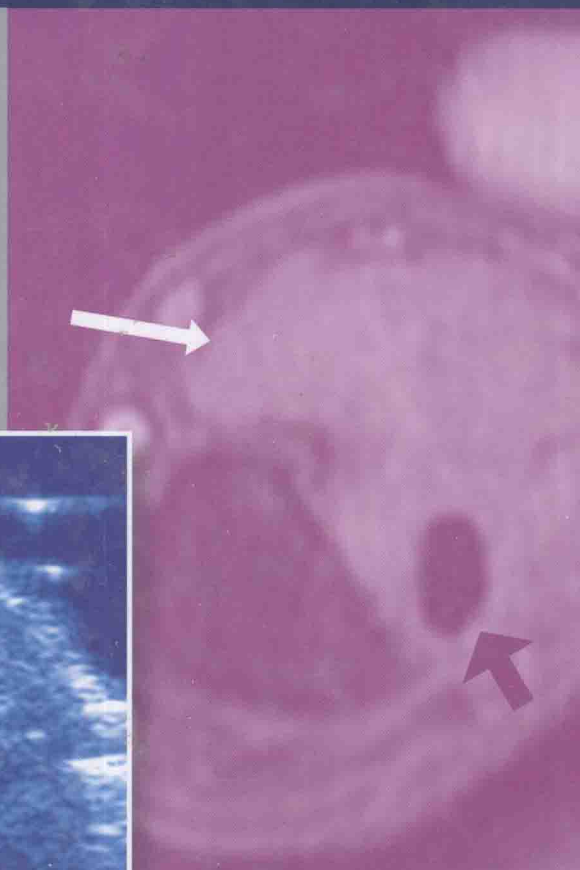
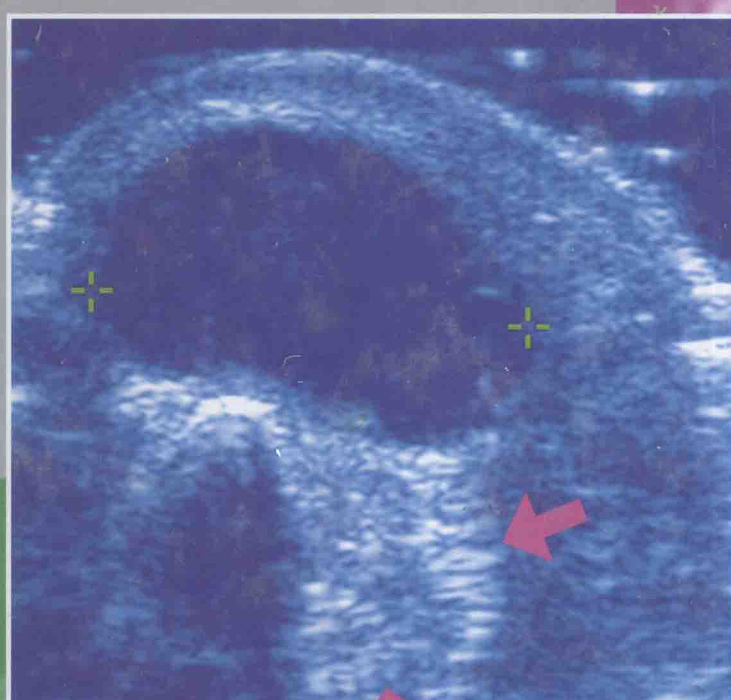
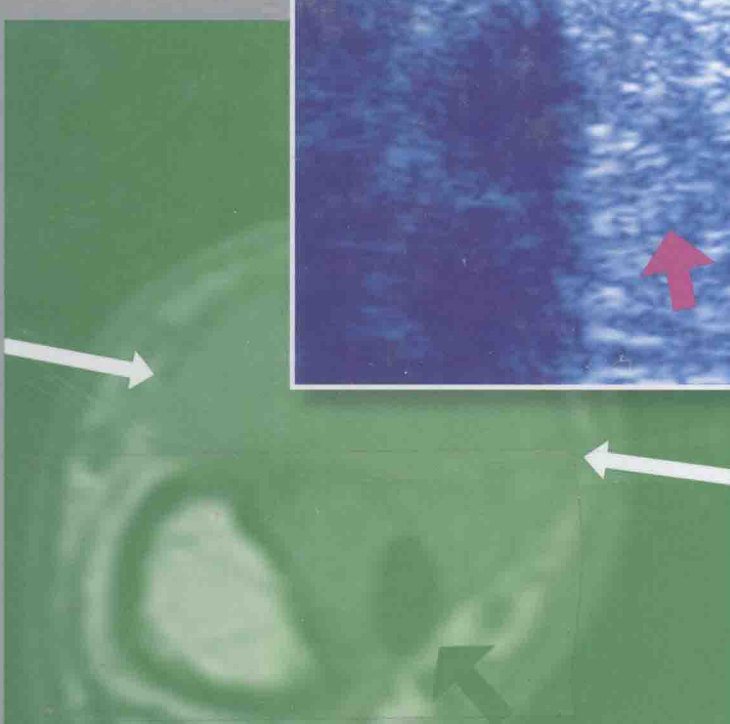
Musculoskeletal Ultrasound with MRI Correlations

Vikram S. Dogra
Diana Gaitini







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Vikram S. Dogra, MD
Professor of Radiology
Director of Ultrasound
Associate Chair for Education and Research
Department of Imaging Sciences
University of Rochester Medical Center
Rochester, New York

Diana Gaitini, MD
Associate Clinical Professor
Director, Ultrasound Unit
Department of Medical Imaging
Rambam Medical Center and Faculty of Medicine
Technion, Israel Institute of Technology
Haifa, Israel

Associate Editor

Johnny U. V. Monu, MD
Professor
Department of Imaging Sciences
University of Rochester Medical Center
Rochester, New York

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This book is dedicated to all my teachers.

—VSD

This book is dedicated to my beloved family, for their support and encouragement, and to my wise teachers, for introducing me to the world of medical imaging.

—DG

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Preface

Imaging is an indispensable tool in the diagnosis and treatment of musculoskeletal disorders. Despite advances in magnetic resonance imaging (MRI) and computed tomographic (CT) imaging, ultrasound remains a useful imaging tool that boasts the advantage of real-time dynamic imaging, lack of radiation, and cost effectiveness. Musculoskeletal (MSK) ultrasound provides a multiplanar real-time high resolution imaging method for anatomy and pathology investigation. Ultrasound is a widely available and low-cost modality that in well-trained hands becomes an invaluable diagnostic tool. Although MRI is widely used in the Western world to diagnose MSK disorders, increasing healthcare costs are leading to a shift in utilizing ultrasound for MSK disorders, especially in the United States.

This book, *Musculoskeletal Ultrasound with MRI Correlations*, is presented in an atlas format. High-quality exemplary ultrasound images with MRI (and occasionally CT) correlation have been included to aid in the understanding of the different pathologies. The book is composed of 13 chapters. The chapters cover clinical indications; technical guidelines; normal anatomy; and degenerative, inflammatory, traumatic, tumoral, and miscellaneous pathologies. Pearls and pitfalls are included at the end of each chapter. The book details a practical, point-by-point checklist of how to perform MSK ultrasound.

We intended to present a well-organized and easy-to-read book, with key facts highlighted separately and in a bulleted style to facilitate learning. We hope and expect that this book will be a valuable addition to the technical know-how of MSK ultrasound as well as a pleasant reading at every level, during and after the training period in medical imaging. The information will be beneficial for sonographers, radiologists, orthopedic specialists, emergency medicine physicians, rheumatologists, and in-training physicians. Our goal was to provide a useful resource in their day-to-day practice.

We have assembled a group of leading MSK experts to contribute. This brings a global perspective to this book. Their valuable knowledge and experience in this field as well as their dedication and hard work allowed this project to materialize. We are very grateful to them.

Vikram S. Dogra, MD
Diana Gaitini, MD

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Contributors

Patricio Azocar, MD
Radiology Department
Hospital del Trabajador
Santiago, Chile

Ian Beggs, MB ChB, FRCR
Royal Infirmary of Edinburgh
Edinburgh, United Kingdom

Michael A. Bruno, MS, MD
Associate Professor of Radiology and Medicine
Department of Radiology
The Penn State Milton S. Hershey Medical Center
Hershey, Pennsylvania

Rethy Chhem, PhD
Adjunct Professor
Department of Radiology
Medical University of Vienna
Vienna, Austria

Tobias De Zordo, MD
Radiology Research Fellow
Department of Diagnostic Radiology and Nuclear Medicine
London Health Science Centre–University Hospital
London, Ontario
Department of Diagnostic Radiology
Medical University Innsbruck
Innsbruck, Austria

Vikram S. Dogra, MD
Professor of Radiology
Director of Ultrasound
Associate Chair for Education and Research
Department of Imaging Sciences
University of Rochester Medical Center
Rochester, New York

Elif Ergun, MD
Instructor in Radiology
Department of Radiology
Ankara Training and Research Hospital
Ankara, Turkey

Diana Gaitini, MD
Associate Clinical Professor
Director, Ultrasound Unit
Department of Medical Imaging
Rambam Medical Center and Faculty of Medicine
Technion, Israel Institute of Technology
Haifa, Israel

Gerd Gruber, Dr Med
Privat Docent
Atos-Klinik
Heidelberg, Germany

Werner Judmaier, MD
Institute of MR Imaging and Spectroscopy
Innsbruck University Hospital
Innsbruck, Austria

Andrea S. Klauser, MD
Associate Professor of Radiology
Department of Radiology
Medical University Innsbruck
Innsbruck, Austria

Werner Konermann, Dr Med
Chefarzt
Rotes Kreuz Krankenhaus Kassel
Gemeinnützige GmbH
Klinik für Orthopädie, Unfallchirurgie und Rehabilitative Medizin
Kassel, Germany

Pınar Koşar, MD
Instructor in Radiology
Department of Radiology
Ankara Training and Research Hospital
Ankara, Turkey

Robert R. Lopez-Ben, MD
Associate Professor
Department of Radiology
University of Alabama at Birmingham School of Medicine
Birmingham, Alabama

Daniela Militianu, MD
Director of the Musculoskeletal Unit
Deputy Director
Department of Medical Imaging
Rambam Health Care Campus
Haifa, Israel

Johnny U. V. Monu, MD
Professor
Department of Imaging Sciences
University of Rochester Medical Center
Rochester, New York

Khamis Al Muzahmi, MD
Senior Consultant
Department of Radiology
Khoula Hospital
Muscat, Sultanate of Oman

Alicia Nachtigal, MD
Director
Department of Medical imaging
Hillel Yaffe Medical Center
Hadera, Israel

Ashok Kumar Nath, MD
Senior Specialist
Department of Radiology
Khoula Hospital
Muscat, Sultanate of Oman

Siegfried Peer, MD
Professor of Radiology
Department of Radiology
Innsbruck University Hospital
Innsbruck, Austria

Cesare Romagnoli, MD
Department of Radiology
University of Western Ontario
London, Ontario
Canada

A. U. Sethu, MD
Senior Consultant
Department of Orthopedics
Khoula Hospital
Muscat, Sultanate of Oman

Seng Choe Tham, MD
Department of Diagnostic Radiology
Tan Tock Seng Hospital
Singapore

Ian Yu-Yan Tsou, MD, FRCR (UK)
Department of Radiology
Mount Elizabeth Hospital and Medical Centre
Singapore

Ahmet Tuncay Turgut, MD
Associate Professor of Radiology
Department of Radiology
Ankara Training and Research Hospital
Ankara, Turkey

Gervais K. L. Wansaicheong, MBBS
Department of Diagnostic Radiology
Tan Tock Seng Hospital
Singapore

Axel W. E. Wismueller, MD, PhD
Department of Radiology
University of Rochester
Rochester, New York

Jacobo Wortsman, MD
Department of Medicine
Southern Illinois University School of Medicine
Springfield, Illinois

Ximena Wortsman, MD
Radiology Department
Clinica Servet
Santiago, Chile

Contents

1 Imaging of the Shoulder

Diana Gaitini, Daniela Militianu, Alicia Nachtigal, and Vikram S. Dogra

Shoulder pain is a common complaint in patients over 40 years old and following trauma or infection, at any age. The underlying pathology is variable, from rotator cuff strain to full thickness rotator cuff tear, tendinosis, calcific tendonitis, acromioclavicular arthritis, and cervical radiculopathy. Similar symptoms and physical findings for different pathologic entities make the differential diagnosis a clinical challenge. Diagnosis and therapy, therefore, is increasingly dependent on medical imaging. Plain radiographs and arthrography have been the primary radiologic examinations used to distinguish among the different conditions. A cross-sectional imaging battery, including magnetic resonance imaging (MRI), spiral computerized tomography (CT), and ultrasound, has been incorporated in the routine clinical practice during the last two decades. The decision on which imaging test is the one to start with is in the hands of the clinician, who is not always aware of the advantages and limitations of each test. Our aim in this chapter is to illustrate the appearance of the normal shoulder and different pathologies on multiplanar modalities, emphasizing ultrasound advantages, such as availability and cost-effectiveness that makes it the modality of choice to start with in most patients.

Technical Guidelines and Normal Anatomy

Transducer and Equipment Capabilities

A shoulder examination is performed with a high-resolution linear array transducer. A 5 to 12 MHz and even higher frequency broad bandwidth is optimal; a lower 4 to 8 MHz frequency is useful in heavier patients. New software and hardware technologies such as tissue harmonic, compound, and extended field-of-view (FOV) imaging are essential for a technically successful shoulder examination; in fact, they have become standard techniques for musculoskeletal ultrasonography.

Patient Position

Patients are examined while seated on a revolving stool, which allows easy positioning during scanning. The examiner is seated on a wheeled chair in front of the patient.

Examination Protocol and Normal Anatomy

Shoulder sonography includes scanning the long tendon of the biceps brachialis, the rotator cuff tendon, which includes the subscapularis, infraspinatus, teres minor, and supraspinatus tendons, the glenohumeral joint, the spinoglenoid notch, and the acromioclavicular joint. The examination is completed with a series of dynamic maneuvers to assess rotator cuff impingement and glenohumeral joint fluid.

Transverse Image of the Bicipital Groove and Long Head of the Bicipital Tendon

The patient is seated facing the operator; his or her hands are placed palms up on the thighs. The operator places the transducer at the humeral head (**Fig. 1.1A**). In an axial scan, the bicipital groove appears as a concavity in the surface of the humeral head, detected as a hyperechoic line between the greater and lesser tuberosities. The groove is an anatomic landmark to differentiate between the subscapularis tendon, which is placed medially to it, from the laterally placed supraspinatus tendon. Within the groove, the long head of the biceps tendon is seen as a hyperechoic oval structure (**Fig. 1.1B**). Care should be taken to avoid probe stirring that might make the tendon appear hypoechoic due to anisotropy of normal tendons (**Fig. 1.1C**).

Longitudinal Image of the Bicipital Groove and Long Head of the Bicipital Tendon

The whole long biceps tendon is visualized from the humeral head extending as far down as the musculotendinous junction in the humeral shaft (**Fig. 1.2A**). The tendon reveals a fine fibril pattern (**Fig. 1.2B**).

Transverse Image of the Subscapularis Tendon

The patient is asked to externally rotate his or her arm with abduction of the forearm; the transducer is turned to a transverse position and moved medially from the bicipital groove (**Fig. 1.3A**). The subscapularis tendon is visualized as a band of medium-level echoes (**Fig. 1.3B**). The subdeltoid bursa, placed over the tendon, is seen as a thin convex echogenic line. Passive internal and external rotation helps in assessing integrity of the tendon.

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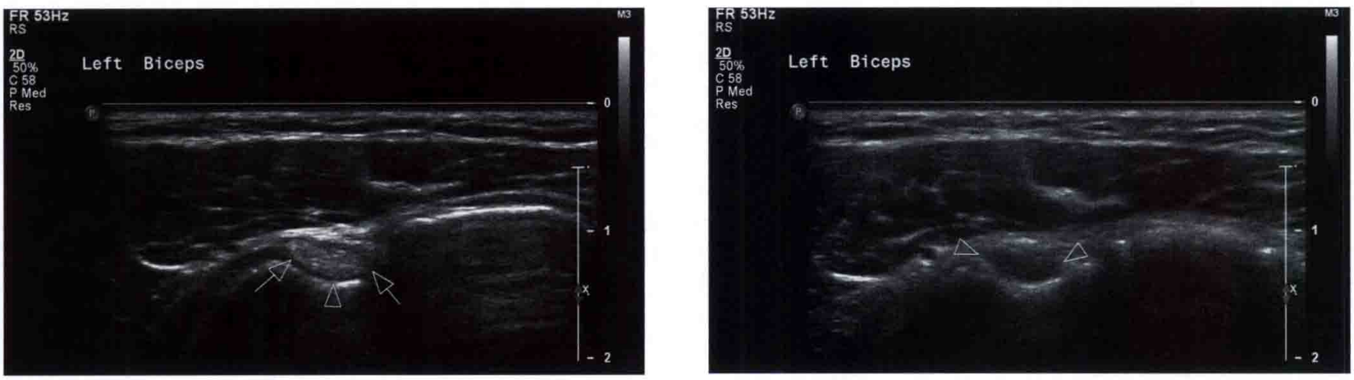
A

Fig. 1.1 Normal long head of the biceps tendon on transverse ultrasound view. **(A)** The probe positioning is over the anterior shoulder on the humeral head. **(B)** A transverse image of the long head of the biceps (*arrows*) that can be seen as a rounded hyperechogenic structure within the bicipital groove (*arrowhead*). **(C)** Tendon anisotropy. There is artifactual low echogenicity of normal biceps tendon (*arrowheads*), while tilting the transducer because of tendon anisotropy.



B

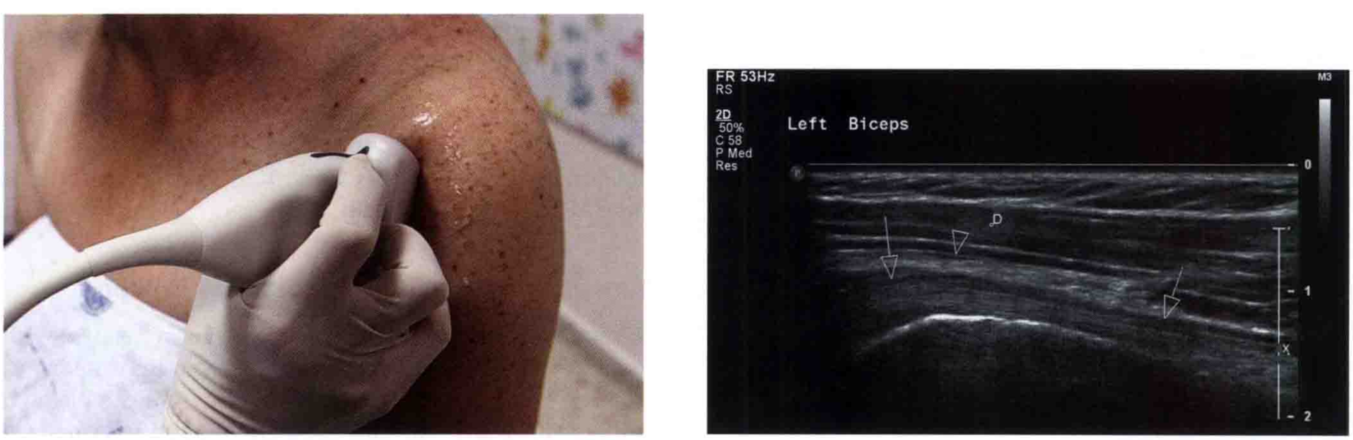
C

Longitudinal Image of the Subscapularis Tendon

The transducer is turned 90 degrees to scan perpendicularly to the tendon axis (**Fig. 1.4A**). The tendon is seen as several groups of fascicles in transverse orientation (**Fig. 1.4B**).

Transverse Image of the Infraspinatus and Teres Minor Tendons

The patient is rotated to be examined from the back, his or her hand is resting on the thigh or is elevated to the opposite



A

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Fig. 1.2 Normal long head of the biceps tendon on longitudinal ultrasound view. **(A)** The probe is positioned over the anterior shoulder on the humeral head. **(B)** The tendon is seen as a fine fibril structure laterally (*arrows*). The collapsed subacromial-subdeltoid bursa (*arrowhead*) can be seen between the tendon and the overlying deltoid muscle (D).

A


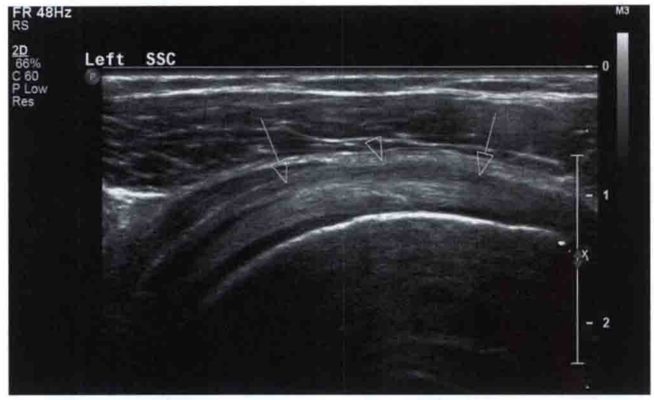

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Fig. 1.3 Normal subscapularis tendon on transverse ultrasound view. **(A)** The probe is positioned medial to the bicipital groove for an axial scan. Note the abduction of the patient's forearm. **(B)** The tendon has a convex superficial margin (*arrows*) and is outlined by the subacromial subdeltoid bursa (*arrowhead*), deep to the subdeltoid fat.

shoulder (**Fig. 1.5A**). The infraspinatus tendon appears as a beak-shaped soft tissue structure attaching to the greater tuberosity (**Fig. 1.5B**). Passive external and internal rotation is useful to examine the infraspinatus tendon. By moving the transducer distal on the humerus, the teres minor may be visualized as a trapezoidal structure, differentiated from the infraspinatus by its oblique internal echoes. This small tendon may be not scanned routinely.

Transverse Image of the Glenohumeral Joint

The transducer is moved slightly laterally to the infraspinatus tendon (**Fig. 1.6A**). The articular cartilage of the humeral head is seen as a thin hypoechogenic layer adjacent to the high-level echoes originating from the bony surface. A portion of the posterior glenoid labrum is seen as a hyperechoic triangular structure (**Fig. 1.6B**).

Transverse Image of the Spinoglenoid Notch

The transducer is moved medially to the glenohumeral joint (**Fig. 1.7A**). A slightly concave bone surface is seen, which contains the suprascapular artery, and beside it, the suprascapular nerve (**Fig. 1.7B**). The artery may be detected as a pulsating structure on grayscale ultrasound, better detected on color Doppler.

Transverse Image of the Supraspinatus Tendon

The patient is again seated facing the operator, his or her arm adducted and externally rotated, placing the hand on

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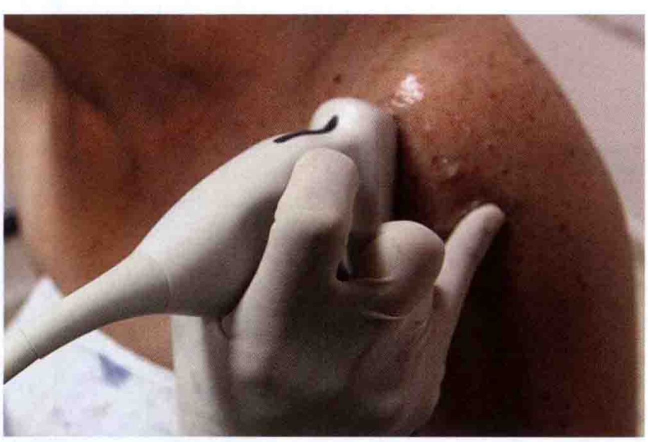

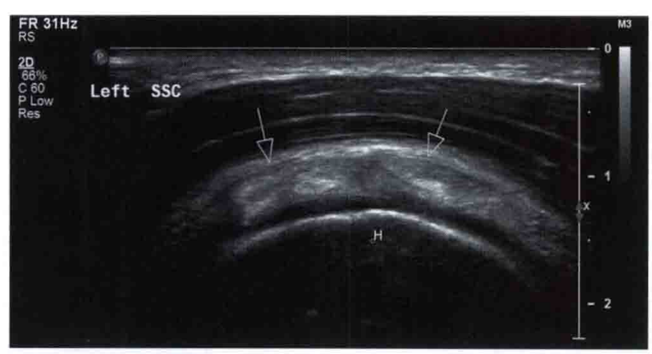

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Fig. 1.4 Normal subscapularis tendon on longitudinal ultrasound view. **(A)** The probe is positioned medial to the bicipital groove for a sagittal scan. **(B)** The tendon is seen as a convex cuff of fibers (*arrows*) over the underlying hypoechogenic cartilage and the echogenic line of the humeral head (H).

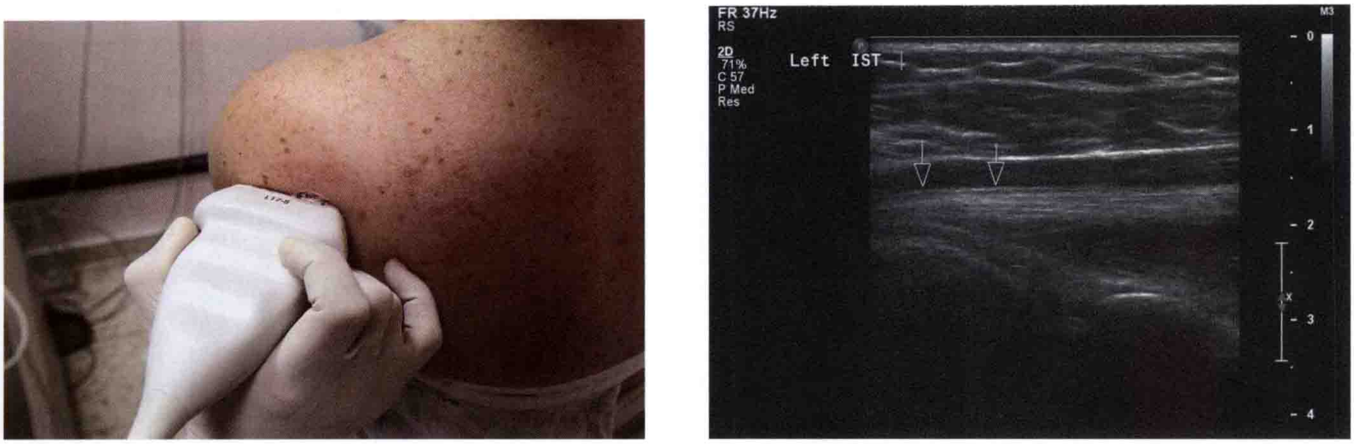
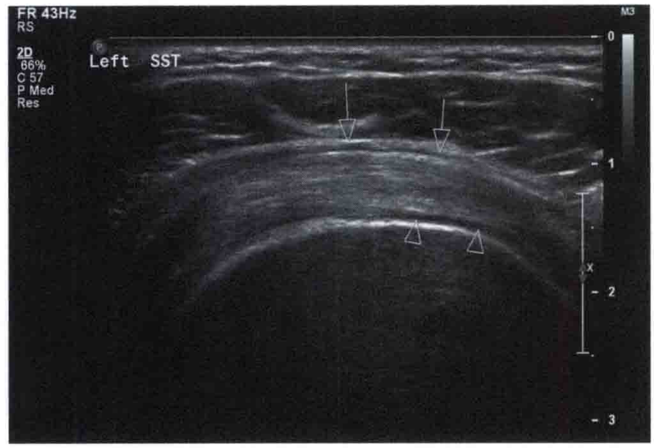


Fig. 1.5 Normal infraspinatus tendon. **(A)** The patient is examined from the back with his or her hand on the opposite shoulder. The probe position is over the posterolateral shoulder. **(B)** A beak-shaped fibril echogenic band (*arrows*) can be seen attached to the greater tuberosity.

Fig. 1.6 Normal glenohumeral joint. **(A)** The probe is positioned slightly lateral to the infraspinatus tendon. **(B)** A normal rounded hyperechoic contour of the posterior humeral head (H) is seen with hypoechogenic adjacent hyaline cartilage (*arrows*) opposite to the glenoid ridge (G). The normal posterior glenoid labrum is seen as a triangular hyperechoic structure in the depth of the joint (*arrowhead*).

Fig. 1.7 Normal spinoglenoid notch. **(A)** The probe is positioned medial to the joint. **(B)** A slightly concave bone surface (*arrow*) is seen medial to the glenohumeral joint.


A



B

Fig. 1.8 Normal supraspinatus tendon on transverse ultrasound view. **(A)** The probe is positioned lateral and posterior to the bicipital groove. Note the patient's arm is adducted and externally rotated, the hand placed backward on the waist on the opposite side. **(B)** The tendon is seen as a band of echogenic fibers, above the hypoechogenic hyaline cartilage on the humeral head (*arrowheads*) and deep to the thin hypoechogenic layer of the subdeltoid bursa and the echogenic subdeltoid fat (*arrows*).

the back or in the rear pocket with the palm against the body and the elbow directed posteriorly. The transducer is moved laterally from the bicipital groove, in a transverse position (**Fig. 1.8A**). The supraspinatus tendon is seen as a band of medium-level echoes (**Fig. 1.8B**). The convex echogenic line of the subdeltoid bursa is seen above the tendon. The hypoechoic layer of the articular cartilage and the bony layer of the humeral head and greater tuberosity are seen below it. The "critical zone" of the supraspinatus tendon is an area of relative avascularity, more susceptible to injury, and thus, essential to be visualized. It is located in the anterior part of the tendon, one centimeter posterolateral to the biceps tendon. The subacromial subdeltoid bursa is seen above the tendon as a very thin hypoechoic layer surrounded by hyperechoic peribursal fat. The bursa is no more than 2 mm thick including a thin internal layer of fluid.

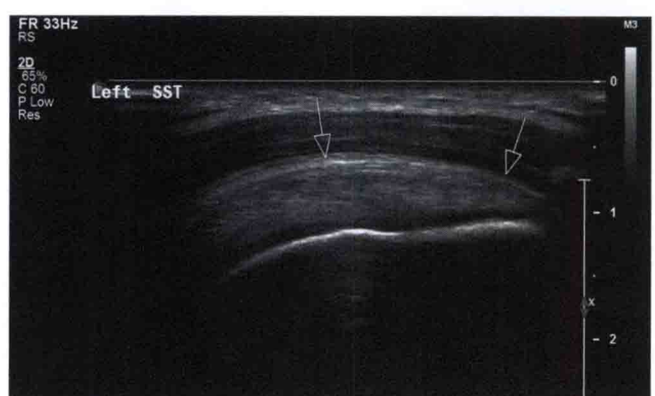
Longitudinal Image of the Supraspinatus Tendon

The transducer is turned 90 degrees to scan perpendicularly to the tendon axis (**Fig. 1.9A**). The tendon appears as a beak-shaped structure of medium-level echogenicity extending below the acromion to its attachment along the greater tuberosity (**Fig. 1.9B**).

Dynamic Maneuvers for Assessment of Rotator Cuff Impingement

The patient places his or her hand again over the thigh, palm up. The transducer is placed transversally over the acromion, the rotator cuff tendon seen below and lateral to the acromion. The patient is asked to raise his or her arm while in internal rotation, pointing the elbow up (**Fig. 1.10A**).

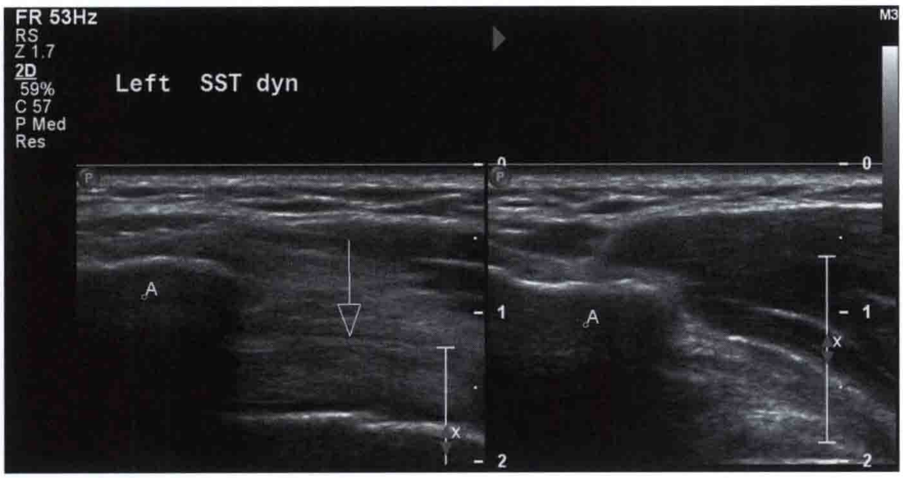

A



B

Fig. 1.9 Normal supraspinatus tendon on longitudinal ultrasound view. **(A)** The probe is positioned perpendicular to the tendon. **(B)** The "parrot-beak" appearance of the tendon (*arrow*) is seen in this view.

A B



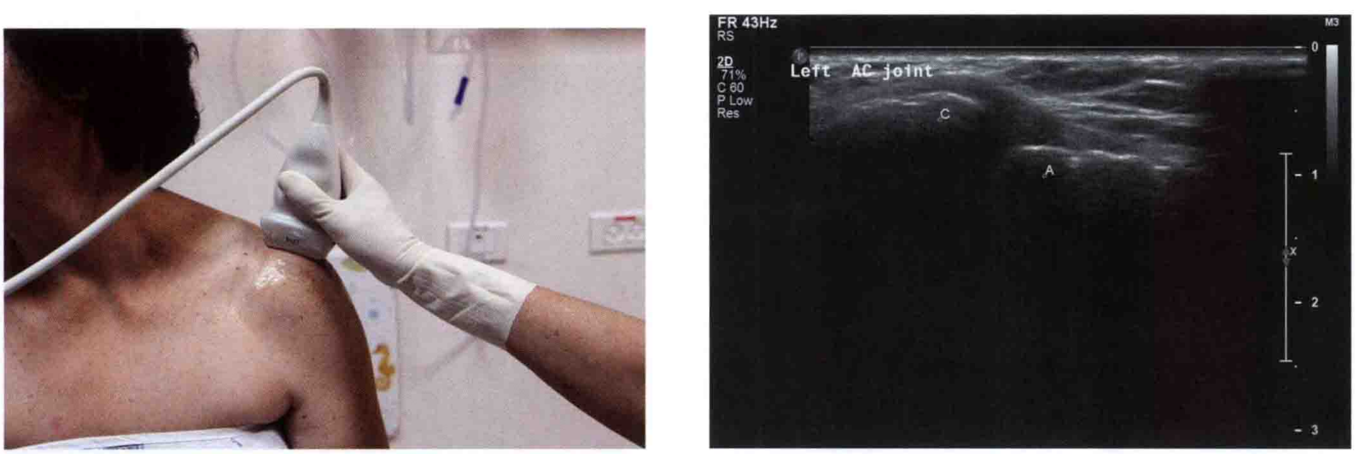
C

Fig. 1.10 Normal rotator cuff tendon on dynamic maneuvers. **(A)** The patient's elbow is raised. **(B)** The patient's arm is moved forward. **(C)** Left plot: the supraspinatus tendon (*arrow*) is seen under the acromion (A). Right plot: the tendon is hidden under the acromion (A) during a dynamic maneuver.

Afterward, the patient is asked to extend the arm with the palm facing backward and to move it forward (**Fig. 1.10B**). During these dynamic maneuvers, the tendon slides below the acromion being hidden by the bone acoustic shadow (**Fig. 1.10C**).

Transverse Image of the Acromioclavicular Joint

The patient turns his or her hand palm up on the thigh; the transducer is placed over the shoulder on a coronal plane (**Fig. 1.11A**). The bone echogenic lines of the clavicular dis-



A B

Fig. 1.11 Normal acromioclavicular joint. **(A)** The probe is positioned in a coronal plane over the shoulder. **(B)** On coronal view, the acromioclavicular ligament is seen as a hypoechogenic structure bridging the bone echogenic lines of the clavicle (C) and the acromion (A).

tal end and the acromion are seen bridged by a hypoechoic convex structure that represents the acromioclavicular ligament (**Fig. 1.11B**).

Pathologies

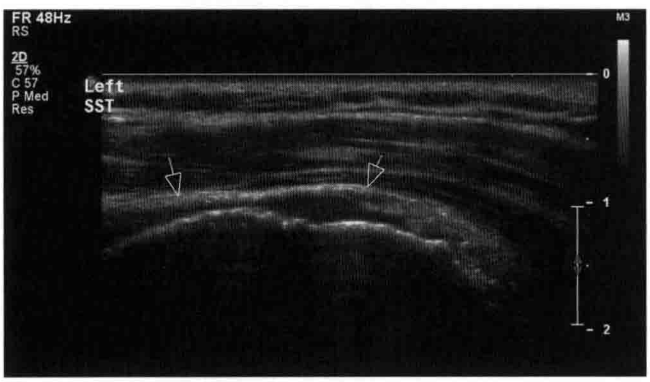
Rotator Cuff Tear

Full-Thickness Tear

A full-thickness tear leads to a total (large full-thickness tear) (**Figs. 1.12, 1.13**) or a focal (small full-thickness tear) (**Figs. 1.14, 1.15**) nonvisualization of the rotator cuff. The majority of focal full-thickness tears are located in the critical zone at the anterior part of the tendon (**Fig. 1.15**). The cuff is compressible by the transducer and the defect may be accentuated by extension and internal rotation of the arm. Full-thickness tears may be filled with synovial fluid or hyperechoic granulation tissue, hypertrophied synovium, or hemorrhage. Passive arm movement is helpful to confirm the absence of cuff tendon. Tears must be confirmed on two perpendicular planes.

Partial-Thickness Tear

A partial-thickness tear is a localized absence in the cuff involving either the articular (**Fig. 1.16**) or the bursal surface, the first being more common. It is seen as a hypoechoic or mixed hypo- and hyperechoic focal discontinuity, sharply demarcated from the surrounding normal cuff. An additional appearance is a large dominant linear echogenic focus within the cuff substance, with or without narrowing of cuff thickness. A partial tear must be confirmed on two orthogonal planes. An 82% positive predictive value and a 98% negative predictive value have been reported for the sonographic demonstration of rotator cuff tears.



A

Fig. 1.12 Supraspinatus tendon large full-thickness tear. **(A)** Transverse ultrasound view. The tendon is not seen and a thin layer of fluid fills the gap between the subdeltoid bursa (*arrows*) and the humeral head. **(B)** Coronal T1-weighted fast spin echo (FSE) and **(C)** coronal proton density (PD) FSE fat-suppressed (FS) magnetic resonance images demonstrate a complete tear and retraction of the supraspinatus tendon (*arrow*). Supraspinatus fat replacement due to muscle atrophy and upper subluxation of the humeral head are secondary findings.

B

C

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