Treatment of Elbow Lesions

New Aspects in Diagnosis and Surgical Techniques

Andrea Celli
Luigi Celli
Bernard F. Morrey

Andrea Celli • Luigi Celli • Bernard F. Morrey

Treatment of Elbow Lesions

New Aspects in Diagnosis and Surgical Techniques

Springer

Andrea Celli
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Luigi Celli
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Bernard F. Morrey
Department of Orthopedics
Mayo Medical School
Rochester, MN, USA

Cover illustration: Leonardo da Vinci, Codice Windsor Vol. A foglio 2 verso (detail).
The Royal Collection © 2007 Her Majesty Queen Elizabeth II

Library of Congress Control Number: 2007929133

ISBN 978-88-470-0317-0 Springer Milan Berlin Heidelberg New York
e-ISBN 978-88-470-0591-4

Springer is a part of Springer Science+Business Media
springer.com
© Springer-Verlag Italia 2008

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the Italian Copyright Law in its current version, and permission for use must always be obtained from Springer. Violations are liable for prosecution under the Italian Copyright Law.

The use of general descriptive names, registered names, trademarks, etc., in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
Product liability: The publisher cannot guarantee the accuracy of any information about dosage and application contained in this book. In every individual case the user must check such information by consulting the relevant literature.

Cover design: Simona Colombo, Milan, Italy
Typesetting: C & G di Cerri e Galassi, Cremona, Italy
Printer: Printer Trento Srl, Trento, Italy
Printed in Italy

Springer-Verlag Italia S.r.l.,Via Decembrio 28, I-20137 Milan, Italy

PREFACE

Because of the relatively low incidence of involvement efforts to enhance the diagnosis and management of elbow pathology are not common. Nonetheless, because of a rapidly expanding knowledge base, both with regard to a more refined understanding of elbow pathology, coupled with exciting and emerging approaches and options for management, it is appropriate and timely to address this deficiency in the orthopedic literature. This volume, therefore, was produced in order to provide current and relevant information with content that is drawn from a very well received symposium of the same name as this book and convened in Modena, Italy recently. As with the symposium, the specific goals of this text are to provide the most updated concepts in the management of a full spectrum of elbow pathology. The content, therefore, is comprehensive in nature, but with a focus on emerging options in the management of traumatic conditions as well as reconstructive options for the sequelae of trauma. These topics are covered in detail in the 31 chapters which comprise this text. The focus of each chapter was specifically designed to address the topic in the most timely fashion and with less of an emphasis on the historical context and more focus on current thinking. The references documenting content are intended to be efficient and focused. In addition, the popular and appropriate expectation of the orthopedic community of enhanced explanation of technique are featured in the appropriate chapters. Probably the most important aspect of the text to allow the attainment of this goal is the involvement of surgeons from the Mayo Clinic as well as the participation of world renowned international surgeons. This group was assembled to serve both as a faculty for the symposium and also to document their experience as contributors to this text.

The organization of this volume is designed to be logical and user friendly. The early chapters include basic information on an array of diagnostic topics and techniques. In this context a very important, but basic, discussion of surgical exposures is provided. A full 8 chapters deal with traumatic conditions of the elbow and 7 assess the rapidly emerging field of radial head deficiency and its management with fixation or prosthetic replacement. The consequences of elbow trauma are addressed in detail with an emphasis on the open and arthroscopic management of the stiff elbow.

Current concepts in elbow joint replacement are discussed with a focus on several design concepts as well as outcomes based on presenting diagnosis. Finally, the postoperative management including the use of continuous motion machine, braces and examination under anesthesia is discussed. Overall, therefore, the editors feel as though the goals of the symposium and the documentation of the proceedings have been well realized with the publication of this volume. It is our expectation that this textbook will provide a useful tool to the busy orthopedic surgeon to enhance the diagnosis and effective management for this difficult spectrum of elbow pathology.

In closing, it should be noted that this documentation of our current thinking on these topics has become a reality due to the drive and vision of Professor Luigi Celli and the organizational skills of his son, Andrea Celli, of the University of Modena, Italy. Their vision and leadership, coupled with the international contributions and a spectrum of thought processes, provides a useful and unique perspective to this joint that has heretofore deserved the dubious reputation for the challenges it poses to the orthopedic community. Hopefully, this text will, therefore, in some measure, provide insight and a successful management for this "problem joint".

September 2007 *B.F. Morrey, M.D.*

TABLE OF CONTENTS

LIST OF CONTRIBUTORS

JULIE E. ADAMS
Department of Orthopedic Surgery
Mayo Clinic
Rochester, MN, USA

ROBERTO ADANI
Department of Orthopaedic Surgery
University of Modena and Reggio Emilia
Modena, Italy

YVES ALLIEU
Hand Institute
Clémentville Clinic
Montpellier, France

LUCA BALDINI
Department of Diagnostic Imaging
AUSL Modena
NOCSE Nuovo Ospedale Civile
S. Agostino and Estense
Baggiovara (MO), Italy

ELISABETTA BERTELLINI
Anesthesia Unit Chief
Department of Critical Care
AUSL Modena
Carpi Hospital
Carpi (MO), Italy

GIANLUCA BONANNO
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

ANDREA CELLI
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

LUIGI CELLI
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

MAURIZIO FONTANA
Orthopaedic and Traumatology Unit
Faenza Hospital
AUSL Ravenna, Italy

FABIO GAZZOTTI
Anesthesia Unit
Department of Surgery
University Hospital Policlinico di Modena
Modena, Italy

MATTHIAS HANSEN
Klinik für Unfallchirurgie
Klinikum Worms
Worms, Germany

MICHAEL W. HARTMAN
Department of Orthopedic surgery
Mayo Clinic
Rochester, MN, USA

ANDREAS HINSCHE
Queen Elizabeth Hospital
Gateshead, United Kingdom

LUCIO V. INDRIZZI
Anesthesia Unit
Department of Surgery
University Hospital Policlinico di Modena
Modena, Italy

STEEN L. JENSEN
Shoulder and Elbow Clinic
Aalborg University Hospital
Aalborg, Denmark

GRAHAM J.W. KING
Hand and Upper Limb Centre
Division of Orthopaedic Surgery
University of Western Ontario
London, Ontario, Canada

GIOVANNI LEO
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Giuseppe Magni
Anesthesia Unit
Department of Surgery
University Hospital Policlinico di Modena
Modena, Italy

Alessandro Marinelli
Rizzoli Orthopaedic Institute
Bologna, Italy

Maria C. Marongiu
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Bruno Martinelli
Department of Orthopaedic Surgery
University of Trieste
Hospital of Cattinara
Trieste, Italy

Claudio Minervini
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Bernard F. Morrey
Department of Orthopedics
Mayo Medical School
Rochester, MN, USA

Lars P. Müller
Johannes Gutenberg Universität Mainz
Klinik für Unfall - Wiederherstellungs -
und Handchirurgie
Mainz, Germany

Philippe de Mourgues
Department of Orthopedics
St. Joseph Clinic
Chambéry, France

Shawn W. O'Driscoll
Department of Orthopedics
Mayo Clinic
Rochester, MN, USA

Jean-Pierre Pequignot
Nice, France

Karl J. Prommersberger
Orthopädische Klinik Markgröningen
Stuttgart, Germany

Pol M. Rommens
Orthopädische Klinik Markgröningen
Stuttgart, Germany

Roberto Rotini
Rizzoli Orthopaedic Institute
Bologna, Italy

Claudio Rovesta
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Alberto G. Schneeberger
Shoulder & Elbow Surgery
University of Zurich
Zurich, Switzerland

Vincenzo Spina
Department of Diagnostic Imaging
AUSL MO
Civil Hospital B. Ramazzini
Carpi (MO), Italy

David Stanley
Shoulder and Elbow Unit
Northern General Hospital
Sheffield, United Kingdom

Scott P. Steinmann
Department of Orthopedic Surgery
Mayo Clinic
Rochester, MN, USA

Luigi Tarallo
Department of Orthopaedic and
Traumatology Surgery
University of Modena
Modena, Italy

Alberto Tassi
Anesthesia Unit Chief
Department of Surgery
University Hospital Policlinico di Modena
Modena, Italy

Matthias Winter
Department of Orthopedics
and Traumatology
St. Roch Hospital
Nice, France

Ken Yamaguchi
Shoulder and Elbow Service
Washington University Orthopedics
Barnes-Jewish Hospital
Saint Louis, MO, USA

CHAPTER 1

Anatomy and Biomechanics of the Elbow

A. Celli

Introduction

The elbow is a complex structure that provides an important function as the mechanical link in the upper extremity between the hand, the wrist, and the shoulder. Its primary functions are to position the hand in the space; loss of this ability can cause significant disability for the activities of daily living. The elbow and the wrist joints associated with the ulna and radius bones linked with the interosseous membrane constitute the anatomical and functional unit of the forearm. This unit provides the rotational movements of the forearm and allows the forces transmission from the hand to the elbow when the elbow joint is the stable fulcrum needed for powerful grasping and fine motions. The elbow joint consists of three separate articulations: the ulnohumeral, radio-capitellar, and proximal radio-ulnar joints, together inside a small capsule with a volume of 15-20 cc. The soft tissue are divided into passive stabilizers (the lateral collateral ligament, the medial collateral ligament, and the capsula) and into active stabilizers as the muscle that provides joint compressive forces and functions. This chapter begins with an overview of the anatomical features, including some anatomical tables of the nonarticular structures, and examines the passive structures of the elbow that are related to joint function and motion. The second section discusses the elbow biomechanics including kinematics, and force transmission through the elbow.

Anatomy of the Elbow

Bone Anatomy

The distal humerus comprises two condyles that form the articular surface of the capitellum laterally and the trochlea medially (Fig. 1). The more prominent medial epicondyle is the region (Fig. 2) where the ulnar collateral ligament and the flexor-pronator muscles are attached. The less prominent lateral epicondyle (Fig. 3) is the attached point for the lateral collateral ligament and the extensor supinator muscles. The articular surface is angled approximately 30° anterior to the axis of the humerus shaft. The medial ridge of the trochlea is larger than the lateral ridge; this gives to the articular surface a slight valgus position, approximately 6° from the epicondylar axis (Figs. 4, 5). During the flexion extension the olecranon moves on the articular surface of the trochlea like a screw tapping on it and it allows the normal valgus angle in extension and the varus in flexion (carrying angle) [1-7]. The coronoid fossa and the olecranon fossa proximally to the articular surface accommodates the olecranon process during the extension and the coronoid tip during the flexion movements, increasing the osseous stability of the joint in these positions [1, 4, 8]. Laterally a small radial fossa accepts the contour of the radial head with the elbow in full flexion.

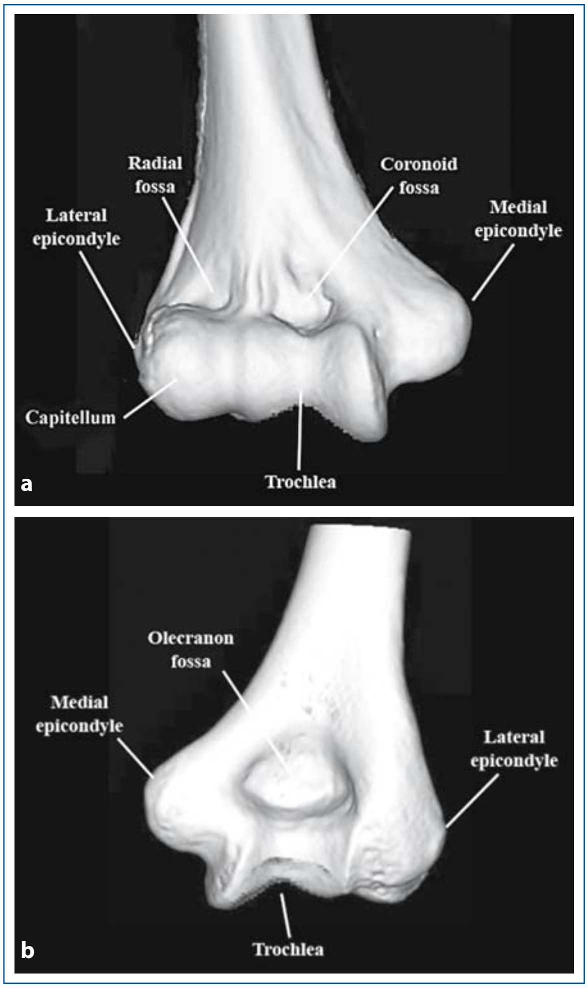

Fig. 1 a, b. The anterior and posterior aspects of the distal humerus with the bone landmarks (TC 3D reconstruction)

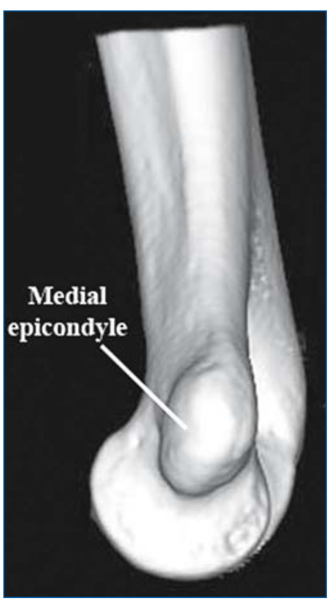

Fig. 2. The medial aspect of the distal humerus (TC 3D reconstruction)

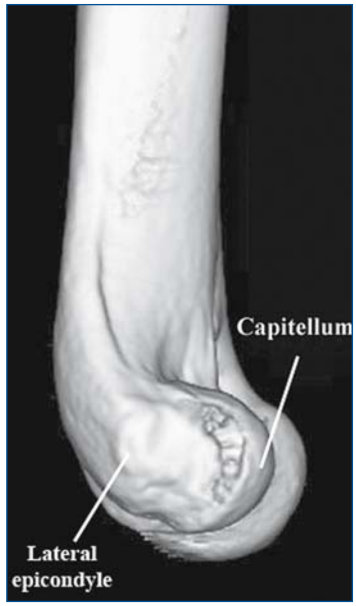

Fig. 3. The lateral aspect of the distal humerus (TC 3D reconstruction)

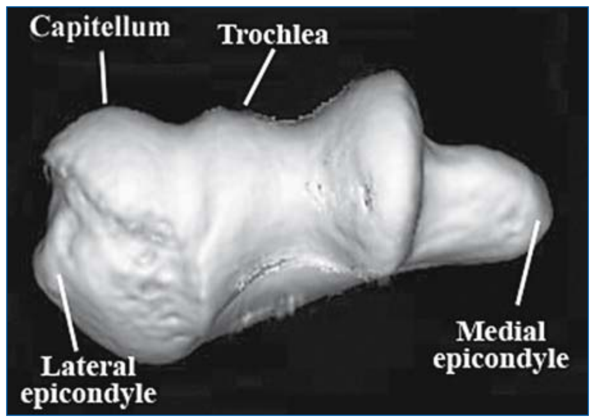

Fig. 4. The distal humerus articular surface: TC 3D reconstruction with bone landmarks

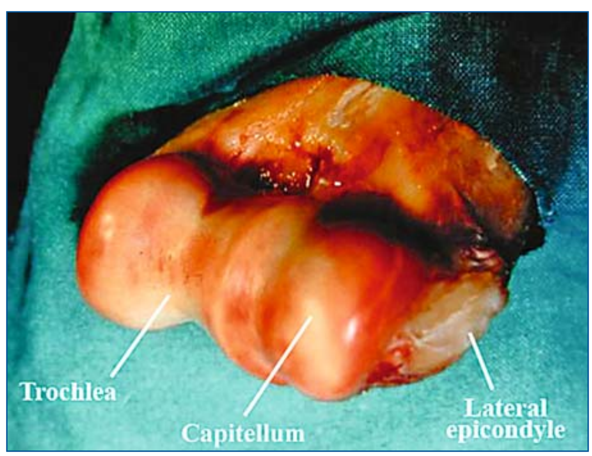

Fig. 5. The distal humerus articular surface anatomical picture with bone landmarks

The proximal ulna provides the elbow articulation; it is divided into the greater sigmoid notch from the coronoid process anteriorly to the tip of the olecranon posteriorly. The contour of the articular surface is not a semicircle but rather is ellipsoid, the articular cartilage is usually discontinuous centrally (nonarticular portion); the forces are distributed on to the articulation into the two functional facets anteriorly and posteriorly [3, 9] (Fig. 6). The greater sigmoid notch is oriented approximately 30° of posterior angulation to match with the anterior angulation of distal humerus. On the frontal plane the shaft is angulated 1°-6° laterally and this contributes in part to the formation of the carrying angle [10]. The coronoid process is constituted laterally by the lesser sigmoid notch, a depression with an arc of 70° that allows the articulation with the radial head [3]. Distally to the lesser sigmoid notch there is an anatomical point called crista supinatoris; it is the insertion of the lateral ulnar collateral ligament (Fig. 7). The medial side of the coronoid provides the insertion of the anterior band of the medial collateral ligament.

The proximal radius includes the cylindrical shape of the radial head with concave disc which articulates with the capitellum and with the lesser sigmoid notch (Fig. 8). The radial margin, which articulates with the ulna, is approximately 240°, the antero-lateral third (120°) of the radial head is void of cartilage. The transverse cross section of

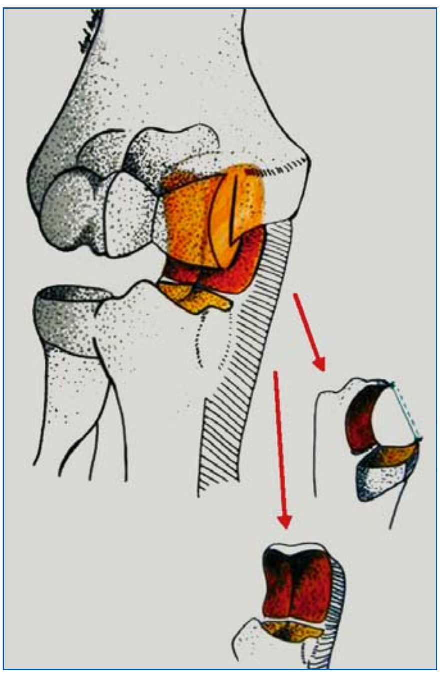

Fig. 6. The articular surface of the olecranon is usually discontinuous centrally (nonarticular portion)

Fig. 7. The olecranon aspect with the bone landmarks (TC 3D reconstruction)

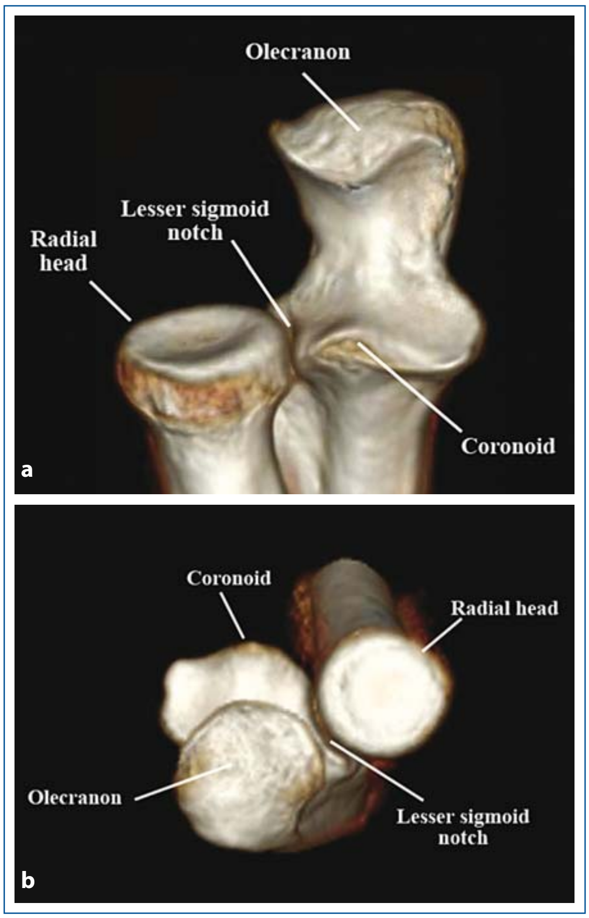

Fig. 8 a, b. The proximal ulna and radius aspects with the bone landmarks (TC 3D reconstruction)

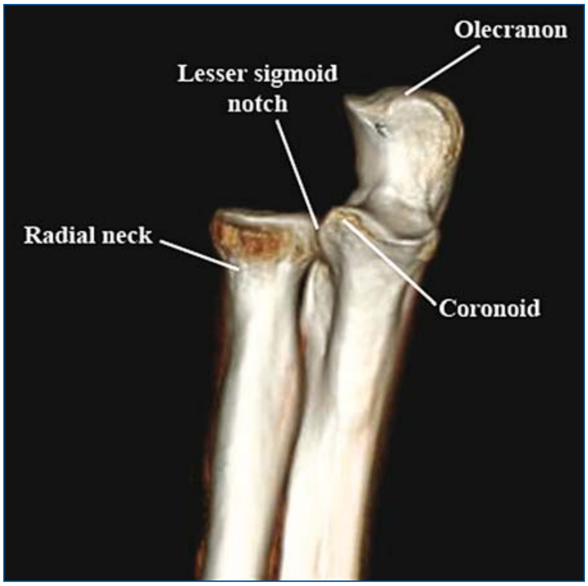

Fig. 9. The proximal radius forms an angle of approximately 15° from the neck and the head

the radial head is not circular but elliptical in shape; the head and the neck form an angle of approximately 15° with the long axis of the proximal radius opposite to the radial tuberosity [3] (Fig. 9). Distal to the neck is the radial bicipital tuberosity which is extra-articular.

Soft Tissue Anatomy

The stability of the elbow is the result of the combination of articulate congruence of the ulno-humeral and radio-capitellum joints and its capsulo-ligamentous structures [11].

The medial collateral complex originates from the distal portion of the medial epicondyle and in particular from the anteroinferior surface of the epicondyle and not from the condilar part of the trochlea [8, 12-16]. The ligament structure consists of three parts; anterior bundle, posterior bundle, and transverse segment [8, 12, 15, 17] (Fig. 10). The anterior bundle is more prominent than the posterior bundle and it is subdivided into anterior, central, and posterior bands [3]. The posterior bundle is thin and inserted into the postero-medial margin of the greater sigmoid notch [8, 12, 15]. The transverse ligament is variable in its definition and appears to have no significant role in stabilizing the elbow. The anterior bundle is stronger than the posterior part and its insertion is in the anteromedial margin of the coronoid, its fibers are sequentially tightened moving the elbow from 20° of extension to 120° of flexion [15, 16, 18]. Morrey and An valuated an average increase of 18% in length of the anterior bundle from full extension to 120° of flexion [9, 17]. The posterior bundle is more posterior to the rotation axis; the change in length was greater than the anterior bundle, with an average of 39% of the resting length [19]. The posterior bundle provides also a minimal stability to valgus stress and provides constraint to hyperflexion.

The lateral collateral complex consists of three parts: the annular ligament, the radial collateral, and the ulnar collateral ligaments [8, 18, 20-22] (Fig. 11). The origin of the lateral collateral complex is on the lateral epicondyle near the axis of rotation of the elbow. The radial part terminates along the course of the annular ligaments; the ulnar part is inserted on

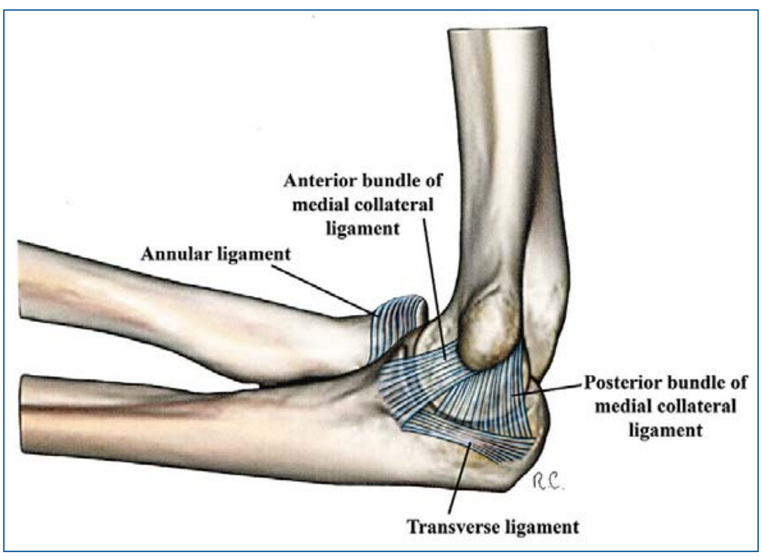

Fig. 10. The medial collateral ligament complex. The ligament consists of three parts: anterior and posterior bundles and transverse segment

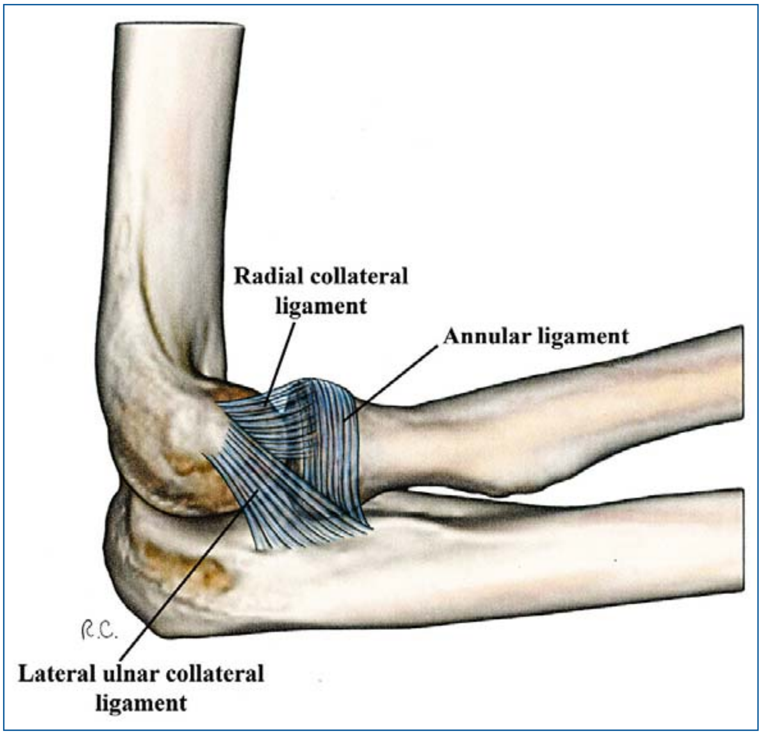

Fig. 11. The lateral collateral ligament complex. The ligament consists of three parts: the annular ligament and the ulnar and radial collateral ligaments

the crista supinatoris of the ulna and has been considered to be an important stabilizer of the elbow. The lateral collateral ligament is almost uniformly taut during the flexion-extension range of motion with little change in distance between the origin and the insertion during the motion (isometric position) [23]. The annular ligament is inserted on the anterior and posterior margins of the less sigmoid notch and it maintains the radial head in contact with the ulna [15] (Fig. 12). The anterior insertion becomes taut during the supination and the posterior insertion during the pronation [16, 22]; this is because the radial head is not a pure circular dish. The annular ligament with the radial part of the lateral collateral ligament are important stabilizers of the radial head avoiding the postero-lateral subluxation. The capsula of the elbow is attached to the articular margins of the joint and its fibers are connected to the annular ligament [24]. Anteriorly it includes the coronoid and the radial fossa, posteriorly the olecranon fossa. Its maximum distension is with the elbow at 70°-80° of flexion. The contribution of the capsula as a passive stabilizer is a controversial point; some studies have suggested no change in the joint laxity after complete capsulotomy and on the other side Morrey reported that this structure has an important function as stabilizer to varus-valgus and distraction loading in extension but not in flexion [17]. The anterior capsula has a transverse and oblique bands that seem to provide a significant stability in extension [19]; on the other side the posterior capsula becomes taut in flexion and may have a role as a static stabilizer.

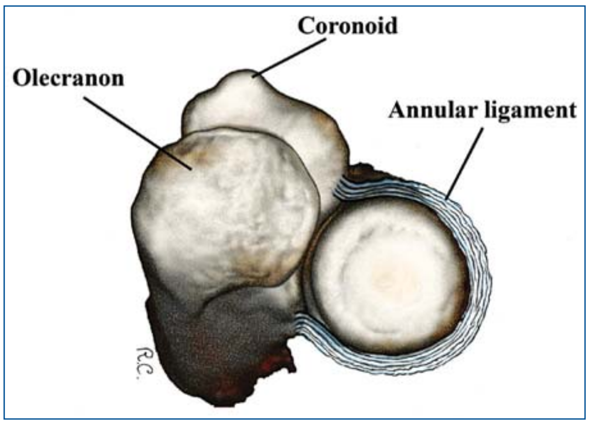

Fig. 12. The annular ligament, which is inserted on the anterior and posterior margin of the less sigmoid notch and it maintains the radial head in contact with the ulna

The Muscles and Neuro-Vascular Structures

The muscle and the neuro-vascular structures across the elbow can be divided into four main groups. Posteriorly, the triceps tendon crosses the elbow joint with the ulnar nerve; laterally, the extensor and supinator muscles (brachio-radialis, extensor carpi radialis longus, extensor radialis brevis, the finger extensors, the extensor carpi ulnaris, and the anconeus) with the radial nerve; anteriorly, the elbow flexors cross the joint with the median nerve; and medially, the flexor-pronator group (pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and the flexor digitorum). The majority of the muscles crossing the elbow work to rotate the forearm and flex and extend the wrist and the fingers. Only a few muscles have an action on moving the elbow joint. The primary elbow flexors are the brachialis, biceps brachii, and brachio-radialis; secondary elbow flexors include the pronator teres, extensor carpi radialis longus, and the flexor carpi radialis. The triceps and the anconeus are the mean extensor muscles of the elbow. Pronation is provided by the pronator teres and pronator quadratus. Supination is performed mainly by the biceps, with assistance from the supinator muscle. Muscle loading results in a compressive force generated across the articulation of the elbow; muscle activities may also produce a dynamic stabilization (compressing the articular surfaces together) and protect the static ligaments constraints [1, 2, 23, 25, 26].

The ulnar nerve derives from the medial cord of the brachial plexus and it descends in the arm posterior to the pectoralis major muscle and medially to the brachial artery. At the inferior border of the pectoralis major the nerve moves medially from the brachial artery and pierces the medial intermuscular septum about 8 cm above the medial epicondyle. A thick fascial band, the arcade of Struthers, is present in 20%-70% of the upper limbs and extends from the medial head of the triceps to the intermuscular septum and it can be a potential point of compression. The ulnar nerve along with the ulnar artery, a branch of the brachial artery, descend distally and medially on the anterior surface of the medial head of the triceps muscle. The artery runs with the nerve as it enters the interval between the medial epicondyle of the humerus and the olecranon. The nerve passes into the ulnar groove on the dorsal aspect of the medial epicondyle, then it passes into a fibrosus arcade (Osborne's arcade), which attaches to the medial epicondyle and the olecranon and connects the ulnar and humeral heads of origin of the flexor carpi ulnaris muscle (Fig. 13). In the first part of the cubital tunnel the nerve provides a small articula branch. In the second portion of the tunnel, it supplies two branches to the flexor carpi ulnaris muscle; the main branch leaves the main trunk horizontally and supplies the humeral head of the flexor carpi ulnaris. The second branch courses distally for several centimeters before entering in the muscle (Figs. 13, 14). As the nerve leaves the cubital tunnel it runs between the flexor carpi ulnaris and the flexor digitorum profundus muscles. The nerve maintains this relationship through the proximal and medial forearm and then it end with sensitive and motor terminal branches in the hand. While the ulnar nerve does not innervate any muscle in the arm, distally at the elbow it supplies the flexor carpi ulnaris (above 0.5-1 cm the medial epicondyle) and the ulnar half of the flexor digitorum profundus muscles.

The radial nerve derives from the posterior cord of the brachial plexus behind the third portion of the axillary artery. In the proximal third of the arm, the nerve descends behind the brachial artery, anterior to the subscapularis muscle, the teres major and the latissimus dorsi tendons, and the long head of the triceps. The nerve crosses the posterior aspect of the humerus next to the bone without interposition of muscle fibers and it sends branches only to the lateral triceps head, and no branch is sent to the medial head. At the humerus lateral aspect the nerve branches off the common branch of the medial head and anconeus and the lower lateral brachial cutaneous nerve while the radial nerve pierces the inter-

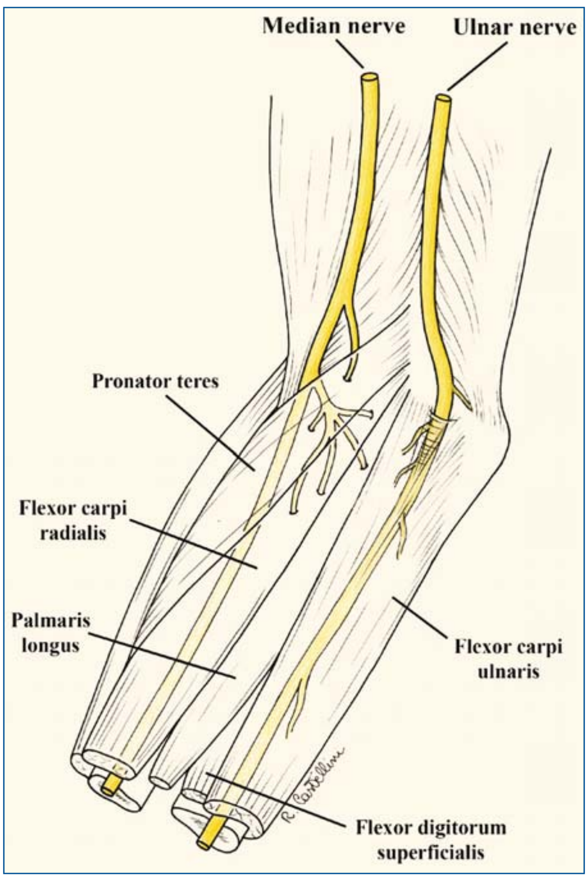

Fig. 13. The ulnar and medial nerves with their terminal branches on the medial side of the elbow

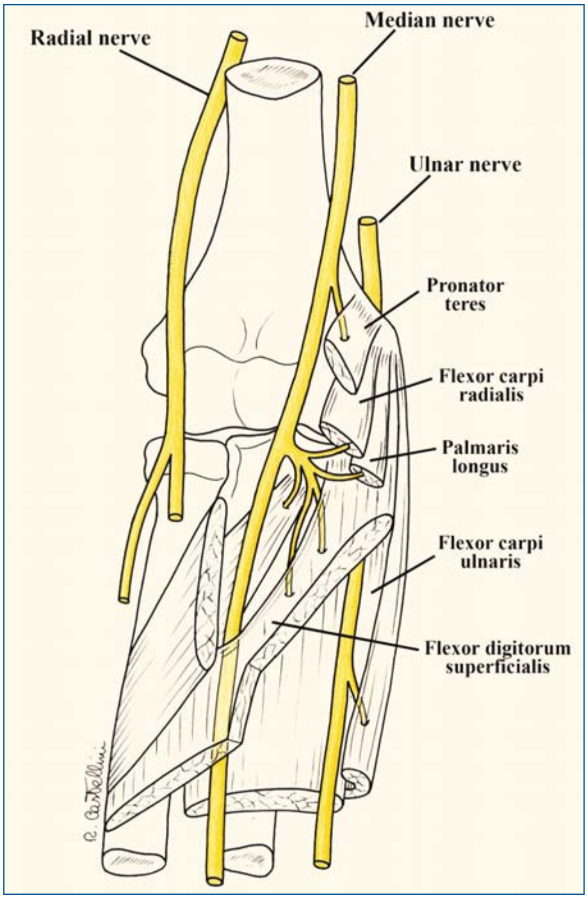

Fig. 14. The ulnar, radial, and medial nerves and their terminal branches on the anterior side of the elbow

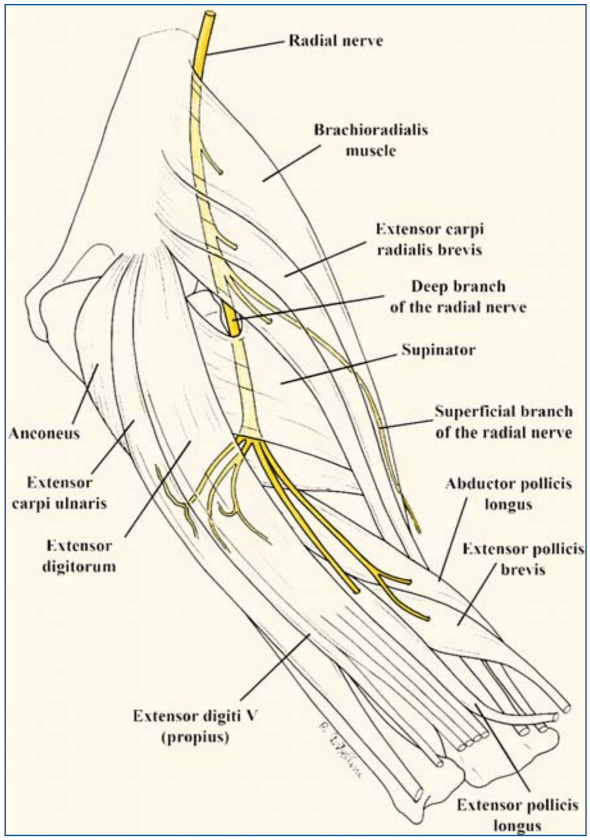

Fig. 15. The radial nerve and its terminal branches at the elbow

muscular septum (at 10-12 cm on average from the lateral epicondyle) (Fig. 15). At the lateral border of the medial head of the triceps muscle, the nerve leaves the extensor compartment and enters in the flexor compartment of the arm, and it runs distally between the brachialis and the brachioradialis muscles. Proximal to the elbow, the radial nerve supplies the brachioradialis and the extensor carpi radialis longus and occasionally medially the brachialis. Then it divides into terminal branches, one superficial sensory and the other deep motor. Those terminal branches passes 1 cm distally to the biceps tendon (Fig. 16). The superficial radial nerve (superficial to the supinator muscle) continues distally on the deep surface of the brachio-radialis muscle and pierces the fascia on the ulnar side of this tendon, about 7 cm above the wrist. Descending in the dorsoradial side of the wrist, it terminates at the hand. The posterior interosseous nerve courses obliquely through the supinator muscle and crossing the proximal radius, to enter into the extensor compartment of the forearm. The motor branches to the extensor carpi radialis brevis arises for the posterior interosseous nerve prior to entering the supinator. The posterior interosseous nerve is separated by the radius from the deep head of the supinator muscle (Fig. 16). As the posterior interosseous nerve exits from the supinator muscle, the variability of its branches becomes so great that only generalizations can be made. The proximal branch heading and supply the extensor carpi ulnaris by one or more little branches. The distal division of the posterior interosseus nerve consists of at least two branches, one to the abductor pollicis longus and sometimes to the extensor pollicis brevis. The most distally innervated muscle is usually the extensor indicis proprius. The terminal portion of the nerve passes deep to the extensor pollicis longus on the interosseous membrane to provide sensory innervation to the wrist. From a surgical point of view, it is important to remember the terminal branches in the arm. From the nerve in the arm arrises cutaneous nerves and several muscular branches and articular fibers supplying the elbow joint. The posterior cutaneous nerve is the first branch arising from the main trunk of the nerve in the axilla, the second branch arising about 7 cm be-

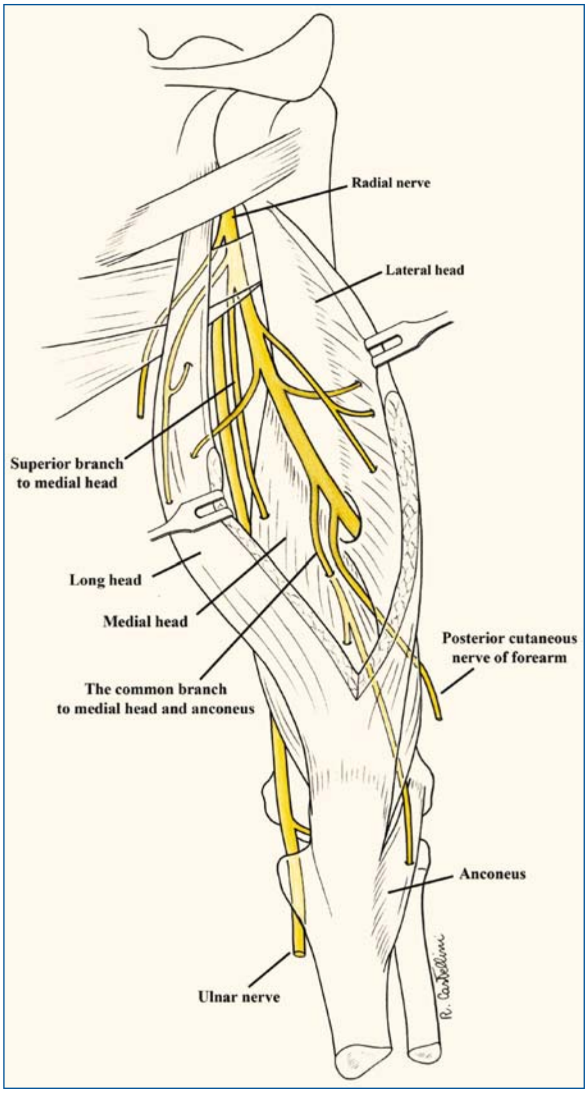

Fig. 16. The radial nerve and its terminal branches at the arm

low the tip of the acromion supplies the long head of the triceps. The branch to the medial portion of the medial head arises just distally to the branch for the long head. As the nerve passes deep to the long head it provides additional branches to this muscle. The posterior muscular branches arise from the main trunk as it lies between the lateral and medial heads near to the spiral groove of the humerus. This is the largest muscular branch of the radial nerve in the arm and it innervates the medial and lateral heads of the triceps. The nerve to the anconeus descends distally within the substance of the medial heads of the triceps muscle, giving several branches to this muscle. Above the elbow it innervates the brachio radialis and the extensor carpi radialis longus and at level of the radio-capitellum joint the radial nerve divides in two its major brances: the posterior interosseus nerve and the superficial sensitive radial nerve.

The median nerve originates from the medial and lateral cords of the brachial plexus then it runs with the artery. The nerve descends in the arm posteriorly to the pectoralis major muscle and laterally to the artery. It runs in the anteromedial side of the brachialis muscle and posteromedial to the biceps muscle. It crosses the medial side of the elbow, where it lies superficial to the brachialis, just deep to the bicipital aponeurosis (Figs. 13, 14). Distally it runs between the two heads of the pronator teres into the forearm between the two flexor digitorum muscles (superficial and profondus). The median nerve does not provide innervation to muscles of the arm. It innervates in the forearm; the pronator teres, flexor carpi radialis, flexor digitorum superficialis, and in most cases the flexor digitorum profondus. Distally in the end, it supplies the index and middle finger lombricalis, abductor pollicis brevis, opponens pollicis, and the flexor pollicis brevis. The anterior interosseous nerve branches supplies the flexor digitorum profundus-2, flexor pollicis longus and the pronator quadratus.

At the elbow the brachial artery enters the cubital fossa on the anterior surface of the brachialis laterally to the median nerve, then both pass under the aponeurosis. In the cubital fossa the artery divides into the radial and ulnar arteries. The radial runs medial to the biceps tendon and then distally superficial to the supinator and to the pronator teres. The ulnar artery passes deep to the head of the pronator teres and runs distally beneath the flexor carpi ulnaris and the flexor digitorum superficialis on the surface of the flexor digitorum profundus.

Kinematics of the Elbow

The elbow has been generally likened to a trochoginglymoid joint in that it has 2° of freedom: flexion-extension (0°-140°) and prono-supination (75°-85°). According to the Morrey's study, the arc of motion necessary to perform most of the activities of daily living is 30°-130° of flexion-extension and 50°-50° of prono-supination [3, 23]. The axis of rotation of the elbow passes through the capitellum in line with the bottom of the trochlea solcus. During the flexion-extension arc of motion, this axis has approximately 3°-5° of internal rotation with respect to the plane of the medial and lateral epicondyles and 4°-8° of valgus with respect to the long axis of the humerus [3, 15, 23, 27, 28]. This is possible because the center of rotation of the elbow in flexion extension is not a fixed single point but rather moves within an area. The olecranon moves on the trochlea (as a screw) during the flexion extension and this justifies the movement of the elbow from the valgus in extension to the varus in flexion (Fig. 17). This movement produces the carry angle, defined as the angle between the long axis of the humerus and the long axis of the ulna measured in the frontal plane [10, 29] (Fig. 18). This angle is generally higher in women than in men, the average has been reported to vary between 7°-12° in men and 2° or 3° greater in women [19]. During the flexion extension the primary constraints of the ulno-humeral joint are as follows: in extension, the posterior part of the olecranon impacts the olecranon fossa associated with the anterior capsula and the ligaments restrained. In flexion, the constraint is the impact of the radial head and of the coronoid process in the corresponding fossa. The forearm motion is clearly influenced by the morphology of the radial head; the axis of rotation of the forearm passes through the center of the radial head proximally and the fovea of the ulna at the base of the ulnar styloid distally [8]. During the forearm rotation, the edge of the radial head maintains contact with the lesser sigmoid notch, and the radial shaft moves away and toward the ulna, in the transverse plane.

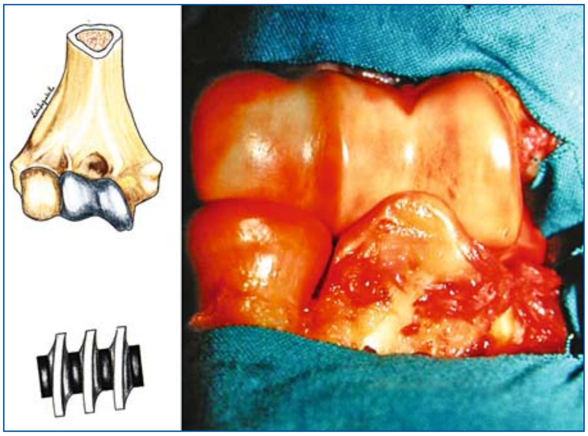

Fig. 17. The olecranon moves on the articular surface of the trochlea like a screw tapping on it

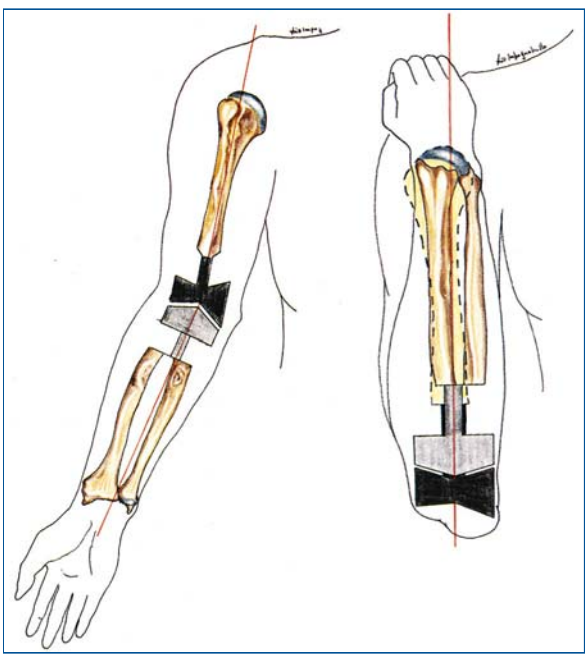

Fig. 18. During the flexion-extension movements the elbow moves from valgus to the varus, producing an angle defined as carry angle

Articular and Capsulo-Ligamentous Stabilizers

The structures that stabilize the elbow during motion can be also divided into two main groups: passive and active stabilizers, which have different actions during the range of motion of the elbow [30-35].

The radial head is a secondary stabilizer to the valgus stress. Morrey et al. have shown that selective radial head resection does not influence the valgus instability as long as the medial ulnar collateral ligament is intact [9, 36]. When the ulnar collateral ligament is released the radial head becomes the primary constraint to the valgus instability [3, 9, 36, 37]. The radial head is the main longitudinal stabilized when the interosseous membrane is injured [38]. Biomechanical tests suggest that the radial head contributes about 30% of the valgus stability in both flexion and extension [19, 23, 38]. The complete release of the ulnar collateral ligament produces an average increase of 18° of valgus laxity and this increases to 36° after radial head excision [19]. The axis loading produces a stress distribution of 40% across the ulna and 60% across the radius; the transmission across the radial head increases when the elbow is 0°-35° of flexion and it also increases when it is placed in supination [19, 23].

The role of the olecranon has been analyzed in different biomechanical studies. An et al., showed that 75%-85% of valgus stress was resisted by the proximal half of the olecranon, and 60%-67% of varus stress was resisted by the coronoid [23]. The olecranon engages the olecranon fossa of the humerus at 20°; at this point the elbow becomes more stable against varus-valgus laxity. The coronoid process plays an important role in preventing the posterior dislocation of the elbow. O'Driscoll et al. reported that when the collateral ligaments are injured and the radial head is compromised, the resection of 30% of the coronoid produces instability [39, 40]. The fracture of the coronoid, even small fragments, can decrease the stability of the elbow in particular when it is associated with ligament injuries. The coronoid is also essential to varus stability when the collateral ligaments are intact [27]. The elbow becomes more unstable as successive portions of the coronoid are damaged; the radial head resection produces an increase in instability correlated to the type of the coronoid fracture [11].

The passive soft tissue stabilizers include the medial and lateral collateral ligaments complexes [30]. Their activities during the elbow motion were analyzed by Morrey and An [9, 23]. At 90° of flexion, the anterior band of the medial collateral ligament is the primary stabilizer to the valgus stress, whereas in extension the medial collateral ligament, the anterior capsula and bony fit are equally resistant to the valgus stress. Its posterior component is more important in higher degrees of flexion. During the elbow motion the midportion and the anterior band of the medial collateral ligament maintain tension; the posterior bundle is taut at 65° to full flexion [8, 27]. The section of this posterior portion to recover the full flexion does not significantly increase the valgus instability [27, 41, 42]. Morrey et al. show that the primary restraint to the valgus stress is the medial collateral ligaments and the secondary stabilizer is the radial head; the radial head becomes the primary restraint to the valgus in case of a medial ligaments complex insufficiency [3, 23].

The lateral collateral ligament was analyzed in different studies. The lateral collateral ligament remains taut throughout elbow range of motion; this is because its origin lies close to the axis of rotation of the elbow. The anterior portion of the annular ligament is taut during the supination; instead the posterior portion is taut in pronation. The function of the lateral collateral ligament was analyzed by O'Driscoll et al.; they described it as the primary ligamentous stabilizer to varus and postero-lateral rotatory instability [39].

The active stabilizers are the muscles crossing the elbow joint; they can be divided into four compartments as previously described [31, 33]. The line of pull and contraction of these muscles create compressive forces around the humerus, ulna, and radius. These forces function as dynamic stabilizers of the joint. The largest force was seen axially at the distal humerus near full extension and decreases when the elbow moves in flexion [23, 25, 26, 43].

Acknowledgements

The Author thanks Dr. Stefano Colopi for his contribution in creating the support to this paper with TC 3D reconstructions.

References

1. Bernstein AD, Jazrawi LM, Rokito AS, Zuckerman JD (2000) Elbow joint biomechanics: basic science and clinical applications. Orthopedics 23:1293-1301
2. Werner FW, An KN (1994) Biomechanics of the elbow and forearm. Hand Clin 10:357-373
3. Morrey BF (ed) (2000) Anatomy of the elbow joint. The elbow and its disorders, 3rd edn. W.B Saunders, Philadelphia, pp 13-42
4. Zimmerman NB (2002) Clinical application of advances in elbow and forearm anatomy and biomechanics. Hand Clin 18:547
5. Werner SI, Fleisig GS, Dillman CJ (2003) Biomechanics of the elbow during baseball pitching. Orthop Sports Phys Ther 17:274-278
6. Duck TR, Dunnig CE, King GJ (2003) Variability and repeatability of the flexion axis at the ulnohumeral joint. J Orthop Res 21:399-404
7. Morrey BF, Tanaka S, An KN (1991) Valgus stability of the elbow. A definition of primary and secondary constraints. Clin Orthop Relat Res 265:187-195
8. Pomianowski S, O'Driscoll SW, Neale PG et al (2001) The effect of forearm rotation on laxity and stability of the elbow. Clin Biomech 16:401-407
9. Morrey BF, An KN (1983) Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 5:315-319
10. Paraskevas G, Papadopoulos A, Papaziogas B et al (2004) Study of the carrying angle of the human elbow joint in full extension: a morphometric analysis. Surg Radiol Anat 26:19-23
11. Fornalski S, Gupta R, Lee T (2003) Anatomy and biomechanics of the elbow joint. Tech Hand Up Extrem Surg 7:168-178
12. Floris S, Olsen BS, Dalstra M et al (1998) The medial collateral ligament of the elbow joint: anatomy and kinematics. J Shoulder Elbow Surg 4:345-351
13. Hannouche D, Begue T (1999) Functional anatomy of the lateral collateral ligament complex of the elbow. Surg Radiol Anat 21:187-191
14. Rongieres M, Akhavan H, Mansat P et al (2001) Functional anatomy of the medial ligamentous complex of the elbow. Its role in anterior posterior instability. Surg Radiol Anat 23:301-305
15. Regan WD, Korinek SL, Morrey BF, An KN (1991) Biomechanical study of ligaments around the elbow joint. Clin Orthop Relat Res 271:170-179
16. Eygendaal D, Olsen BS, Jensen SL et al (1999) Kinematics of partial and total ruptures of the medial collateral ligament of the elbow. J Shoulder Elbow Surg 8:612-616
17. Morrey BF, An KN (1985) Functional anatomy of the ligaments of the elbow. Clin Orthop Relat Res 201:84-90

18. Dunning CE, Zarzour ZD, Patterson SD et al (2001) Ligamentous stabilizers against posterolateral rotatory instability of the elbow. J Bone Joint Surg Am 83:1823-1828
19. King GJ, An KN (1997) Biomechanics and fuctional anatomy of the elbow. In: Norris T (ed) Shoulder and Elbow (Orthopaedic Knowledge Update) ASES published by AAOS
20. Olsen BS, Sojbjerg JO, Dalstra M, Sneppen O (1996) Kinematics of the lateral ligamentous constraints of the elbow joint. J Shoulder Elbow Surg 5:333-341
21. Nielsen KK, Olsen BS (1999) No stabilizing effect of the elbow joint capsule. A kinematic study. Acta Orthop Scand 70:6-8
22. Olsen BS, Vaesel MT, Sojbjerg JO et al (1996) Lateral collateral ligament of the elbow joint: anatomy and kinematics. J Shoulder Elbow Surg 5:103-112
23. An K, Morrey BF (2000) Biomechanics of the elbow. In: Morrey BF (ed) The elbow and its disorders, 3rd edn. W.B. Saunders, Philadelphia, pp 43-60
24. O'Driscoll SW, Morrey BF, An KN (1990) Intraarticular pressure and capacity of the elbow. Arthroscopy 6:100-103
25. An KN, Hui FC, Morrey BF et al (1981) Muscles across the elbow joint: A biomechanical analysis. J Biomech 14:659-669
26. Funk DA, An KN, Morrey BF, Daube JR (1987) Electromyographic analysis of muscles across the elbow joint. J Orthop Res 5:529-538
27. Alcid JG, Ahmad CS, Lee TQ (2004) Elbow anatomy and structural biomechanics. Clin Sports Med 23:503-517
28. Stroyan M, Wilk KE (1993) The functional anatomy of the elbow complex. J Orthop Sports Phys Ther 17:279-288
29. An KN, Morrey BF, Chao EY (1984) Carrying angle of the human elbow joint. J Orthop Res 1:369-378
30. Safran MR, Baillargeon D (2005) Soft-tissue stabilizers of the elbow. J Shoulder Elbow Surg 14[1 Suppl S]:179S-185S
31. Davidson PA, Pink M, Perry J, Jobe FW (1995) Functional anatomy of the flexor pronator muscle group in relation to the medial collateral ligament of the elbow. Am J Sports Med 2:245-250
32. Dunning CE, Zarzour ZD, Patterson SD et al (2001) Muscle forces and pronation stabilize the lateral ligament deficient elbow. Clin Orthop Relat Res 388:118-124
33. Park MC, Ahmad CS (2004) Dynamic contributions of the flexor-pronator mass to elbow valgus stability. J Bone Joint Surg Am 86:2268-2274
34. Hotchkiss RN, Weiland AJ (1987) Valgus stability of the elbow. J Orthop Res 5:372-377
35. Stein J, Murthi AM (2005) Current concepts in elbow kinematics and biomechanics. Curr Opin Orthop 16:276-279
36. Morrey BF, An KN (2005) Stability of the elbow: Osseous constraints. J Shoulder Elbow Surg 14[1 Suppl S]:174S-178S
37. Cohen MS, Bruno RJ (2001) The collateral ligaments of the elbow: anatomy and clinical correlation. Clin Orthop Relat Res 383:123-130
38. Morrey BF, An KN, Stormont TJ (1988) Force transmission through the radial head. J Bone Joint Surg Am 70:250-256
39. O'Driscoll SW, Bell DF, Morrey BF (1991) Postero lateral rotatory instability of the elbow. J Bone Joint Surg Am 73:440-446
40. O'Driscoll SW, Jaloszynski R, Morrey BF, An KN (1992) Origin of the medial ulnar collateral ligament. J Hand Surg Am 17:164-168
41. Callaway GH, Field LD, Deng XH et al (1997) Biomechanical evaluation of the medial collateral ligament of the elbow. J Bone Joint Surg Am 79:1223-1231
42. Sojbjerg JO, Ovesen J, Nielsen S (1987) Experimental elbow instability after transection of the medial collateral ligament. Clin Orthop Relat Res 218:186-190
43. Askew LJ, An KN, Morrey BF, Chao EY (1987) Isometric elbow strength in normal individuals. Clin Orthop Relat Res 222:261-266

CHAPTER 2
The Clinical Examination of the Elbow

A. Hinsche, D. Stanley

Introduction

In order to perform a satisfactory examination of the elbow it is essential for the clinician to have a sound knowledge of the anatomy of the elbow joint. This should include an understanding of the bony anatomy of the distal humerus and proximal radius and ulna. In addition, the attachment of the capsule and the medial and lateral collateral ligaments should be known, together with the arrangement of the muscles and tendons that encircle the joint. Finally, the relationship of the neurovascular structures to the joint must be appreciated. By applying this anatomical knowledge it is usually possible for the clinician who takes a careful history and performs a meticulous examination to reach a firm provisional diagnosis prior to understanding confirmatory diagnostic tests [1].

History

When taking the history it is important to know the patient's age, sex, hand dominance, and occupation since these factors are of special value in the initial assessment and will often give the first indication as to the possible cause of the patient's symptoms.

Age is the first discriminator. A child presenting with intermittent locking and swelling of the elbow is most likely to have a loose body within the joint secondary to osteochondritis dissecans, whereas the same symptoms in an adult over the age of 40 years would be consistent with degenerative arthritis. Progressive pain and swelling of the elbow in a female patient may suggest an early presentation of rheumatoid arthritis, which in turn would require specific investigations for that condition.

Symptoms affecting the dominant elbow may prevent the patient working, participating in sports, and at times undertaking activities of daily living. In this situation it is appropriate to enquire whether the patient believes their work or sporting activities are responsible for, or aggravate, the symptoms they experience.

In elbow disorders the symptoms most frequently noted by patients are pain often associated with local tenderness, reduced elbow movement, and intermittent swelling and locking. Less commonly the patient may complain of symptoms of elbow instability. At times combinations of symptoms will be present.

Past Medical History

A review of the patient's past medical history should also be performed and may identify previous elbow trauma, chronic inflammatory joint disease, psoriasis, haemophilia, or other local or generalised disease processes which may be of relevance to the patient's current complaints.

Presenting Symptoms

Pain

In the assessment of elbow pain it is always essential to specifically enquire about neck symptoms, since at times the elbow pain may be referred from a primary cervical spine pathology. Providing this is not the case the site of the elbow pain should be identified together with its duration, nature, and frequency. It is also important to note whether the pain is associated with elbow movement suggesting an articular pathology, or whether the pain is experienced at the end of movement, which would be consistent with impingement. Pain at rest suggests an inflammatory component or infection. Acute intermittent pain associated with locking is often caused by loose bodies within the joint or less commonly by intra-articular plicae.

Frequently patients will present with lateral or medial elbow pain suggesting lateral or medial epicondylitis. However, it should be remembered that these diagnoses are most uncommon below the age of 40 years and a differential diagnosis should be thought of, e.g. PIN syndrome [2]. In addition, pain on the medial aspect of the elbow may relate to ulnar nerve neuropathy, and for this reason specific note should be made as to whether the patient's pain radiates into the hand and whether there are symptoms of paraesthesia and intrinsic muscle weakness within the ulna nerve distribution [3].

Stiffness

Reduced elbow movement occurs most frequently as a result of elbow trauma [4]. This may be associated with an *intrinsic* joint abnormality due to malunion of a fracture or an *extrinsic* problem resulting from fibrosis and scarring of the soft tissues. The second cause for reduced elbow motion is of degenerative nature, causing loose bodies within the joint and particularly in the olecranon fossa as well as osteophyte formation at the tip of the olecranon and coronoid process [5].

Instability

Recurrent instability of the elbow is an uncommon problem which is often associated with a dislocation of the elbow joint occurring below the age of 15 years. The patient presents with recurrent clicking and giving way of the elbow. When asked the patient will state that the elbow cannot be locked fully in extension when pushing out of a chair or when attempting a "press-up". In these situations the patient is apprehensive that the elbow will dislocate.

Clinical Examination

Since the elbow is a subcutaneous joint, a careful examination will often indicate the likely cause of the patient's symptoms. In order, however, that no areas of the examination are missed it is essential that the clinician develops a methodical examination technique. The process we have found most useful is inspection, palpation, and movement, following Apley's classical principle of "Look, Feel and Move". The examination is completed by specific provocation tests concentrating on that part of the elbow, which is thought to be responsible for the patient's symptoms.

Inspection – "Look"

On initial inspection the posture of the symptomatic elbow should be noted. A painful elbow will often be protected by the contralateral arm and held closely to the side of the body. In contrast, an elbow lacking extension may be supported by placing the ipsilateral hand in the trouser pocket. Skin changes including scars from previous injury or surgical procedures together with olecranon bursae, rheumatoid nodules, and psoritic plaques must also be recorded.

Assessment of the carrying angle should be made with the elbow in full extension. Although some variation is common, the average valgus angulation is 15° in females and 10° in males. Varus deformity is always abnormal and is usually the result of a supracondylar fracture in childhood. Previous bony injury of the lateral humeral condyle may result in an increased valgus angulation, which can cause ulna neuropathy (cubitus tarda).

It is important to remember that with the elbow fully extended the forearm is in valgus relative to the upper arm, whilst in full flexion the forearm is in varus, facilitating the movement of the hand towards the face.

Palpation – "Feel"

Palpation should be performed systematically working progressively around the elbow. Our preferred starting point is lateral, moving anteriorly to the medial side and ending posteriorly.

Lateral

On the lateral side the palpation begins on the lateral supracondylar ridge and progresses distally (Fig. 1). The extensor carpi radialis longus and brevis are identified and palpated for tenderness. The typical trigger point for lateral epicondylitis is just distal and anterior to the lateral epicondylar ridge over the origin of extensor carpi radialis brevis [6]. If tenderness is detected it is reasonable at this stage to perform the appropriate provocation test to confirm the diagnosis. However, a posterior interosseous nerve syndrome should be excluded by palpating the extensor mass deep and medial to the radial neck.

Tenderness over the capitellum in a child may indicate osteochondritis dissecans, which can be associated with an effusion detectable in the infracondylar recess between the capitellum and radial head. At times this recess may have a boggy feel consistent with inflammatory process within the joint.

The radial head should then be palpated with respect to its position and orientation with the capitellum and with regards to tenderness and crepitus on movement. In all positions of the arm the radial head aligns with the capitellum, and if it is subluxed or dislocated as the result of injury or a congenital abnormality this should be identifiable at this stage. Crepitus at the radiocapitellar joint, best appreciated by getting the patient to grip the examiner's fingers and undertake pronation and supination movement, may indicate a recent injury to either the radial head or capitellum. Alternatively, if there is no history of recent trauma, crepitus is consistent with degenerative or inflammatory arthritis.

Anterior

Palpation from lateral to medial across the anterior aspect of the elbow allows identification of the brachioradialis muscle, biceps tendon and aponeurosis, brachial artery, and median nerve (Fig. 2). Of these structures avulsion of the biceps insertion is the one most likely to present pathologically. The patient usually has a history of recent injury with significant bruising around the anterior aspect of the elbow and proximal prominence of the biceps muscle [7]. Loss of flexion and supination strength will be found on specific muscle testing. Occasionally if the patient has suffered a previous dislocation of the elbow, palpation of the anterior aspect of the elbow will reveal bony hardness consistent with myositis ossificans.

Fig. 1. Examination of the lateral aspect of the elbow. The lateral supracondylar ridge, extensor carpi radialis longus and brevis, capitellum and radial head can be palpated

Fig. 2. Examination of the anterior aspect of the elbow allows indentification of brachioradialis, the biceps tendon and aponeurosis, brachial artery and median nerve

Medial

The two structures that are easily palpated on the medial aspect of the elbow are the common flexor origin and the ulnar nerve (Fig. 3). Tenderness anteriorly over the common flexor origin is consistent with medial epicondylitis, and, as with epicondylitis on the lateral side of the joint, it is appropriate on eliciting tenderness to perform the confirmatory provocation tests [8].

The ulnar nerve lies more posteriorly behind the medial epicondyle, although in up to 10% of patients it may subluxate anteriorly during flexion of the elbow. A subluxing ulnar nerve is a cause of medial elbow pain. More commonly, however, ulnar nerve symptoms arise because of entrapment of the nerve, usually between the two heads of flexor carpi ulnaris. Associated with this the patient may complain of pins and needles or numbness affecting the ipsilateral little and ring fingers. Specific testing may reveal sensory disturbance in these fingers together with small-muscle wasting in the hand. A comparison with the unaffected hand should always be performed [9].

Posterior

The bony anatomy of the elbow can be easily palpated posteriorly (Fig. 4). In the uninjured extended elbow the lateral epicondyle, tip of the olecranon, and medial epicondyle form a straight line. When the elbow is flexed at 90° these bony structures form an isosceles triangle. If, however, there has been a previous fracture this arrangement of the bony architecture may be disrupted.

Palpation of the triceps insertion may reveal local tenderness suggesting a partial tear, whilst an inability to extend the elbow against gravity indicates a complete avulsion. In this situation a defect between the distal triceps and olecranon is usually palpable [10].

Finally palpation of the posterior aspect of the elbow will, if present, reveal an olecranon bursa or rheumatoid nodules.

Movement – "Move"

In order to avoid missing subtle abnormalities the range of movement of the symptomatic elbow

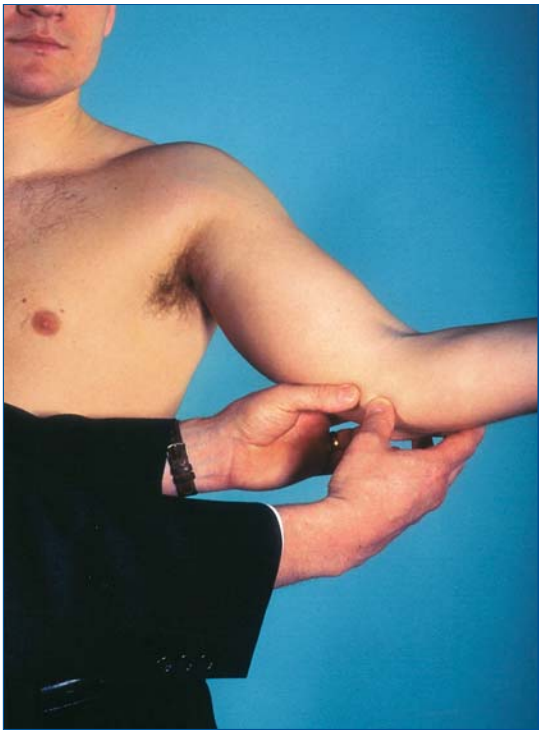

Fig. 3. On the medial aspect of the elbow the common flexor origin and ulnar nerve can be palpated

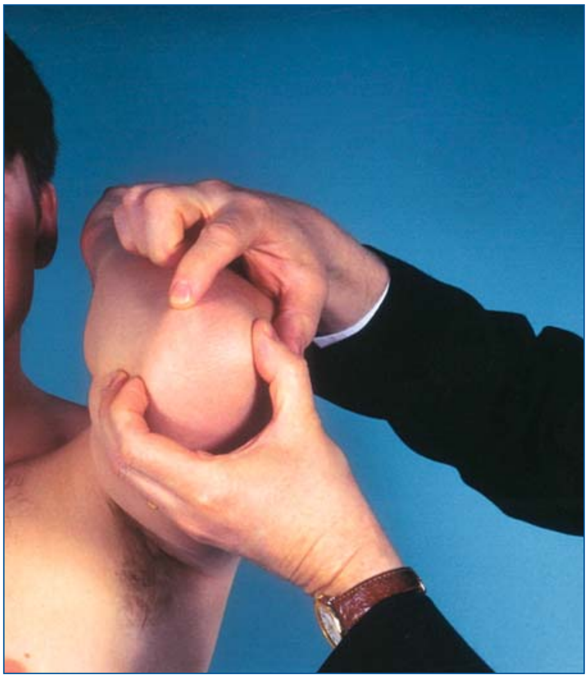

Fig. 4. With the elbow flexed the lateral epicondyle, tip of the olecranon and medial epicondyle form an isosceles triangle. When the elbow is fully extended these structures form a horizontal straight line

should be compared with the asymptomatic joint. The normal range of flexion and extension at the elbow is 140°. This is measured from 0° when the forearm is supinated and fully extended to 140° when fully flexed. Ten degrees of hyperextension is not uncommon, but a greater amount suggests hypermobility or previous bony injury. Hyperextension is recorded as a negative integer [11].

Loss of extension is an early sign of an intra-articular abnormality. Although loss of extension may not be appreciated by the patient, loss of flexion is usually noted. The functional range of movement at the elbow is 100°, and once patients have less than this their ability to work and perform activities of daily living becomes compromised.

Assessment of pronation and supination should be undertaken with compensatory shoulder movement excluded. This is achieved by stabilising the elbow joint against the side of the body with the elbow flexed at 90°. Average supination is 85° whilst pronation is usually a few degrees less. For functional rotation the patient requires approximately half the normal supination and pronation movement. Loss of supination has traditionally been regarded as the more serious functional loss, although in today's world as keyboards are used extremely commonly, loss of pronation may also now be a significant handicap.

Instability

Valgus Instability

Valgus instability results from damage to the ulnar collateral ligament of the elbow. It is most commonly seen in throwing athletes who may sustain either an acute or chronic injury. It can be demonstrated by fully externally rotating the arm to stabilise the shoulder, flexing the elbow approximately 30° to unlock the olecranon from the fossa, and applying a valgus force whilst palpating the ulnar collateral ligament. Opening of the elbow, together with local pain and tenderness, are compatible with damage to the ligament.

Partial tears of the ligament can be assessed using O'Brien's test. This involves holding the patient's thumb with the elbow fully flexed. Pain over the medial ligament suggests a partial tear of the ligament.

Varus Instability

Assessment of the integrity of the lateral collateral ligament is achieved by fully internally rotating the shoulder, flexing the elbow to approximately 30° to unlock the olecranon from its fossa, and applying a varus stress to the elbow. If the lateral collateral ligament is deficient, the gap between the capitellum and radial head will increase.

Rotatory Instability

Posterolateral rotatory instability results from insufficiency of the lateral ulnar collateral ligament. It is best assessed by performing the lateral pivot shift test. This is undertaken with the patient in the supine position and with the shoulder and elbow flexed to 90°. The patient's forearm is fully supinated, and with the examiner holding the patient's wrist and forearm a valgus and axial compression force is applied to the elbow whilst the elbow is slowly extended. This will often reproduce the patient's symptoms and produce apprehension such that the patient prevents further movement. The radius and ulna sublux from the humerus producing a prominence posterolaterally and a dimple between the radial head and capitellum. At approximately 40° of flexion the ulna suddenly reduces with a palpable and visible clunk [12].

Instability testing is best appreciated if performed under general anaesthesia using image intensification. This provides a permanent record of the ligament injury and is of assistance when reconstruction is being planned (Fig. 5).

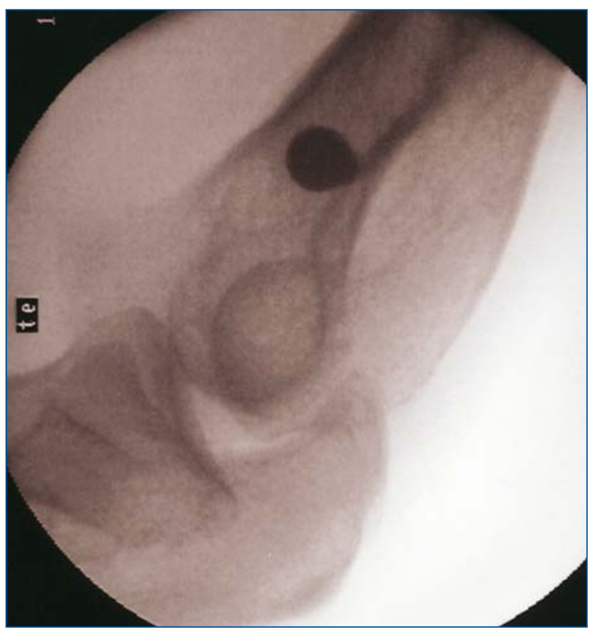

Fig. 5. Rotatory instability is demonstrated by the lateral pivot shift test and confirmed under general anaesthesia using image intensification

Specific Tests

The clinical examination is completed by performing specific tests based on the clinical findings so far.

Provocation Tests

Lateral Epicondylitis

Several provocation tests can be performed for lateral epicondylitis:

1. Resisted wrist extension with the wrist in neutral results in localised pain over the extensor origin at the elbow epicondyle (Fig. 6).
2. Resisted extension of the middle finger with the wrist in extension and radial deviation produces pain over the origin of extensor carpi radialis brevis.
3. Passive volar flexion of the wrist with the forearm pronated and the elbow extended also produces pain at the lateral epicondyle.

If any of these tests are positive the diagnosis can be confirmed by injecting a small amount of local anaesthetic. The injection should be at the common extensor origin and should obliterate the patient's symptoms.

Medial Epicondylitis

Provocation tests for medial epicondylitis include:

1. Resisted wrist flexion which should produce pain at the medial epicondyle (Fig. 7).
2. Passive extension of the wrist and elbow results in medial epicondylar pain.

Local anaesthetic injected at the common flexor origin should obliterate the symptoms to confirm the diagnosis. Care, however, should be taken when the injection is performed in order to be certain that local anaesthetic does not affect the ulnar nerve, which can also be a cause of medial elbow pain.

Impingement Tests

Impingement of the elbow may involve both the posterior or anterior elbow compartments. Normally it results from osteophytes on the tip of the olecranon impinging in the olecranon fossa or osteophytes on the coronoid process impinging into the coronoid fossa. Posterior impingement is more common and occurs due to repetitive hyperextension movements of the elbow. Classically it is stated to occur in "boxers", although we have seen it more commonly in those undertaking racquet sports. It can be demonstrated by applying a hyperextension force to the elbow. This manoeuvre which normally

Fig. 6. Provocation test for lateral epicondylitis. Resisted wrist extension results in localised pain over the extensor origin at the lateral epicondyle

Fig. 7. Provocation test for medial epicondylitis. Resisted wrist flexion results in localised pain over the flexor origin at the medial epicondyle

is pain-free results in posterior elbow pain in patients with posterior elbow impingement. Hyperflexion will similarly demonstrate anterior elbow impingement by causing anterior elbow pain.

Clinical Examination Checklist

Look

- Swelling, deformity, scarring, wasting
- Skin changes, e.g. RA nodules, eczema, erythema
- Carrying angle
- Resting position

Feel

- Bony surface landmarks
- Extensor origin
- Radial head
- PIN
- Biceps tendon
- Flexor-pronator origin
- Ulna nerve
- Olecranon tip and fossa

Move

- Extension
- Flexion
- Supination
- Pronation
- Valgus/varus stress testing
- Pivot shift test
- Provocation tests
- Impingement test

Always examine and compare both elbows.

Common Pathologies ("The Big 10")

- Lateral/medial epicondylitis
- Cubital tunnel syndrome
- RA, OA
- Dislocated radial head (congenital/acquired)
- Altered carrying angle (previous supracondylar fracture)
- Bony lump (myositis ossificans, nonunion)
- Bicipital avulsion/tendonitis
- Radio-ulna synostosis
- Post-traumatic stiffness
- Instability

Presenting Problem and Differential Diagnosis

- Pain lateral side
  - Lateral epicondylitis
  - Lateral compartment OA
  - PIN syndrome
  - Nonunion
  - Acute avulsion fracture lateral (epi-) condyle
  - Radial head fracture
  - Osteochondritis dissecans
  - Varus instability
  - Posterolateral instability
- Pain medial side
  - Medial epicondylitis
  - Cubital tunnel syndrome
  - Nonunion
  - Acute avulsion fracture medial (epi-) condyle
  - Valgus instability
- Anterior elbow pain
  - Biceps tendonitis
  - Biceps avulsion
  - Anterior impingement
- Posterior elbow pain
  - Posterior impingement
  - Triceps tendon injury
  - Olecranon spur
  - Olecranon bursitis
- Elbow stiffness
  - Intrinsic
    - Post-traumatic
    - Degenerative
    - Inflammatory
    - Infective
  - Extrinsic
    - Post-traumatic
  - Neurological
- Elbow instability
  - Medial
  - Lateral
  - Rotatory
  - Complex

Don't forget systemic disease; e.g. Ehlers-Danlos and Marfan Syndrome.

References

1. Doyle JR (2003) Elbow in doyle and botte. Surgical anatomy of the hand and upper extremity. Lippincott, Williams and Wilkins, Philadelphia
2. Andrews JR, Whiteside JA (1993) Common elbow problems in the athlete. J Orthop Sports Phys Ther 17:289-295
3. Major HP (1883) Lawn tennis elbow. BMJ 2:557
4. Thompson H, Garcia A (1967) Myositis ossificans: Aftermath of elbow injuries. Clin Orthop 50:129-134

5. Stanley D (1994) Prevalence and aetiology of symptomatic elbow osteoarthritis. J Shoulder Elbow Surg 3:386-389
6. Nirschl RP (1992) Elbow tendinosis/tennis elbow. Clin Sports Med 4:851-870
7. Baker BE, Bierwagen D (1985) Rupture of the distal tendon of biceps brachii. Operative versus non-operative treatment. J Bone Joint Surg 67:414-417
8. Gabel GT, Nirschl RP (2002) Medial Epicondylitis. In: Morrey BF (ed) Masters techniques: The elbow. Lippincott, Williams and Wilkins, Philadelphia
9. Spinner M, Kaplan EP (1976) The relationship of the ulnar nerve to the medial intermuscular septum in the arm and it's clinical significance. Hand 8:239-242
10. Holleb PD, Bach BR (1990) Triceps brachii injuries. Sports Med 10:273-276
11. Morrey BF, Chow EY (1976) Passive motion of the elbow joint. J Bone Joint Surg Am 58:501-508
12. O'Driscoll SW, Bell DF, Morrey BF (1991) Postero-lateral rotatory instability of the elbow. J Bone Joint Surg Am 73:440-446

CHAPTER 3
Imaging of the Elbow

V. Spina, L. Baldini

Introduction

The technological innovations of recent decades have greatly improved the diagnostic information offered by imaging modalities in the study of skeletal and joint diseases. This is due to the addition of multiplanar modalities with high contrast and spatial resolution, such as computed tomography (CT), magnetic resonance (MR), and ultrasonography (US) to traditional modalities like plain radiography (X-ray) and nuclear medicine (NM) [1-3]. Being that the elbow has traditionally been a challenging joint not only for the orthopedic surgeon but also for the radiologist, imaging has been limited for a long time by the complexity of the elbow's anatomy as well as technical difficulties. For example, elbow stiffness, a typical result of traumatic lesions, is the factor that more than others in the past made it difficult to obtain good diagnostic imaging. Nowadays, the existing variety of imaging modalities permit a detailed analysis of several joint diseases of the elbow by providing images of high quality [4-6]. The use of contrast agents in the intra-articular space (arthrography) combined with the tomographic view offered by CT (arthro-CT) and MR (arthro-MR) examinations makes the diagnostic information more accurate in the evaluation of joint lesions [7-10].

Plain Radiography

Radiographic examination makes use of standard and additional projections [11]. Standard projections consist of two orthogonal views: an anteroposterior view (AP) and a lateral view (LL).

In the anteroposterior (AP) projection, the forearm is in a supine position with the elbow completely extended and the fingers slightly flexed. The central X-ray beam is directed perpendicular to the elbow joint. The distal humerus, especially the profiles of the medial and lateral epicondyles, the radial head, and the proximal ulna are highly visible in this view. The criteria for a correct projection are a slight superimposition of the radial head, neck and biceps tuberosity over the proximal ulna, and the visualization of the humeroradial joint space (Fig. 1).

Fig. 1. Anteroposterior view of the elbow. This projection shows the medial and lateral epicondyles, the capitellum and the radial head, the olecranon fossa. The coronoid process is seen frontally and the olecranon is superimposed on the trochlea. Note a traction spur of the coronoid process and small calcification of collateral ligament. Calcific tendinitis of the common extensor tendon