MUSCULOSKELETAL ULTRASOUND CROSS-SECTIONAL ANATOMY
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To my parents, Louis and Antoinette Cianca, who gave me their unwavering support and confidence. Their selfless dedication to my growth and development enabled me to achieve my goals. My mother’s gentle and compassionate thoughtfulness and my father’s devotion to a job well done have inspired me and shaped me.

—John Cianca

To my mom, thank you for teaching me how to draw and for cultivating my love of art.

To Chloe, thank you for making me chase you, your energy never ceases to motivate me.

And most of all to my wife, Payal, thank you for your unequivocal love and support. You are my rock. Thank you for putting up with me and for encouraging me to pursue my passions.

—Shounuck Patel
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The field of musculoskeletal sonography has advanced rapidly during the past decade. Today, technological innovations, supportive research, and an accumulated collective clinical experience continue to inspire clinicians and sonographers to integrate this powerful modality into clinical practice. Many medical schools, residency programs, and fellowships now offer MSK sonography training as part of their standard curricula. The proliferation of MSK sonography has created a knowledge gap with respect to education. Although this gap has been narrowed by an increasing number of textbooks, online courses, and live educational experiences, there remains a need for a contemporary, high-quality MSK sonographic anatomical atlas. This atlas fulfills that need.

When I started learning MSK sonography in 2003, I was continually reminded by my mentors that anatomy was the key to MSK sonography—ANATOMY—ANATOMY—ANATOMY. Despite reading articles and textbooks and attending courses, the foundation of my MSK sonography training was built using a standard anatomy textbook while I scanned myself, someone else, or worked in the anatomy lab. In fact, it was only after truly understanding the sonographic anatomy that I could optimally benefit from reading those articles and textbooks, or attending those courses.

As an experienced sonologist, Dr. John Cianca also recognizes the importance of cross-sectional anatomy in the field of MSK sonography. When John informed me he was working on this project, I immediately acknowledged the need for a high-quality atlas demonstrating MSK sonographic cross-sectional anatomy. This atlas takes the user on a comprehensive ultrasound guided tour of the MSK system. The atlas is well organized, intuitive, and user friendly. Although it can be read “cover to cover” it is certainly not necessary to do so. The user can easily find an anatomic region of interest and rapidly learn or review the relevant sonographic anatomy. The combination of figures and extensively labeled ultrasound images is a differentiating factor among ultrasound texts. The emphasis on pattern recognition—echotextural differences between various tissue types—is appreciated. A major strength of this atlas is its wide scope of influence, as its content is equally applicable to both the medical
student initially learning MSK sonography and the experienced sonologist or sonographer needing to quickly review a specific region in the clinic.

I am privileged to contribute this foreword to Dr. Cianca’s *Musculoskeletal Ultrasound Cross-Sectional Anatomy*. This work represents a much-needed addition to the exciting and expanding field of MSK sonography. Although I regret that I did not have access to it during my initial MSK sonographic training, I am pleased that it is now available for everyone to learn from and use to improve the care of our patients. I will certainly have a copy on my shelf.

*Jay Smith, MD*
Rochester, Minnesota
Diagnostic and interventional sonography has become an important clinical tool for physicians treating musculoskeletal conditions. It is practical to use in the clinic setting and even in the field. It is cost-effective and provides point-of-care results. Furthermore, as a clinical imaging modality it is much more adaptable to a clinical question than other modalities. It has made my practice more informed and using sonography has brought anatomy to life in my office. Sonography is a very useful tool for those who desire to fill out and test the differential diagnosis that is created with history and physical examination.

Having taught musculoskeletal ultrasound for more than 10 years, I have become aware that learners often lack understanding of spatial relationships within an anatomic region. They need to develop visual acuity to cross-sectional anatomy, which is not a focus of teaching anatomy in medical school. However, this visual awareness is essential to being able to understand sonoographic images.

It is the aim of this atlas to use cross-sectional sonoographic images to promote a better understanding of clinical anatomy. Each image is accompanied by an illustration that serves as a road map to the image and highlights important structures. This will help the learner develop an eye for anatomic relationships in the body by comparing the sonograph to a more familiar format (the illustration). Furthermore, both image and illustration will make apparent the dynamic nature of these anatomic relationships.

One of the hurdles I have seen in mastering ultrasound as a diagnostic tool is learning to understand the spatial relationships of anatomic structures. One of the first things taught in training sonographers is the echogenic appearance of various tissues. This pattern recognition is critical to deciphering a sonographic image. This atlas will expand that pattern recognition to include all of the tissues in a cross-sectional image and each accompanying illustration provides a visual translation of the sonograph.

An ultrasound beam is remarkably thin and gives a very narrow field of view. When a structure is viewed in long axis, it is a very limited field of view indeed. However, when viewed
in short axis that field of view expands dramatically and becomes demonstrative of the regional anatomic relationships, albeit in a 1-mm slice. This is how a learner develops spatial awareness of a region. The cross-sectional images displayed in this atlas, many of which are extended field of view, were chosen to highlight important aspects of an anatomic region. There are also selected extended field of view images along the long axis of a structure to add another dimension to the area of study. Using an extended field of view image can make long axis imaging much more demonstrative of an entire structure. These images can be very striking in their illustrative nature. In some areas, this image can take on the visual magnitude of an axial MRI image.

I have identified cross-sections of each segment of the upper extremity and lower extremity that are important to understand as visual touchstones for anyone performing diagnostic sonography. Each is placed alongside an illustration that documents the structures in the sonograph. I am indebted to Shounuck Patel, DO, my coauthor. His artistic talent coupled with his understanding of anatomy will allow this atlas to be a guide to sonographers. Each illustration is a key that unlocks the content of the sonographic image it accompanies by translating each sonograph into the more common visual language of anatomy. These translations will enable the reader to assimilate the sonographs into their visual acumen and thus move forward in their use of musculoskeletal sonography.

There is also a legend for every image/illustration couplet that allows the user to identify individual structures in each. There is a body icon with the cursor in the location of each image/illustration couplet to help the reader localize the position of each sonograph. In addition to the normal anatomy, there are also a few images of pathology that demonstrate how pathology is represented in a sonograph.

My journey into diagnostic sonography has been wonder-filled and fascinating. I hope that you find this atlas helpful in guiding you to understand the complex and dynamic musculoskeletal relationships of the human body in a more complete spatial context.

John Cianca, MD
I would like to thank Christopher Visco, MD, and Jeffrey Strakowski, MD, for reviewing this work. Their thoughtful edits and insights have been invaluable.

I would also like to thank Sandra Shriner, MD; Kathy Travnicek, MD; Carolyn Kienstra, MD; Katie Cannizzaro, PT; Ugochi Azuike, MD; Barbara Trautner, MD; Cathy Thompson; Uzoh Ikpeama, MD; Phuong Nguyen; Alan Swearingen, MD; Angela Cortez, MD; Bao Van, MD; Joslyn John, MD; and Prathap Jayaram, MD, for their help in creating these images.

I would also like to thank Joe Stubenrauch and the staff at Demos Medical Publishing, LLC, for their technical support. Finally, I would like to thank Beth Barry, whose support gave me the courage to pursue this idea and whose patience with me allowed it to be completed.

John Cianca, MD

If I have seen further than others, it is by standing upon the shoulders of giants.

Isaac Newton

I would like to thank my influencers and mentors who have been instrumental in my learning art, anatomy, and ultrasound: Ila Patel; Jim Lee; Frank Netter, MD; Dennis Dowling, DO; Todd Stitik, MD; Patrick Foye, MD; Gautam Malhotra, MD; Susan Garstang, MD; Rex Ma, MD; Gerard Malanga, MD; Mooyeon Oh-Park, MD; Gary Chimes, MD; Chris Visco, MD; Mike Furman, MD; Jim Gilhool, DO; Marco Bodor, MD; Scott Primack, DO; and John Cianca, MD.

I would also like to thank Joslyn and Prathap for connecting me with John for this collaboration. John, thank you for this amazing opportunity and for opening all our eyes to this new perspective on musculoskeletal ultrasound. Finally, thank you to Beth; this project would not have been possible without your guidance and perseverance.

Shounuck Patel, DO
PART I

UPPER EXTREMITY

ABBREVIATIONS USED IN THIS SECTION

Muscles

<table>
<thead>
<tr>
<th>m1</th>
<th>Trapezius</th>
</tr>
</thead>
<tbody>
<tr>
<td>m2</td>
<td>Deltoid</td>
</tr>
<tr>
<td>m3</td>
<td>Subscapularis</td>
</tr>
<tr>
<td>m4</td>
<td>Latissimus dorsi</td>
</tr>
<tr>
<td>m5</td>
<td>Supraspinatus</td>
</tr>
<tr>
<td>m6</td>
<td>Infraspinatus</td>
</tr>
<tr>
<td>m7</td>
<td>Teres minor</td>
</tr>
<tr>
<td>m8</td>
<td>Teres major</td>
</tr>
<tr>
<td>m9</td>
<td>Biceps</td>
</tr>
<tr>
<td>m9L</td>
<td>Biceps long head</td>
</tr>
<tr>
<td>m9S</td>
<td>Biceps short head</td>
</tr>
<tr>
<td>m10</td>
<td>Coracobrachialis</td>
</tr>
<tr>
<td>m11</td>
<td>Pectoralis major</td>
</tr>
<tr>
<td>m11b</td>
<td>Pectoralis minor</td>
</tr>
<tr>
<td>m12</td>
<td>Brachialis</td>
</tr>
<tr>
<td>m13</td>
<td>Triceps</td>
</tr>
<tr>
<td>m13l</td>
<td>Triceps long head</td>
</tr>
<tr>
<td>m13l</td>
<td>Triceps lateral head</td>
</tr>
<tr>
<td>m13m</td>
<td>Triceps medial head</td>
</tr>
<tr>
<td>m14</td>
<td>Brachioradialis</td>
</tr>
<tr>
<td>m15</td>
<td>Extensor carpi radialis longus</td>
</tr>
<tr>
<td>m16</td>
<td>Extensor carpi radialis brevis</td>
</tr>
<tr>
<td>m17</td>
<td>Anconeus</td>
</tr>
<tr>
<td>m18</td>
<td>Extensor carpi ulnaris</td>
</tr>
<tr>
<td>m19</td>
<td>Extensor digiti minimi</td>
</tr>
<tr>
<td>m20</td>
<td>Extensor digitorum</td>
</tr>
<tr>
<td>m20i</td>
<td>Extensor indicis proprius</td>
</tr>
<tr>
<td>m21</td>
<td>Extensor pollicis longus</td>
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<tr>
<td>m22</td>
<td>Abductor pollicis longus</td>
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<td>m23</td>
<td>Extensor pollicis brevis</td>
</tr>
<tr>
<td>m24</td>
<td>Pronator teres</td>
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<tr>
<td>m25</td>
<td>Supinator</td>
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<td>m26</td>
<td>Flexor carpi radialis</td>
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<td>m27</td>
<td>Palmaris longus</td>
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<tr>
<td>m28</td>
<td>Flexor carpi ulnaris</td>
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<td>m29</td>
<td>Flexor digitorum superficialis</td>
</tr>
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<td>m30</td>
<td>Flexor digitorum profundus</td>
</tr>
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<td>m31</td>
<td>Flexor pollicis longus</td>
</tr>
<tr>
<td>m32</td>
<td>Pronator quadratus</td>
</tr>
<tr>
<td>m33</td>
<td>Flexor pollicis brevis</td>
</tr>
<tr>
<td>m34</td>
<td>Abductor pollicis brevis</td>
</tr>
<tr>
<td>CJT</td>
<td>Conjoint tendon (coracobrachialis/short head biceps)</td>
</tr>
<tr>
<td>apo</td>
<td>Triceps long head aponeurosis</td>
</tr>
<tr>
<td>pis</td>
<td>Posterior intermuscular septum</td>
</tr>
<tr>
<td>mis</td>
<td>Medial intermuscular septum</td>
</tr>
</tbody>
</table>

© Springer Publishing Company
The shoulder is a region with complex anatomical geometry. It can be challenging to interpret the spatial relations of the structures within the shoulder.

The superior and anterior regions of the shoulder are examined with the subject sitting upright or lying supine. The examiner is alongside the subject and the scans are in the coronal plane for the superior shoulder and transverse plane for the anterior shoulder.

The posterior and lateral aspects of the shoulder are examined with the subject sitting and facing the ultrasound machine while the examiner is positioned alongside but slightly behind the subject. Images are taken in the sagittal plane and in the transverse plane.

Several images of the rotator cuff are taken anterior to posterior in an arc that crosscuts the terminal aspects of the rotator cuff and as such are neither distinctly sagittal nor transverse.

**Superior and Anterior Shoulder**

1.1: Superior Shoulder ........................................... 4
1.2: Coracoacromial Arch ...................................... 6
1.3: Superior Rotator Interval .................................. 8
1.4: Rotator Interval Middle .................................. 10
1.5: Rotator Interval Distal ................................... 12
1.6: Rotator Interval at the Intertubercular Sulcus ................. 14
1.7: Biceps Musculotendinous Junction .................. 16
1.8: Biceps Musculotendinous Junction .................. 18

**Posterior Shoulder**

1.9: Medial Scapula Sagittal Plane ......................... 20
1.10: Lateral Scapula Sagittal Plane ....................... 22
1.11: Far Lateral Scapula Sagittal Plane .................. 24
1.12: Posterior Rotator Cuff Sagittal Plane .......... 26

**Rotator Cuff**

1.13: Rotator Cuff Tendons ................................. 28
1.14: Supraspinatus/Infraspinatus Tendons .......... 30
1.15: Greater Tuberosity Facets ............................. 32
1.16: Infraspinatus .............................................. 34
1.17: Supraspinatus .............................................. 36
1.18: Infraspinatus Insertion ................................. 38
1.19: Subscapularis .............................................. 40
1.20: Long Head of Biceps ................................. 42
1.1: Superior Shoulder

This is a coronal plane image of the superior shoulder. The acromioclavicular joint is seen in the center right portion of the image. The acromion is in the center and the clavicle to the right. Lateral to this on the left center portion of the image is the supraspinatus tendon with the subdeltoid bursal tissue and the deltoid muscle overlying it. The insertion of the supraspinatus can be seen on the greater tuberosity of the humerus.
Superior Shoulder

- m2: Deltoïd
- m5t: Supraspinatus
- SDB: Subdeltoid bursa
- b1a: Acromion
- b2: Clavicle
- b3: Humerus
- GT: Greater tuberosity
- right: Medial
- left: Lateral
- t: Tendon
1.2: Coracoacromial Arch

This image is taken anterior and inferior to Image 1.1. The deltoid muscle, as well as the pectoralis major and minor, can be seen in the superior right portion of the image. The center left side of the image reveals the coracoacromial arch. The acromion is to the left while the coracoid occupies the center of the image. The coracoacromial ligament can be seen traversing the two bony prominences and creating the coracoacromial arch. In the lower right-hand portion of the image the thoracic outlet is seen with the lateral, medial, and posterior chords of the brachial plexus surrounding the axillary artery underlying the pectoralis minor tendon as it approaches the coracoid process.
Coracoacromial Arch

- m2: Deltoid
- m5t: Supraspinatus
- m11: Pectoralis major
- m11bt: Pectoralis minor
- b1a: Acromion
- b1c: Coracoid process

- CAL: Coracoacromial ligament
- b3: Humerus
- BP: Brachial plexus
- BPlc: Lateral chord
- BPmc: Medial chord
- BPpc: Posterior chord
- v1a: Axillary artery
- right: Inferior
- left: Superior
- t: Tendon
1.3: Superior Rotator Interval

This is an extended field of view from medial to lateral over the superior aspect of the rotator interval. The pectoralis major and the subscapularis can be seen moving laterally from the right. The humerus is in the center inferior portion of the image. The long head of the biceps tendon sits atop the humerus over the articular surface. The coracohumeral ligament stretches over the top of the biceps tendon. On the lateral aspect of the image the deltoid muscle as well as the terminal aspect of the supraspinatus can be seen. The subdeltoid bursa underlies the deltoid muscle over the entirety of the rotator interval.
Superior Rotator Interval

- m2: Deltoid
- m3t: Subscapularis
- m5t: Supraspinatus
- m9L: Biceps
- m11: Pectoralis major
- SDB: Subdeltoid bursa
- CHL: Coracohumeral ligament
- right: Medial
- left: Lateral
- t: Tendon

- b3: Humerus
1.4: Rotator Interval Middle

This image spans the middle aspect of the rotator interval. The same structures are highlighted as in the previous image with the addition of the superior glenohumeral ligament. This structure is seen interposed between the biceps tendon and the humerus and together with the coracohumeral ligament form the reflection pulley of the long head of the biceps tendon.
Rotator Interval Middle

- **m2**: Deltoid
- **m3t**: Subscapularis
- **m5t**: Supraspinatus
- **m9L**: Biceps
- **m11**: Pectoralis major
- **SDB**: Subdeltoid bursa
- **b3**: Humerus
- **GT**: Greater tuberosity
- **LT**: Lesser tuberosity
- **CHL**: Coracohumeral ligament
- **SGHL**: Superior glenohumeral ligament
- **right**: Medial
- **left**: Lateral
- **t**: Tendon
1.5: Rotator Interval Distal

This image highlights the distal portion of the rotator interval. The long head of the biceps tendon is now in the proximal portion of the bicipital groove. Immediately lateral to it are the terminal fibers of the supraspinatus at greater tuberosity. The subscapularis tendon can be seen on the medial aspect of the biceps tendon. The right portion of the image represents the medial aspect of the shoulder. The pectoralis major and minor are seen overlying the conjoint tendon of the short head of the biceps tendon and the coracobrachialis as they originate from the coracoid process.
Rotator Interval Distal

- m2: Deltoid
- m3t: Subscapularis
- m5t: Supraspinatus
- m9Lt: Biceps
- m11: Pectoralis major
- m11b: Pectoralis minor
- CJT: Conjoined (coracobrachialis/short head biceps)
- b3: Humerus
- b1c: Coracoid process
- GT: Greater tuberosity
- LT: Lesser tuberosity
- right: Medial
- left: Lateral
- t: Tendon
1.6: Rotator Interval at the Intertubercular Sulcus

This is a close-up view of the distal rotator interval at the intertubercular sulcus.
Rotator Interval at the Intertubercular Sulcus

- m2: Deltoid
- m3t: Subscapularis
- m5t: Supraspinatus
- m9L: Biceps
- b3: Humerus
- GT: Greater tuberosity
- LT: Lesser tuberosity
- left: Lateral
- right: Medial
- t: Tendon
1.7: Biceps Musculotendinous Junction

This image and Image 1.8 focus on the terminal aspects of the biceps tendons as they exit the shoulder region. It shows the pectoralis major muscle forming its tendon and moving toward the humeral insertion point. The tendons of the long head and the short head of the biceps can be seen approaching their exit point from the shoulder. This is designated by the pectoralis major tendon insertion. In the lower right-hand portion of the image the musculocutaneous nerve can be seen on the most medial aspect of the coracobrachialis which underlies the short head of the biceps tendon. In the center inferior portion of the image the tendinous insertion of the latissimus dorsi can be seen just prior to the attachment onto the floor of the intertubercular groove of the humerus.
Biceps Musculotendinous Junction

- m2: Deltoid
- m4: Latissimus dorsi
- m9Lt: Biceps long head
- m9St: Biceps short head
- m10: Coracobrachialis
- m11t: Pectoralis major
- n3: Musculocutaneous nerve

right: Medial
left: Lateral
t: Tendon

b3: Humerus

m11t: Pectoralis major
m9Lt: Biceps long head
m9St: Biceps short head
m2: Deltoid
m4: Latissimus dorsi

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1.8: Biceps Musculotendinous Junction

This image and Image 1.7 focus on the terminal aspects of the biceps tendons as they exit the shoulder region. Here the pectoralis major can be seen arcing over both the long and short head tendons of the biceps which are now side by side. The deltoid muscle occupies the upper third of the image. The lower third of the image contains the humerus to the left and the coracobrachialis muscle and tendon in the center right. The musculocutaneous nerve is seen in the center of the image at the most medial and superior aspect of the coracobrachialis. It will move laterally as scanning progresses distally.
Biceps Musculotendinous Junction

- m2: Deltoid
- m9Lt: Biceps long head
- m9St: Biceps short head
- m10: Coracobrachialis
- m10t: Coracobrachialis
- m11: Pectoralis major
- m11t: Pectoralis major
- b3: Humerus
- n3: Musculocutaneous nerve
- right: Medial
- left: Lateral
- t: Tendon
1.9: Medial Scapula Sagittal Plane

This is the most medial of the images. The trapezius can be seen on the left-hand side of the image overlying the supraspinatus muscle. In the center left of the image is the scapular spine, which separates the supraspinatus from the infraspinatus. The infraspinatus sits in the infraspinatus fossa of the scapula. Immediately distal to this is the origin of the teres minor.
Medial Scapula Sagittal Plane

- m1: Trapezius
- m5: Supraspinatus
- m6: Infraspinatus
- m7: Teres minor
- b1: Scapula
- b1s: Scapular spine
- right: Inferior
- left: Superior