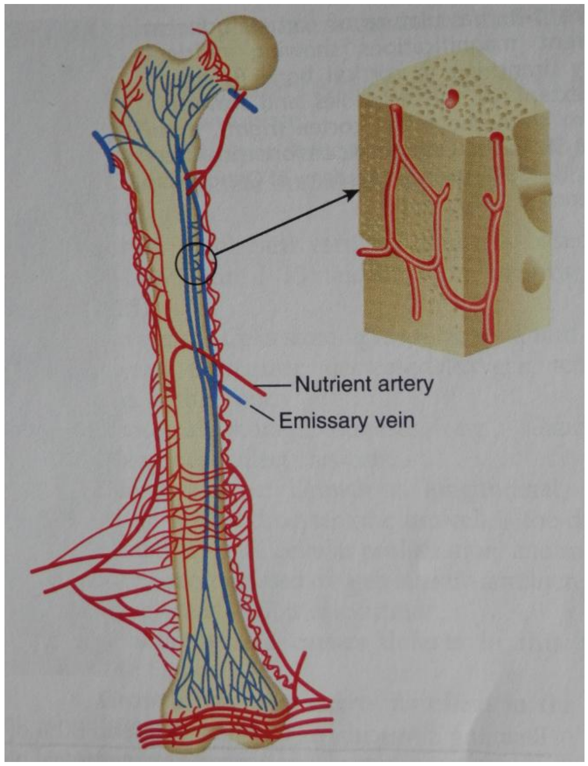

Fig. 2 Blood supply to bone (Adapted from Miller M. D., Review of Orthopedics, 6th Edition, Page 7)

2.1.4 FRACTURE HEALING

Fracture healing originally been describe based upon histological observations consisting of sequential stages with haematoma formation, inflammation, repair and remodeling. With advancement of cellular and molecular technologies, it is now discovered that there is a continuum process involving a diversity type of cells and their receptors, biochemical mediators, endocrines and growth factors which effects on fracture healing. (Miller.2008)

At initial phase, bleeding from the fracture site and surrounding tissues give rise to haematoma, which provides a source of hematopoietic cells that capable of secreting growth factors such as Bone Morphogenetic proteins, Transforming Growth Factor-β, Insulin- like Growth Factor, Platelet Derived Growth Factor and Fibroblast Growth Factor. Injured tissues and platelets also take part at this inflammatory phase by releasing the vasoactive mediators, inflammatory cytokines (Interleukin 1 and 6) and growth factors.Cytokines influence the cell migration, proliferation, differentiation and matrix synthesis. Macrophages, polymorphonuclear and mast cells then accumulate at fracture site to begin process of removing tissue debris and clots. Necrotic bone will be removed by osteoclasts. Growth factors recruit fibroblasts, mesenchymal cells and osteoprogenitor cells to fracture site. (Miller.2008)

At the reparative stage, vascularisation process taken place with the presence of local vasodilatation and neovascularisation. Undifferentiated mesenchymal cells that originate from inner layer of periosteum and cancellous bone migrate to fracture site and have the ability to form cells which in turn form cartilage (chondroblast), woven bone (osteoblast) or fibrous tissue (fibroblast). Fracture haematoma organize, fibroblasts and chondroblast appear between bone ends and cartilage is formed (type II collagen). Primary callus response occurs within 2 weeks. At bone ends, the bridging callus (soft callus) will be formed. It later being replace via the process of enchondral ossification by the woven bone (hard callus). Another type of callus, medullary callus will forms at the later stage to augment the bridging callus. Periosteal callus forms directly from the inner periosteal cell layer via the process of intramembranous ossification to form woven bone. Amount of callus formed is inversely proportional to amount of immobilization of fracture.Consolidation stage takes place from weeks to months. Woven bone transformed into lamellar bone with continuing osteoclastic and osteoblastic activity. (Solomon.,2010)

Remodeling stage begins during middle of the repair phase and continues up to 7 years. Remodeling allows the bone to return to its normal configuration and shape based on the mechanical stress that applied on it (Wolff's law). Fracture healing is complete when there is repopulation of medullary canal. (Solomon.,2010)

In the cortical bone, the remodeling occurs by invasion of osteoclast "cutting cone", followed by osteoblasts which lay down new lamellar bone (osteon). In the cancellous bone, the remodeling occurs on the surface of trabeculae which causes trabeculae to become thicker. (Solomon.,2010)

2.1.5 THE GROWTH PLATE

The growth plate, or physis, is the essential structure adding bone through endochondral ossification . The primary function of the physis is rapid, integrated longitudinal and latitudinal growth. Injuries to this component are unique to skeletally immature patients. The physis is divided into four zones from the center of the epiphysis to the metaphysis: germinal, proliferative, hypertrophic, and provisional calcification (Miller.,2008) (Fig. 3). The germinal and proliferative zones are the location of cellular proliferation, whereas the hypertrophic and provisional calcification zones are characterized by matrix production, cellular hypertrophy, apoptosis, and matrix calcification.(Miller.2008)

The physeal cartilage remains radiolucent, except for the final stages of physiologic epiphysiodesis, its exact location follows the metaphyseal contour. The region of the ossification center nearby to the physis forms a discrete subchondral bone plate that the essential epiphyseal blood vessels must penetrate to reach the physeal germinal zone. Damage to this osseous plate in a fracture may cause localized physeal ischemia. (Wilkins.,1996)

If a segment of the epiphyseal vasculature is compromised, whether for the short term or permanently, the zones of cellular growth associated with these particular vessels cannot go through suitable cell division. In contrast, unaffected regions of the physis continue longitudinal and latitudinal growth, leaving the affected region behind . The growth rates of the cells directly adjacent to the affected area are more mechanically compromised than areas farther away. The inconsistent growth results in an angular or longitudinal growth deformity, or both . The central region seems more sensitive to ischemia than the periphery, which may have a variable capacity to recover through continued latitudinal growth . (Wilkins.,1996)

CLOSE-UP VIEW OF DEVELOPING EPIPHYSIS AND EPIPHYSEAL GROWTH PLATE

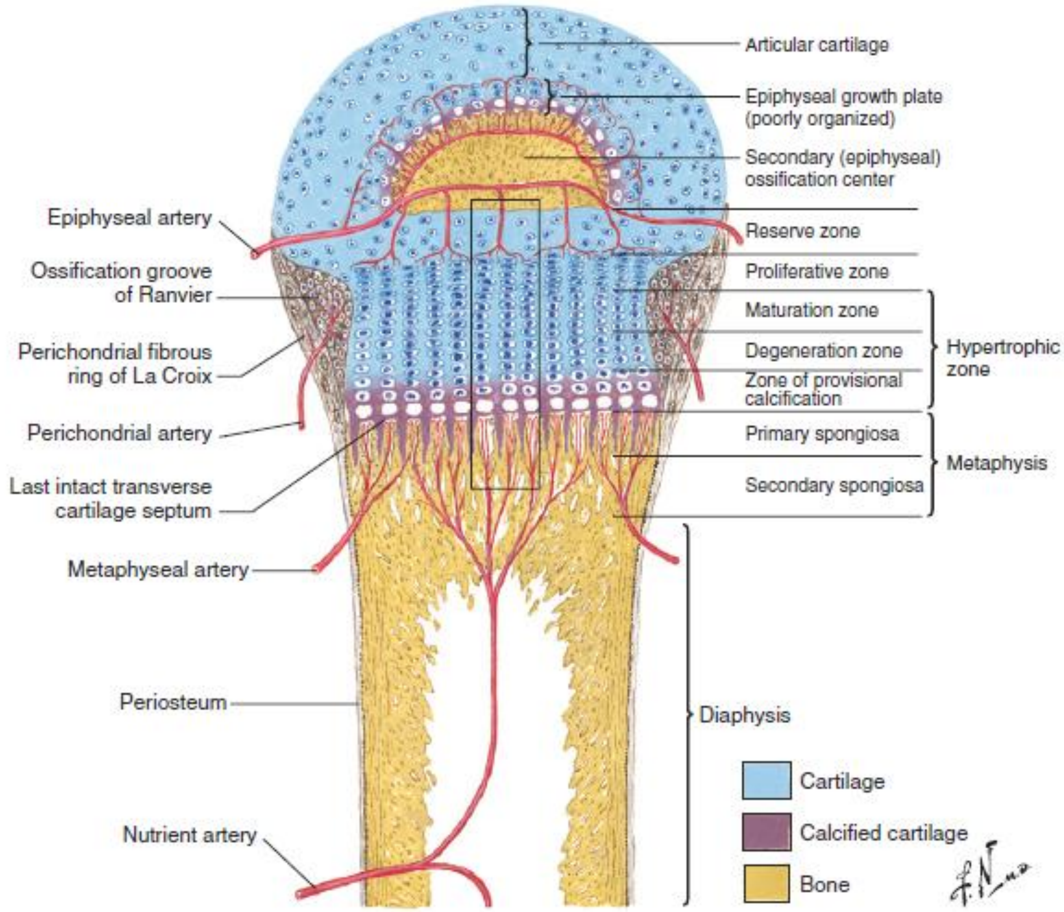

Fig. 3 Structure and blood supply of a typical growth plate. (From Netter FH: *CIBA collection of medical illustrations*, vol 8: *Musculoskeletal system*, part I: *Anatomy, physiology and developmental disorders*, Basel, Switzerland, 1987, CIBA, p 166.

2.2 ELBOW FRACTURE IN CHILDREN

Upper-extremity fractures account for 65% to 75% of all fractures in children. This is because children tend to protect themselves with their outstretched arms when they fall. Distal forearm is the most common area of the upper extremity injured; while 7% to 9% of fractures involve the elbow.In the elbow region, the distal humerus accounts for approximately 86% of fractures. Supracondylar fractures are the most frequent elbow injuries in children, reported to occur in 55% to 75% of patients with elbow fractures. This is followed by lateral condylar fractures, and thirdly the medial epicondylar fractures. Olecranon, radial head and neck, and medial epicondyle and T-condylar fractures are much less common. (Landin et al .,1986)

Fractures involving the lateral condylar region in the immature skeleton either cross the physis or follow it for a short distance into the trochlea. 16.9% of distal humeral fracture constitute fractures of the lateral condylar physis. The diagnosis of lateral condylar physeal injuries may be less obvious both clinically and on x-ray than that of supracondylar fractures, especially if the fracture is minimally displaced. Functional loss of range of motion in the elbow is much more frequent with lateral condylar physis fractures because the fracture line often extends into the articular surface (Wilkins.,1996). A poorly treated lateral condylar physeal injury, however, is likely to result in a significant loss of range of motion that is not as responsive to surgical correction. The poor outcome of a lateral condylar physeal fracture may not be obvious until months or even years later (Ippolito et al.,1996)

Fractures of the lateral condylar physis are only occasionally associated with injuries outside the elbow region. Within the elbow region, the associated injuries that can occur with this fracture include dislocation of the elbow (which may be a result of the injury to the lateral condylar physis rather than a separate injury), radial head fractures, and fractures of the olecranon, which are often greenstick fractures. Acute fractures involving only the anatomic capitellum are rare in the immature skeleton. (Landin et al .,1986)

Elbow injuries are much more frequent in children and adolescents rather than in adults with peak age for fractures of the distal humerus is between 5 and 10 years old (Wilikins.,1996). In older children between the ages of 10 and 13 , physeal injuries is common ; however, the peak age for injuries to the distal humeral physis is 4 to 5 years in girls and 5 to 8 years in boys. There is increased incidence with advanced age in most physeal injuries. It is believed to be due to weakening of the perichondrial ring as it matures . (Wilkins.,1996).

2.2.1 FUNCTIONAL ANATOMY OF ELBOW JOINT

The elbow joint acts as a lever arm when positioning the hand. It thus functions as a fulcrum for forearm lever. In patients using crutches, it functions as aweight bearing joint. During throwing, there is transfer of energy between the shoulder and elbow It is crucial for activities of daily living. The elbow is a complex joint composed of three individual joints which consists of radio-capitellar joint, ulnahumeral joint and proximal radio-ulna joint . It is made up from the distal flare of humerus includes the medial and lateral epicondyles the flare accounts for half of the elbow joint . The trochlea is spool shaped and is located medially whilst the capitellum is located laterally. (Morrey et al.,1983).

These joints are contained within a common articular cavity. Elbow is composed of a hinge joint (the humeroulnar articulation) and a pivot joint (the humeroradial articulation).The radiohumeral articulation is a pivot joint with the radial head is covered by cartilage for approximately 240 degrees. However the lateral 120 degrees contains no cartilage which is crucial for internal fixation of radial head fractures. (Sinnathamby.,2006)

The ulnohumeral articulation is a hinge joint with coronoid fossa on distal humerus receives the coronoid tip in deeper flexion. The coronoid tip has a buttress effect in the prevention of posterior dislocations. The sublime tubercle on the ulna is where the anterior bundle of the medial ulnar collateral ligament attaches distally. (Wilkins et al 1996).

The elbow joint range of motion for flexion and extension 0 to 150 degrees. Functional ROM: 30 to 130 degrees to allow daily activities such as feeding and perform perineal hygiene. Pronation and supination has range of motion at 80 degrees and 85 degrees respectively while functional motion is 50 degrees each. Axis of rotation for the elbow is centered through the trochlea and capitellum and passes through a point anteroinferior on the medial epicondyle. (Beals et al.1976)

The carrying angle of the elbow is the clinical measurement of varus–valgus angulation of the arm with the elbow fully extended and the forearm fully supinated. The intersection of a line along the midaxis of the upper part of the arm and a line along the midaxis of the forearm defines this angle. It has valgus angle at the elbow. For boys and men: 7 degrees; for girls and women, 13 degrees. Carrying angle decreases with flexion. (Beals et al.1976)

The entire articular surface of the distal end of the humerus is intra-articular; however, the medial and lateral epicondyles are both extra-articular. The elbow capsule attaches the ulna distal to the olecranon and coronoid process, so these structures are intra-articular. In addition, the entire radial head is located within the capsule, thus making it intra-articular. Two elbow fat pads are located between the capsule and the distal end of the humerus: one anterior and the other posterior. (Sinnathamby.2006)

The process of differentiation and maturation begins at the center of the long bones and progresses distally. The ossification process begins in the diaphyses of the humerus, radius, and ulna at the same time. By term, ossification of the humerus has extended distally to the condyles. In the ulna, it extends to more than half the distance between the coronoid process and the tip of the olecranon. The radius is ossified proximally to the level of the neck. The bicipital tuberosity remains largely unossified . (Chessare et al 1977).

Knowledge of the developmental anatomy of the distal humerus is important in diagnosing bony injuries around the elbow, especially in the pediatric population. The distal humerus has four ossification centers (Figure 4). The capitellum is the first center to appear, at age 6 to 12 months, followed by the medial epicondylar ossification center at 5 to 7 years of age, and then by the trochlea, between 7 and 10 years of age. The fourth center, the lateral epicondyle, appears at 12 to 14 years of age and serves as the origin of the lateral collateral ligament and supinatorextensor muscle group.(Gravis et al.1993)

Ossification of the distal humerus proceeds at a predictable rate. In general, the rate of ossification in girls exceeds that of boys (Chessare et al 1977). In some areas, such as the olecranon and lateral epicondyle, the difference between boys and girls in ossification age may be as great as 2 years . During the first 6 months, the distal humerus' ossification border is symmetric . On average, the ossification center of the lateral condyle appears just before 1 year of age but may be delayed as late as 18 to 24 months When the lateral condyle's ossific nucleus first appears, the distal humeral metaphyseal border becomes asymmetric before the end of the second year, where this border becomes well define and concave. (Bede et al .1975).

The lateral epicondyle of the humerus is a small, tuberculated eminence, curved a little forward, and giving attachment to the radial collateral ligament of the elbow-joint, and to a tendon common to the origin of the supinator and some of the extensor muscles. Specifically, these extensor muscles include the anconeus muscle, the supinator, extensor carpi radialis brevis, extensor digitorum, extensor digiti, and extensor carpi ulnaris. (Sinnathamby.2006)

The vascular anatomy around the elbow is structured in three general arcades: medial, lateral, and posterior (Figure 5). The medial arcade is formed by superior ulnar collateral, inferior ulna collateral, anterior and posterior ulnar recurrent arteries and supply medial condyle and medial aspect of trochlear. Lateral arcade is formed by radial recurrent, interosseous recurrent , and radial collateral arteries. These lateral arcade supplied the capitellum, lateral condyle and radial head. Posterior arcade was formed by the medial and lateral arcade, as well as medial collateral arteries, and provided blood supply to supracondylar region of humerus through olecranon. In general the posterior segmental vessels predominately supplied the lateral column while the medial column is supplied by both anteror and posterior segmental vessels. This suggest that minimal amount of posterolateral periosteum stripping should be avoided intraoperatively.(Yamaguchi et al.1997)

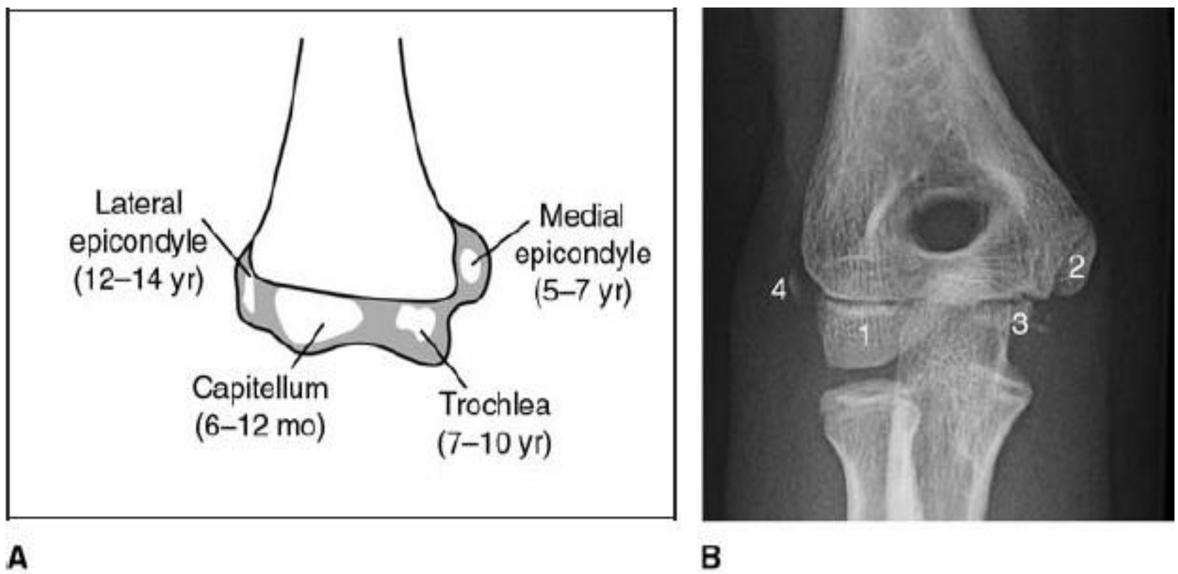

FIG. 4: A, Illustration of the average time of appearance of ossification centers at the distal humerus. **B,** AP radiograph of a right elbow demonstrating the different ossification centers. 1 = capitellum, 2 = medial epicondyle, 3 = trochlea,
4 = lateral epicondyle (From Wilkins KE: Fractures involving the epicondylar apophysis, in Rockwood CA Jr, Wilkins KE, King RE, *Fractures in Children*, ed 3. Philadelphia, PA, 1991, pp 509-828.)

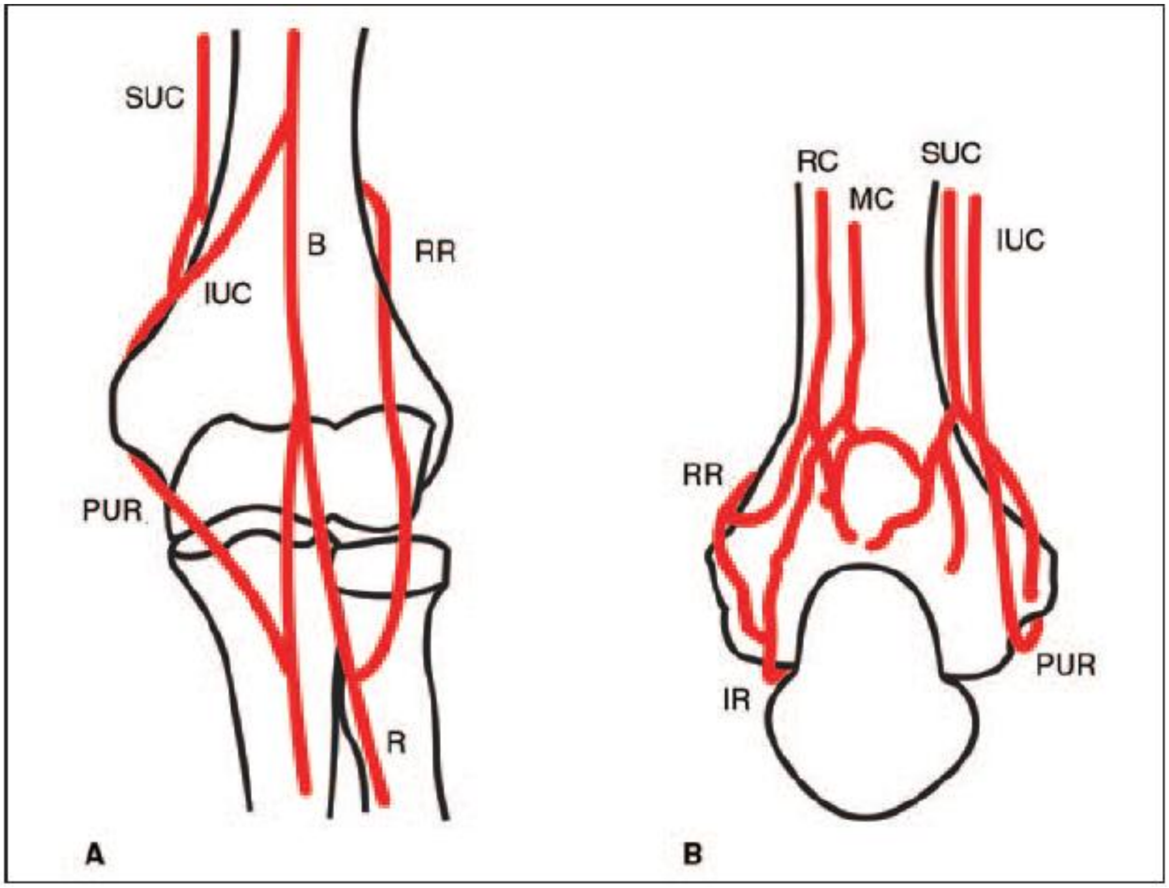

Fig. 5: Anterior (**A**) and posterior (**B**) extraosseous vascular anatomy around the elbow. B = brachial artery, IR = interosseous recurrent artery, IUC = inferior ulnar collateral artery, MC = middle collateral artery, PUR = posterior ulnar recurrent artery, R = radial artery, RC = radial collateral artery, RR = radial recurrent artery, SUC = superior ulnar collateral artery.

(Adapted from Yamaguchi K, Sweet FA, Bindra R, Morrey BF, Gelberman RH: The extraosseous and intraosseous arterial anatomy of the adult elbow. *J Bone Joint Surg Am* 1997,76(11),1653-1662.)

2.2.2 FRACTURE CLASSIFICATION OF LATERAL CONDYLE HUMERUS

All the physes of the distal humerus are vulnerable to injury, each with a distinct fracture pattern. Milch et al (1964) described two lateral condylar fracture patterns (Figure 6). Type I is a simple fracture of the lateral condyle, “resulting from a force directed along the radius and impacting the head of the radius in the capitulotrochlear sulcus” according to Milch (1964).

Type I fractures are characterized by a fracture line that courses lateral to the trochlea and into the capitulotrochlear groove, resulting in a Salter- Harris type IV fracture. The elbow remains stable because the trochlea is intact. Milch type II fracture is a fracture-dislocation of the lateral condyle resulting from a force “directed upward and outward along the ulna, impacting the olecranocoronoid ridge against the trochlear groove.” (Milch et al.1964)

Type II fracture is characterized by a fracture line that extends into the apex of the trochlea, resulting in a Salter-Harris type II fracture. The elbow is unstable because the trochlea is disrupted. This classification system is of little use in determining fracture management and is largely of historical interest. (Milch et al.1964)

Jakob et al (1975) described pediatric lateral humeral condylar fracture based on fracture fragment displacement (Figure 7). Type I fracture is nondisplaced, with an intact articular surface. The fracture line does not completely traverse the cartilaginous epiphysis. Type II fracture is complete and extends through the articular surface. The fracture may be moderately displaced. Type III fracture