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HUMAN ANATOMY

Anatomical structure and nerve branching pattern of the human infraspinatus muscle

Philip A. Fabrizio, PT, MS, DPT [a,*], F. Richard Clemente, PT, PhD [b]

[a] *Department of Physical Therapy, College of Pharmacy and Health Sciences, Mercer University, 3001 Mercer University Drive, Atlanta, GA 30341-4155, USA*
[b] *Department of Physical Therapy, Duquesne University, Pittsburgh, PA, USA*

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Summary The function of the infraspinatus muscle, critical to rotator cuff function, is dependent upon the muscle's structure and innervation pattern. The morphology of the infraspinatus muscle has been inconsistently described in the literature. Additionally, the branching pattern of the suprascapular nerve in the infraspinous fossa has not been addressed in the literature. The purposes of this study were to determine: the arrangement of the infraspinatus muscle bellies; the branching patterns of the suprascapular nerve to the infraspinatus muscle; if the infraspinatus muscle was composed the neuromuscular compartments. Forty-eight infraspinatus muscles from 24 embalmed cadavers were studied using standard dissection techniques to determine morphological characteristics and innervation patterns. Results demonstrated that the infraspinatus muscles were comprised of three separate muscular partitions with each partition residing in a thin fascial compartment but all residing deep to the posterior scapular fascia. A first order suprascapular nerve branch was present in 91.6% of superior, 100% of middle, and 70.8% of inferior partitions. A first order nerve was present in all 3 muscular compartments of the same infraspinatus muscle in 62.5% of cases. Second order nerve branches were present in 8.3% of superior, 0% of middle, and 29.2% of inferior partitions. These findings help to determine a more complete and accurate understanding of the structure of the infraspinatus muscle. A better understanding of its structure could lead to a better understanding of the function of the muscle. Such information will enable more effective rehabilitation strategies for injuries involving the infraspinatus component of the rotator cuff.

* Corresponding author. Tel.: +1 678 547 6178; fax: +1 678 547 6202.
E-mail address: fabrizio_pa@mercer.edu (P.A. Fabrizio).

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Introduction

The gross anatomical structure of the infraspinatus muscle has been inconsistently described in the literature. Further, there are no reports in the literature that describe the branching pattern of the suprascapular nerve in the infraspinous fossa. Accurate descriptions of muscle morphology and motor innervation patterns can lead to a more accurate understanding of a muscle's function (Segal et al., 1991, 2002; English et al., 1993). However, there is a lack of consensus regarding the structure of the infraspinatus muscle and the motor innervation pattern has not been fully described for the infraspinatus muscle.

Current literature describes the gross anatomical appearance of the infraspinatus muscle as multipennate, bipennate, or being partitioned into two separate compartments (Keating et al., 1993; Johnson and Pedowitz, 2006; Bigliani and Flatow, 2005; Standring, 2008; Moore et al., 2010; Kato et al., 2011). The infraspinatus muscle has been described as being inseparably blended with the teres minor muscle and inserting together with the teres minor muscle on the posterior aspect of the greater tuberosity of the humerus, making the muscular separation difficult to differentiate (Morris and McMurrich, 1907; Heisler, 1920). However, Gray described a fibrous septum distinguishing the infraspinatus muscle from the teres minor muscle (Gray and Lewis, 1918). This fibrous septum arises from "an elevated ridge located along the lateral border of the dorsal surface of the scapula, which runs from the lower part of the glenoid cavity to the vertebral border and 2.5 inches above the inferior angle" (Gray and Lewis, 1918). The infraspinatus muscle has also been described as having two bellies connected by a central raphe where the superior muscle belly represents the infraspinatus muscle while the inferior belly represents the teres minor muscle (Bigliani and Flatow, 2005; Johnson and Pedowitz, 2006; Heisler, 1920). Bigliani and Flatow described the infraspinatus muscle as "bipennate and when three groups of muscle fibers can be seen, the upper two represent the infraspinatus muscle and the lower separation represents the teres minor muscle" (Bigliani and Flatow, 2005). The authors further distinguish the two muscles according to their distal attachments with the infraspinatus muscle inserting on the middle facet of the greater tuberosity of the humerus and the teres minor muscle inserting on a distinct smaller facet, which is inferior and typically palpable (Bigliani and Flatow, 2005). Heisler also reported that the infraspinatus muscle can sometimes be divided into upper and lower portions (Heisler, 1920). Dwight et al. described the infraspinatus muscle as arising from the infraspinous fossa and infraspinatus fascia. Further, a variation of the infraspinatus muscle was described, where the upper portion of the muscle may be distinctly separated from the rest of the muscle and termed it the "infraspinatus minor" muscle (Dwight et al., 1907). Recently, the infraspinatus muscle has been described as consisting of two parts, an oblique portion and a transverse portion (Kato et al., 2011). Kato et al. described the transverse portion as arising from the scapular spine and attaching into a common tendon while the oblique portion was depicted as arising from the infraspinous fossa and attaching distally to the greater tuberosity of the humerus (Kato et al., 2011).

The course and number of primary nerve branches arising from the suprascapular nerve and innervating the infraspinatus muscle have not been clearly addressed in the literature. The suprascapular nerve typically passes into the supraspinous fossa by passing superior to the scapular notch, inferior to the superior transverse scapular ligament. As it passes through the supraspinous fossa the suprascapular nerve supplies two motor branches to the supraspinatus muscle (Warner et al., 1992). The suprascapular nerve leaves the supraspinous fossa by passing through the spinoglenoid notch, enters the infraspinous fossa and distributes branches to the infraspinatus muscle. The specific branching pattern of the suprascapular nerve to the infraspinatus muscle has been inconsistently described as two motor branches (Ozer et al., 1995; Standring, 2008) or three to four motor branches (Warner et al., 1992).

One way of examining the gross morphology and motor innervation pattern of a muscle is to determine the neuromuscular partitioning of the muscle. Neuromuscular partitioning is defined by two criteria. One criterion is the specific architectural characteristics of the muscle such as muscle fiber angle and direction and the existence of tendinous boundaries within the muscle. The second criterion is that the innervation to the partitioned regions of the muscle is from a primary nerve branch (English et al., 1993; Segal et al., 2002).

Neuromuscular partitioning has been demonstrated in some upper and lower extremity human skeletal muscles (Romeny et al., 1984; Segal et al., 1991, 2002; Wolf et al., 1992). The results of work by Romeny et al. indicate that there is a correlation between neuromuscular compartments in the biceps brachii muscle and the motions of elbow flexion and supination (Romeny et al., 1984). The lateral compartment of the biceps brachii muscle showed more electrical activity during elbow flexion, while the medial compartment showed electrical activity during forearm supination or during the linear combination of elbow flexion and forearm supination (Romeny et al., 1984). The central part of the muscle showed more electrical activity during the nonlinear combination of elbow flexion and forearm supination than in any other motions monitored in the study (Romeny et al., 1984). A consistent pattern neuromuscular compartmentalization was described for the flexor carpi radialis muscle (FCR) and the extensor carpi radialis longus muscle (ECRL) (Segal et al., 1991). The pattern of motor innervation of the FCR divides the muscle into three neuromuscular compartments. The proximal division of the primary motor branch innervates the lateral and intermediate fibers of the FCR, and the distal division of the primary motor branch innervates the medial fibers of the FCR. Similar discrete partitioning was also shown to occur in the ECRL. The superficial head of the ECRL is supplied by the distal division of the primary motor branch, and the deep head by the proximal division of the primary motor branch (Segal et al., 1991). Wolf, Segal and English were able to selectively activate the lateral head of the human gastrocnemius muscle while the subjects performed functional tasks (Wolf et al., 1992). Their research suggested that partitions within the gastrocnemius, a two joint muscle, displays selectively different levels of muscle activity depending on the motor