VOLUMETRIC MEASUREMENT OF THE SUBACROMIAL SPACE AT THE SHOULDER

[1]Paula M Ludewig, [2]Edward Gonda, and [3]Fred A Wentorf
[1]Program in Physical Therapy, [2]Biomedical Engineering, and [3]Department of Orthopaedics
University of Minnesota, Minneapolis, MN; email: ludew001@umn.edu

INTRODUCTION

Shoulder pain is a common and debilitating condition. One theorized mechanism for the development of shoulder pain and associated rotator cuff tendonitis is compression of the soft tissues within the subacromial space of the shoulder as the arm is elevated. However, current methods of subacromial space measurement are limited. The purpose of this study was to develop and validate a volumetric description of the subacromial space at the shoulder, and describe changes in this space during passive humeral scapular plane abduction.

METHODS

The subacromial volume was defined as an extension of the supraspinatus outlet area described by Zuckerman et al.[1] Shoulder anatomical landmarks for 3 cadaveric specimens and an anatomical shoulder model were digitized in 3-D from CT scans (1mm contiguous helical slices) of the scapula and humerus with the arm in a neutral position (at side). Sets of 3 specific anatomical landmarks were used to define planes representing superior, medial, lateral, anterior and posterior borders of the subacromial space (Figure 1). Sequential triangular volumes were defined within the space and summed to define the overall volume (Vo). This volume is then further subdivided into anterior (Va), middle (Vm), and posterior (Vp) subvolumes representative of specific anatomic subcomponents of the subacromial space.

A portion of the humeral head crosses the plane defining the lateral border of the Vo, and the volume of this intersecting portion of the humerus is determined (Vi). Finally, Vo-Vi = the remaining space available to accommodate the rotator cuff soft tissues (Vr). Reductions in this remaining volume may increase impingement risk. Motion data is also collected for each specimen using 3-D electromagnetic motion sensors rigidly fixed to the bony segments via intercortical pins. Registration blocks which can be defined in the sensor frames by surface digitizing and are visible in the CT are used to build reference frames linking the motion data to the CT anatomical data.[2] The Vi and Vr can then be calculated in multiple arm positions using matrix transformations from the sensor data to rotate the anatomical data. Motion and CT data from 1 cadaver were used to describe these changing volumes

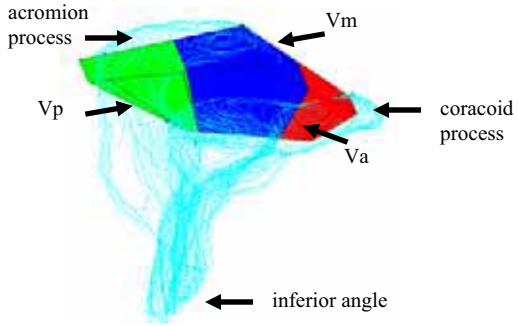

Figure 1. Superior/medial view of the subacromial volume superimposed on the scapula.

at neutral, 40°, 60°, 90°, and 120° of humeral scapular plane abduction relative to the thorax. For validation, the anatomical model was rigidly fixed in 2 positions, anatomical neutral and with the humerus abducted ~ 90° relative to the scapula. Sensor orientation data and CT scans were collected in both positions. Volume measures calculated from the rotated anatomical data (experimental method) were compared to calculations based on the CT scan in the second position (criterion reference).

RESULTS AND DISCUSSION

The available subacromial volumes prior to considering humeral intersection are represented in Table 1. The Vr progressively decreased as humeral elevation increased with the smallest value at the 90° arm position, consistent with the clinically described position of shoulder impingement. The Vr then increased slightly in the 120° arm position (Table 2). The Vr calculated from the experimental method was 20.43 ml and the criterion reference value 20.45 ml, representing a 0.1% error. These volumetric measures may provide additional insight into mechanisms of development and rehabilitation for shoulder impingement syndrome.

REFERENCES

1. Zuckerman JD, et al. *J Shoulder Elbow Surg* **1**, 4-14, 1992.
2. Fischer KJ, et al. *J Biomech* **34**:377-383, 2001.

ACKNOWLEDGEMENTS

Funded by NIH/NICHD/NCMRR K01-HD42491.

Table 1. Non-intersected subacromial volumes (ml).

		Specimen			
Volume	**Model**	**# 1- Right Shoulder**	**# 2 - Right Shoulder**	**# 3 - Left Shoulder**	**Mean (SD)**
Overall	38.42	21.43	29.98	39.44	32.32 (8.41)
Middle	23.27	16.20	15.37	21.61	19.11 (3.92)
Anterior	4.84	1.56	2.47	4.68	3.39 (1.63)

Table 2. Remaining subacromial volumes (Vr -ml) across humeral elevation angles.

	Neutral	**40°**	**60°**	**90°**	**120°**
Middle	21.61	20.22	19.03	14.37	17.45
Anterior	4.68	3.90	3.29	0.17	2.59