Gregory I. Bain
Eiji Itoi
Giovanni Di Giacomo
Hiroyuki Sugaya
Editors

Normal and Pathological Anatomy of the Shoulder

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Editors
Gregory I. Bain
Department of Orthopedics and Trauma
Flinders University
Adelaide
South Australia
Australia

Eiji Itoi
Department of Orthopaedic Surgery
Tohoku University School of Medicine
Sendai
Miyagi
Japan

Giovanni Di Giacomo
Orthopaedic
Concordia Hospital for Special Surgery
Rome
Italy

Hiroyuki Sugaya
Funabashi Orthopaedic Sports
Med Cn Shoulder and Elbow Service
Chiba
Japan

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Foreword

This book is a product of the upper extremity committee of ISAKOS. While the anatomy of the shoulder has been studied well for many centuries and has not changed, the authors of this book highlight what has improved: our ability to evaluate and understand anatomy in health and disease in a dynamic and living body. In the past, researchers have been limited to cadaver dissections to uncover the secrets of functional anatomy. Those works have been important for our understanding, but they have limitations.

During the last 30 years, dramatic changes in the tools available for practitioners and researchers have become available. The arthroscope has been central to this effort but has had a great deal of help from imaging modalities including MRI, CT and ultrasound. These new tools have allowed greater understanding of how the anatomy is modified by disease processes. This book points us to a better understanding of normal anatomy and its variations as well as the changes that have occurred secondary to pathological processes. These insights will guide us to perform the necessary reconstructions to overcome functional losses. This enhanced understanding will also prevent us from having complications that will occur without the clear knowledge of how the pathological process has changed the anatomy.

We all are indebted to Drs Gregory Bain, Eiji Itoi and all the members of the upper extremity committee of ISAKOS for their work. The insights of this important manuscript will extend beyond the membership of ISAKOS to have an impact on the wider surgical community and the patients they manage. An additional benefit is that this book will form the basis for future research as we continue our quest to maintain the function of the musculoskeletal system in a minimally invasive and cost-effective way.

Gary G. Poehling, MD
Professor of Orthopedics
Wake Forest University Medical Center
Emeritus Editor in Chief Journal of Arthroscopy

Preface

Introduction

The principles of human gross anatomy have been developed for centuries and are the foundation of current medicine. Over the last two decades, there have been many advances in biomechanics, imaging and arthroscopy, which have enhanced our understanding of clinical, surgical and functional anatomy.

Why Anatomy and Pathology?

Pathology is the basic science of medicine, and anatomy is the basic science of surgery. Despite advances in both basic sciences, the concept of patho-anatomy is often overlooked. The way in which normal anatomy is affected by pathological processes such as trauma, disease and degeneration still requires further investigation.

The Monograph

The aim of this monograph is to bring together the newer concepts of shoulder anatomy and patho-anatomy. It commences with a discussion on comparative and developmental anatomy. For each clinically relevant anatomical area, there is an overview of gross anatomy; a discussion of the ultra-structure, imaging and arthroscopy and a review of how the anatomy is affected by pathological processes.

In creating this document, we have exchanged many concepts of applied, pathological and surgical anatomy of the shoulder. The relevant historical and latest literature has been analysed to develop new concepts, which are shared in this monograph. We trust that dissemination of this new understanding will advance the assessment and management of patients with disorders of the shoulder.

The Editors and Authors

The upper extremity committee of ISAKOS is enriched with many surgeons who have advanced the science of surgical anatomy over the last 20 years. The publication was developed and principally written by the members of the committee.

Acknowledgement

We sincerely thank the editors and authors for their time, effort and expertise in enabling this project to be completed. We acknowledge the significant contribution of the following individuals:

Editor Giovanni Di Giacomo, Italian Orthopaedic Surgeon and Anatomist, who also provided many wonderful images of cadaveric dissections from his book *Atlas of Functional Shoulder Anatomy* [1]

Henry V Crock AO, Australian Orthopaedic Surgeon and Anatomist, for providing the detailed vascular anatomical images that were reproduced from his book *An Atlas of Vascular Anatomy of the Skeleton and Spinal Cord* [2]

Mark Ross, Australian Orthopaedic Surgeon, for providing many excellent images from his cadaveric dissections

Pau Golano, Spanish Anatomist who tragically passed away at the time of preparation of this manuscript. His passing is a great loss to Orthopaedic Surgery. We were able to obtain a few of his images, which are beautifully demonstrated in the book.

Martin Langer, German Orthopaedic Surgeon, Artist and Anatomist, for his spectacular graphic illustrations

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Gregory I. Bain
Editor
Deputy Chairman, Upper Extremity Committee, ISAKOS
Professor of Upper Limb Surgery and Research
Department of Orthopaedic Surgery
Flinders University
Adelaide, Australia

Eiji Itoi
Editor
Chairman, Upper Extremity Committee, ISAKOS
Professor, Department of Orthopaedic Surgery,
Tohoku University School of Medicine
Sendai, Japan

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2. Henry V, Crock AO. An atlas of vascular anatomy of the skeleton and spinal cord. Published by Martin Dunitz; 1996. Henry V Crock AO maintains copyright of these images.

Contents

Part I

Introduction

Comparative Anatomy of the Shoulder

1

W. Jaap Willems

1.1 Introduction

Over a period of 370 million years, there has been an evolution from fish, through amphibians, reptiles and birds, to tetrapods. Fish have fins, which are rays with webbed or membranous processes. The evolution of fins in fishes to limbs in tetrapods was a very elegant progression, which has enabled the skeletal elements to be used for support, locomotion, followed by suspension and ultimately the ability to throw projectiles. The limbs in tetrapods are muscular appendages with well-defined joints.

In tetrapods, the limb (*chiridium)* is composed of three well-defined regions: the *autopodium* (wrist and fingers), *zeugopodium* (ulna and radius) and the *stylopodium* (humerus).

The pectoral girdle is the brace that supports the limbs [1]. Both pectoral girdles fused in the midline on the ventral surface of the body through a medium of the interclavicle.

In this chapter, the evolution of this pectoral girdle is described, with emphasis on the various tetrapods. Secondly, a comparison of the different animals models that can be used to study pathologies of the shoulder is described.

W.J. Willems, MD, PhD
Shoulder Unit, De Lairesse Kliniek,
Amsterdam, The Netherlands
e-mail: w.j.willems@xs4all.nl

1.2 Phylogeny of the Shoulder Girdle: Osseous Architecture

In the evolution of the pectoral girdle in fishes, two essential changes occurred. The pectoral girdle both in fishes (rhipdistians) and tetrapods (vertebrate with four limbs) consisted of dermal and endoskeletal elements.

1.2.1 Fish

In fishes, the pectoral girdle is attached to the skull and during evolution the skull becomes completely detached from the skull in vertebrates. After this detachment, the pectoral girdle consists of a ventral *dermal* part (*cleithrum* and *clavicle*) and *endoskeletal* (*scapula* and *procoracoid*) components.

While this latter originally was one element, in tetrapods it arises from two distinct embryonic centres of enchondral ossification, leading to two distinct bones, the scapula and procoracoid (Fig. 1.1) [1].

1.2.2 Amphibians

In amphibians, with the acquirement of terrestrial habits, the tripartite type of pectoral girdle made its first appearance: the coracoid became segmented into the anterior procoracoid and posterior coracoid, while the clavicle formed a connection to the procoracoid [2].

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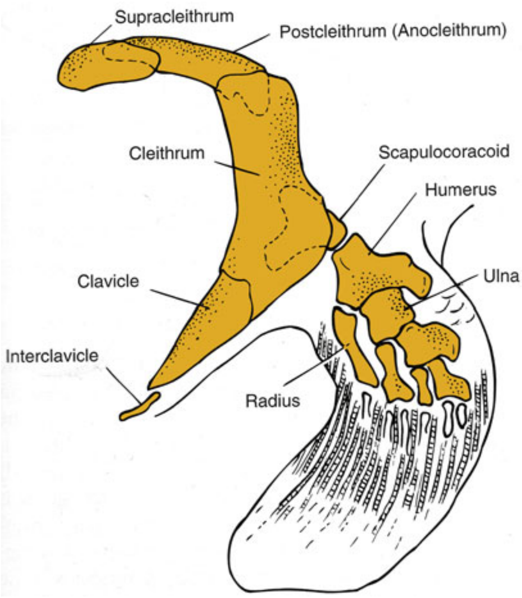

Fig. 1.1 Appendicular skeleton of the earliest tetrapods (rhipidistian, bony fish), where the earlier connection to the skull was lost leading to the formation of the pectoral girdle and an increase of the mobility of the head. The cleithrum and clavicula are located more ventrally, the scapulocoracoid more dorsally; the interclavicle connects both the clavicles (Reprinted with permission from: Kardong [1])

1.2.3 Reptiles

In reptiles, the pectoral girdle has migrated caudally from its intimate relation to the head, as seen in fish. The reptilian pectoral girdle comprised a scapula, a clavicle, which replaced the provoracoid, and a coracoid.

The evolution of the procoracoid varies by species. It becomes part of the anterior scapula around the glenoid fossa; in others, it is fused with the sternum, or is replaced by the clavicle. Although the scapula and coracoid process are anatomically united, genetic patterning of the coracoid and the scapula is under the control of different Hox genes, lending further support to the view that each is a separate phylogenetic derivative [2].

1.2.4 Birds

The avian pectoral girdle became specialized to enable flight. The clavicles became essential in suspending the limb away from the body and the coracoid became large and strong in response to the muscular demands of flight. Consequently, the scapula was small, curved and narrow to allow greater motion. The keeled attachment for the strong pectoral muscles used in flight. The sternum became keel shaped to provide attachment for the strong pectoral muscles used in flight.

1.2.5 Mammals

The coracoid in mammals tends to become greatly reduced, forming an insignificant process on the scapula. The only other vestige of the bone is the coracoid ligament, extending from the coracoid process to the bone, in which may be found isolated masses of cartilage. This arrangement frees the scapula from any bone attachment to the skeleton. In mammals without clavicles, the scapula has no bony attachments whatsoever. It becomes the sole support for limb and provides attachments for muscles necessary for a freely movable extremity. New functional demands on the girdle resulted in the development of a projection of bone on the dorsal surface of the scapula, the spine, which extends downwards and ends in the acromion [2].

The clavicle undergoes changes during evolution, when in tetrapods a change in limb posture arises. In a sprawled posture, the forces are medially directed toward the shoulder girdle, conferring on medial elements a major role in resisting these forces: In these animals the clavicles are interconnected, a so-called interclavicle. As the limbs are brought under the body, these forces are directed less toward the midline and more in vertical direction, leading to a less prominent role of the clavicles (Fig. 1.2) [1].

In mammals, which have acquired freedom of the forelimb to a marked degree, such as insectivores, primates and some marsupials and rodents, the clavicle is well developed. In others, including ungulates, carnivores and some rodents and marsupials, it is absent or rudimentary.

1.3 Phylogeny of the Shoulder Girdle: Musculature

Development of the shoulder and forelimb muscles in tetrapods comes from four sources: branchiomeric (jaw and pharyngeal muscles), axial, dorsal limb and ventral limb muscles (Fig. 1.3).