TABLE E-1 Hypothesis 1: Clinical Signs and Tests Can Reliably Differentiate the So-Called Impingement Syndrome from Other Conditions

Study	Year	Type*	No. of Subjects	Support†	Critical Finding	Outcome‡
Neer and Hawkins signs						
Leroux et al.[1]	1995	I	55	NS	Sensitivity of clinical tests for "impingement syndrome" was satisfactory, but specificity was poor	Surgical findings
Frost et al.[2]	1999	II	73	NS	MRI findings of cuff pathology were not different for workers with and without impingement signs	MRI
Caliş et al.[3]	2000	II	120	NS	Neer sign was 89% sensitive and 31% specific. Hawkins sign was 92% sensitive and 25% specific	MRI
Litaker et al.[4]	2000	II	448	NS	Impingement sign was 97% sensitive and 9% specific	Arthrography
MacDonald et al.[5]	2000	I	85	NS	Neer sign was 75% sensitive and 48% specific. Hawkins sign was 92% sensitive and 44% specific	Arthroscopy
Valadie et al.[6]	2000	C	9	NS	Intra-articular contact of the supraspinatus with the posterosuperior glenoid was observed in all specimens in both Neer and Hawkins sign positions	Dissection
Roberts et al.[7]	2002	N	10	NS	Neer and Hawkins impingement signs in normal patients did not elicit mechanical contact between the rotator cuff and the acromion	MRI
Park et al.[8]	2005	I	552	NS	Neer sign was 68% sensitive and 69% specific. Hawkins sign was 72% sensitive and 66% specific	Arthroscopy
Ardic et al.[9]	2006	I	59	NS	Impingement signs were 78% sensitive and 50% specific	Sonography
Pappas et al.[10]	2006	N	8	NS	Intra-articular contact of the supraspinatus with the posterosuperior glenoid was observed in all subjects in both Neer and Hawkins sign positions. Rotator cuff contact with the acromion did not occur in any subject in the Neer position	MRI
Silva et al.[11]	2008	I	30	NS	Neer sign was 68% sensitive and 30% specific. Hawkins sign was 73% sensitive and 40% specific	MRI
Yamamoto et al.[12]	2009	C	8	NS	The Neer and Hawkins signs do not represent the same impingement mechanism	Dissection and/or pressure-sensitive film
Nomden et al.[13]	2009	I	91	NS	There was 74% agreement on the presence or absence of the impingement sign	Interobserver agreement
Michener et al.[14]	2009	I	55	NS	Neer sign was 81% sensitive and 54% specific. Hawkins sign was 63% sensitive and 62% specific	Surgical findings
Jia et al.[15]	2011	I	398	NS	Neer sign more often relates to contact of the rotator cuff with the superior aspect of glenoid than to contact between the rotator cuff and acromion	Arthroscopy
Kelly et al.[16]	2010	I	34	NS	Neer sign was 62% sensitive and 0% specific. Hawkins sign was 74% sensitive and 50% specific	Ultrasound
Bak et al.[17]	2010	I	52	NS	Neer sign was 70% sensitive and 36% specific. Hawkins sign was 83% sensitive and 23% specific	Ultrasound and arthroscopy
Injection test						
Partington and Broome[18]	1998	C	24	NS	Subacromial bursa injection was successful in 83% of shoulders, but in 63% of shoulders other structures were also infiltrated	Dissection
Kirkley et al.[19]	2002	II	30	NS	There was no significant correlation between the impingement test and the outcome following arthroscopic acromioplasty	WORC score

Yamakado[20]	2002	II	53	NS	Intended subacromial injections reached subacromial bursa alone in 38%, bursa and glenohumeral joint in 29%, glenohumeral joint in 4%, and deltoid in 21%	Radiographs
Mathews and Glousman[21]	2005	C	20	NS	Anterolateral injection of bursa accurate in 60%. Posterior injection of bursa accurate in 80%	Dissection
Hanchard et al.[22]	2006	C	7	S	Subacromial injection successful in 91% of cadavers with use of "optimized" technique	Dissection
Henkus et al.[23]	2006	II	33	NS	Anterior injection of bursa accurate in 69%. Posterior injection of bursa accurate in 76%. The deltoid, cuff, and glenohumeral joint were also injected	MRI
Rutten et al.[24]	2007	II	20	S	100% of subacromial injections successful	MRI of injected gadolinium
Kang et al.[25]	2008	II	60	NS	Accuracy of subacromial injection was 70% with no difference among the anterior, lateral, or posterior portals	Radiographs
Posterior capsular tightness as a confounder in Hawkins sign						
Harryman et al.[26]	1990	C	8	NS	Operative tightening of the posterior capsule increased the anterior or superior translation of the humeral head on flexion and cross-body movement	Electromagnetic spatial sensor
Muraki et al.[27]	2010	C	8	NS	Posteroinferior capsule tightening led to higher contact pressure under the subacromial arch when the arm was elevated and internally rotated	Pressure-sensitive film
Poitras et al.[28]	2010	C	10	Neither	Posteroinferior capsule tightening did not lead to higher contact pressure under the subacromial arch when the arm was elevated in neutral rotation	Pressure-sensitive film

*I = Level-I clinical study, II = Level-II clinical study, C = cadaver study, N = study of normal subjects. †NS = does not support hypothesis, and S = supports hypothesis. ‡MRI = magnetic resonance imaging, and WORC = Western Ontario Rotator Cuff Index.

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TABLE E-2 Hypothesis 2: Clinically Common Forms of Rotator Cuff Abnormality Are Caused by Contact with the Coracoacromial Arch

Study	Year	Type*	No. of Subjects	Support†	Critical Finding	Outcome‡
Animal studies						
Schneeberger et al.[1]	1998	A	28	NS	The type of partial tears that are most frequently observed in clinical practice, intratendinous and articular-side tears, were not seen in this model of subacromial impingement	Histology, biomechanical testing
Soslowsky et al.[2]	2002	A	108	NS	Without an additional factor, extrinsic compression alone may be insufficient to cause tendinosis	Histology
Location of partial-thickness tears						
Tuite and Rubin[3]	1998	II	110	NS	56 had partial tears only on the articular side, 16 involved only the bursal side, and 14 involved both surfaces	MRI and/or arthroscopy and bursoscopy
Sano et al.[4]	1999	C	76	NS	Degeneration was more prominent on the articular sides compared with the bursal side ($p < 0.0001$)	Histology
Kim et al.[5]	2010	O	360	NS	Degenerative cuff tears most commonly involve a posterior location, near the junction of the supraspinatus and infraspinatus, not an anterior location	Ultrasound

*A = animal study, II = Level II clinical study, C = cadaver study, and O = observational study. †NS = does not support hypothesis. ‡MRI = magnetic resonance imaging.

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TABLE E-3 Hypothesis 3: Contact Between the Coracoacromial Arch and the Rotator Cuff Does Not Occur in Normal Shoulders

Study	Year	Type*	No. of Subjects	Support†	Critical Finding	Outcome‡
Normal shoulders in cadavers						
Burns and Whipple[1]	1993	C	5	NS	In normal shoulders in cadavers, the supraspinatus tendon contacts acromion, especially in 30°-60° of flexion and internal rotation	Dissection
Flatow et al.[2]	1994	C	9	NS	In normal shoulders in cadavers, the acromion and distal supraspinatus are in closest proximity between 60° and 120° of elevation	Stereophotogrammetry
Brossmann et al.[3]	1996	C	3	NS	In normal shoulders in cadavers, the distal supraspinatus tendon contacts acromion, especially at 60° of flexion, 60° of abduction, and internal rotation	MRI
Parentis et al.[4]	2004	C	4	NS	In the coronal plane, internally rotated normal specimens revealed contact between the supraspinatus tendon and the lateral aspect of acromion	Stereophotogrammetry
Casino et al.[5]	2008	C	4	NS	In normal shoulders in cadavers, contact between supraspinatus and coracoacromial arch was seen at 50°-90° of elevation and 45°-70° of abduction	Spatial tracker and/or simulation
Su et al.[6]	2009	C	6	NS	Coracoacromial ligament section and acromioplasty led to an increase in anterosuperior translation of superiorly loaded humeral head	MTS
Yamamoto et al.[7]	2010	C	7	NS	In normal shoulders in cadavers, contact between the cuff tendons and the coracoacromial arch occurred during all motions	Flexible force sensor
Normal and abnormal shoulders in cadavers						

Lee et al.[8]	2001	C	40	NS	The contact geometry of the acromial undersurface with the underlying cuff was not significantly different between shoulders with and without a rotator cuff tear	Pressure-sensitive film
Normal shoulders in subjects						
De Maeseneer et al.[9]	2006	N	3	NS	Images of normal shoulder showing contact of cuff with arch with arm in neutral position	MRI
Campbell and Dunn[10]	2008	N	2	NS	Images of normal shoulder showing contact of cuff with arch with arm in neutral position	MRI
Rudez and Zanetti[11]	2008	N	1	NS	Images of normal shoulder showing contact of cuff with arch with arm in neutral position	MRI

*C = cadaver study, and N = study of normal subjects. †NS = does not support hypothesis. ‡MRI = magnetic resonance imaging, MTS = materials testing system.

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TABLE E-4 Hypothesis 4: Spurs on the Anterior Aspect of the Acromion Extend Beyond the Coracoacromial Ligament and Encroach on the Underlying Rotator Cuff

Study	Year	Type*	No. of Subjects	Support†	Critical Finding	Outcome‡
Sarkar et al.[1]	1990	H	11	NS	The cells and the matrix in the coracoacromial ligament suggest the chronic effects of strain on the ligament	Ultrastructural analysis
Ogata and Uhthoff[2]	1990	C	76	NS	The acromial spur was a result of enchondral bone formation caused by tensile forces transmitted through the ligament	Radiographs and/or histology
Burns and Whipple[3]	1993	C	5	NS	In normal cadavers, the coracoacromial ligament was stretched by the greater tuberosity passing beneath it	Dissection
Edelson and Luchs[4]	1995	C	750	NS	The hooked acromial configuration developed as a result of calcification of the coracoacromial ligament.	Dissection
Soslowsky et al.[5]	1996	C	16	NS	An in situ load existed in the coracoacromial ligaments of cadavers with and without cuff tears	MTS and/or optical image analysis
Shaffer et al.[6]	1997	C	28	NS	When released from the anterior portion of the acromion, the coracoacromial ligament could not be anatomically reattached in normal specimens	Dissection
Lee et al.[7]	2001	C	40	NS	The osseous spur develops in the coracoacromial ligament; the undersurface of the traction spur is usually congruent with the cuff	Dissection
Shah et al.[8]	2001	C	22	NS	Different shapes of acromion are acquired as a response to traction	Dissection
Chambler et al.[9]	2003	O	5	NS	In normal shoulders, the coracoacromial ligament was found to be under tension, a stimulus for acromial spur formation	Linear variable differential transformer
Chambler et al.[10]	2003	H	15	NS	Acromial insertion of the coracoacromial ligament involved in bone turnover; supports concept of spur formation being secondary in cuff tears	Quantitative enzyme analysis
Fealy et al.[11]	2005	C	56	NS	Spur formation always in the anterolateral band of the coracoacromial ligament, suggesting it is a major load-bearing structure	Dissection
Natsis et al.[12]	2007	C	423	NS	16% of scapulas had enthesophytes localized at the site of the coracoacromial ligament insertion on the	Dissection

					acromion	
Milz et al.[13]	2008	C	15	NS	The prominence of fibrocartilage at the acromial enthesis may relate to the frequency with which enthesophytes develop	Histology and/or immunolabeling
Wang et al.[14]	2009	N	50	NS	In normal shoulders, the coracoacromial ligament is maximally deformed by internal rotation and horizontal abduction	Ultrasound
Yamamoto et al.[15]	2010	C	7	NS	In normal shoulders in cadavers, bending of the coracoacromial ligament occurred during flexion, abduction, and horizontal abduction	Linear variable differential transformer

*H = histological and/or biochemical study, C = cadaver study, O = observational study, and N = study of normal subjects. †NS = does not support hypothesis. ‡MTS = materials testing system.

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TABLE E-5 Hypothesis 5: Successful Treatment of the Impingement Syndrome Requires Surgical Alteration of the Acromion and/or Coracoacromial Arch

Study	Year	Type *	Number of Subjects	Support †	Critical Finding	Outcome‡
Nonsurgical						
Hardy et al.[1]	1986	I	36	NS	Medical therapy (indomethacin or steroid injection) successfully treated patients with impingement syndrome	Relief of symptoms
Blair et al.[2]	1996	I	19	NS	Subacromial corticosteroid injections successfully treated patients with impingement syndrome	Pain, range of motion
Conroy and Hayes[3]	1998	I	14	NS	Joint mobilization, stretching, strengthening, and education successfully treated patients with impingement syndrome	Pain, function
Plafki et al.[4]	2000	I	50	NS	Subacromial corticosteroid injections successfully treated patients with impingement syndrome	Pain, function
Bang and Deyle[5]	2000	I	52	NS	Manual physical therapy combined with supervised exercise successfully treated patients with impingement syndrome	Pain, function, strength
Ludewig and Borstad[6]	2003	II	67	NS	Home exercise program successfully treated patients with impingement syndrome	Shoulder rating questionnaire
Akgun et al.[7]	2004	I	48	NS	Subacromial corticosteroid injections successfully treated patients with impingement syndrome	VAS pain scale, Constant score
Walther et al.[8]	2004	II	60	NS	Physical therapy program successfully treated patients with impingement syndrome	Constant score

Johansson et al.[9]	2005	I	85	NS	Acupuncture and home exercises successfully treated patients with impingement syndrome	3 shoulder disability measures
Alvarez et al.[10]	2005	I	58	NS	Subacromial injections with either steroid or local anesthetic alone successfully treated patients with impingement syndrome	WORC, ASES, DASH, range of motion
Paoloni et al.[11]	2005	I	53	NS	Continuous topical glyceryl trinitrate successfully treated patients with impingement syndrome	Shoulder pain, range of motion, strength
Aktas et al.[12]	2007	I	46	NS	Physical therapy successfully treated patients with impingement syndrome; electromagnetic therapy is of no additional benefit	Pain, Constant score, disability
Senbursa et al.[13]	2007	II	30	NS	Manual therapy with supervised exercises successfully treated patients with impingement syndrome.	Pain, range of motion, Neer questionnaire
Kachingwe et al.[14]	2008	II	33	NS	Glenohumeral mobilization and supervised exercises successfully treated patients with impingement syndrome	VAS, Neer and Hawkins signs, SPADI, range
Lombardi et al.[15]	2008	I	60	NS	Progressive resistance training successfully treated patients with impingement syndrome	SF-36, DASH, range of motion, Cybex
Østerås et al.[16]	2008	II	61	NS	High-grade exercise therapy successfully treated patients with impingement syndrome	Work absence
Cummins et al.[17]	2009	I	100	NS	Subacromial steroid injection and physical therapy successfully treated patients with impingement syndrome	ASES score, VAS pain score
Engebretsen et al.[18]	2009	I	104	NS	Supervised exercises successfully treated patients with impingement syndrome	SPADI

Ekeberg et al.[19]	2009	I	106	NS	Subacromial steroids or systemic steroids improved patients with rotator cuff disease	SPADI, WORC
Santamato et al.[20]	2009	II	70	NS	High-intensity laser therapy successfully treated patients with impingement syndrome	Constant score, SST, VAS pain scale
Yeldan et al.[21]	2009	II	67	NS	Exercise program with or without laser therapy successfully treated patients with impingement syndrome	Outcome measurements
Karthikeyan et al.[22]	2010	I	58	NS	Subacromial corticosteroid injections successfully treated patients with impingement syndrome	DASH, Oxford shoulder score
Osterås and Torstensen[23]	2010	II	61	NS	High-grade exercise therapy successfully treated patients with impingement syndrome	Shoulder rating questionnaire
Randomized controlled trials comparing acromioplasty with treatments that do not modify coracoacromial arch in treatment of impingement syndrome						
Brox et al.[24]	1993	I	125	NS	Arthroscopic acromioplasty did not significantly improve the outcome of patients with impingement syndrome in comparison with exercises	Neer score
Rahme et al.[25]	1998	I	42	NS	Open acromioplasty did not significantly improve the outcome of patients with impingement syndrome in comparison with physiotherapy	VAS pain score
Brox et al.[26]	1999	I	125	NS	Arthroscopic acromioplasty did not significantly improve the outcome of patients with impingement syndrome in comparison with	Neer score

					exercises	
Gartsman and O'Connor[27]	2004	I	93	NS	Arthroscopic acromioplasty did not significantly improve the outcome of arthroscopic repair in comparison with cuff repair without acromioplasty	ASES score
Haahr et al.[28]	2005	I	84	NS	Arthroscopic acromioplasty did not significantly improve the outcome of patients with impingement syndrome in comparison with exercises	Constant score, pain score, dysfunction
Haahr and Andersen[29]	2006	I	79	NS	Arthroscopic acromioplasty did not significantly improve the outcome of patients with impingement syndrome in comparison with exercises	Constant score, pain score, dysfunction
Milano et al.[30]	2007	I	80	NS	Arthroscopic acromioplasty did not significantly improve the outcome of arthroscopic repair in comparison to cuff repair without acromioplasty	DASH, Constant
Taverna et al.[31]	2007	I	60	NS	Arthroscopic acromioplasty did not significantly improve the outcome of cuff tendinosis in comparison with radiofrequency-based microtenotomy	ASES, Constant, UCLA
Henkus et al.[32]	2009	I	57	NS	Arthroscopic acromioplasty did not significantly improve the outcome of the impingement syndrome in comparison with arthroscopic bursectomy	Constant score, VAS pain scale
Ketola et al.[33]	2009	I	140	NS	Arthroscopic acromioplasty and exercises did not significantly improve the outcome of impingement syndrome in comparison with exercises alone	VAS pain score

*I = Level-I clinical study, and II = Level-II clinical study. †NS = does not support hypothesis. ‡WORC = Western Ontario Rotator Cuff Index, ASES = American Shoulder and Elbow Surgeons, VAS = visual analog scale, SF-36 = Short Form-36, DASH = Disabilities of the Arm, Shoulder and Hand, SST = Simple Shoulder Test, SPADI = Shoulder Pain and Disability Index, and UCLA = University of California at Los Angeles.

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