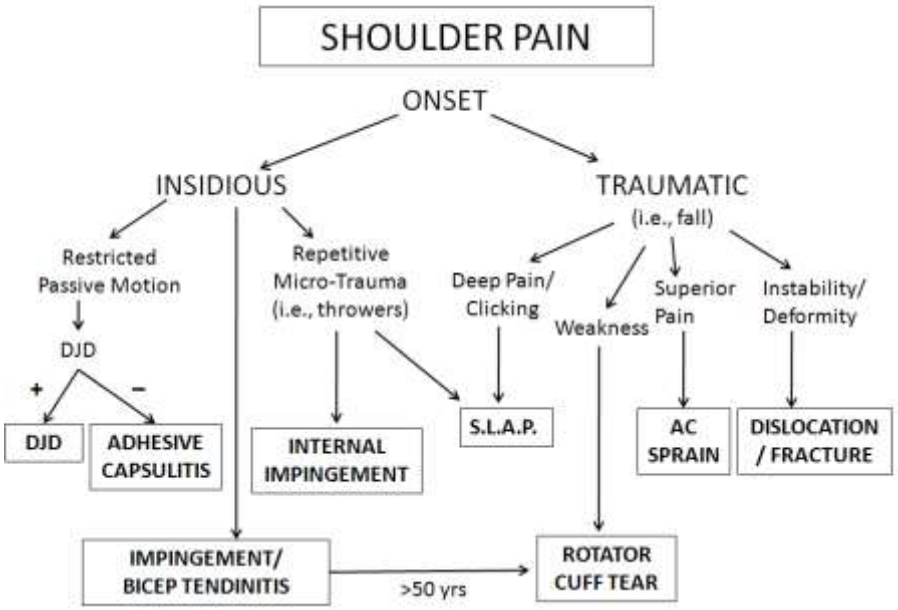
NASA-STD-3001 Medical Technical Brief

Shoulder Injury Overview & Treatment Guidance

OCHMO-MTB-006

Executive Summary

Shoulder pain is among the most common musculoskeletal complaints in the general population, after low back pain. Being the joint with the greatest range of motion, the shoulder often compromises stability for mobility and relies heavily on ligaments and muscles for steadiness and proper function. Because it lacks bony stability, it is the most common joint in the body to have dislocations, and the prevalence of accompanied disability is approximately 20%. Astronauts in particular have experienced a significantly higher number of these injuries from shoulder overuse as a result of the rigid biomechanics of wearing extravehicular activity (EVA) suits during training activities. These injuries may often adversely impact the performance of crew members making early detection and treatment a priority in order to minimize long term and permanent disabilities in addition to preventing the need for surgery.



Guideline Decision Flow Diagram

The evaluation of shoulder injury should occur upon initial symptoms at any point during an astronaut's training, pre-flight and post-flight missions. This flow diagram is meant to aid in the management of shoulder pain. The ultimate judgment for the course of action of a patient with shoulder pain is made by the physician in light of the presenting circumstances.

Ho AM, Goitz HT, Goitz RJ. *Examination of the Shoulder*. In Hand Surgery Update IV. Eds. Trumble TE, Budoff JE: American Society for Surgery of the Hand, 903-916, 2007.

Pathophysiology

Common Shoulder Injuries in Space Medicine

Numerous shoulder injuries have been reported in space medicine and the most common ones are summarized below. *Note, these guidelines are not meant to stand alone as a means for establishing a firm diagnosis but rather to aid in the management of shoulder pain.*

1. **Glenohumeral Joint Osteoarthritis:** This condition is a result of degenerative changes leading to loss of joint space resulting in shoulder pain. There is a loss of passive and active mobility that is often debilitating. In addition, instability, crepitus and a "catching" feeling are often reported. Pain usually prevents sleep and morning stiffness is often reported but usually found to improve throughout the day. The population usually affected is those greater than 40 years of age.
2. **Rotator Cuff Tear:** This involves the tearing of any of the four muscles that make up the rotator cuff either from an acute traumatic injury (common in patients younger than 40) or as a result of chronic overuse causing wear and tear (usually in those greater than 40). This condition prevents patients from doing overhead activity and exacerbating pain is often reported at night. Patients are unable to externally rotate the arm (infraspinatus involvement) and experience weakness or pain during the empty-can (supraspinatus involvement) or lift-off (subscapularis involvement) maneuvers.
3. **Biceps Tendinitis:** This is a condition where the tendon around the long head of the biceps muscle is inflamed causing pain to the anterior shoulder. This often occurs as a result of sudden overuse and pain is exacerbated by overhead movement. Palpating the bicipital groove often reproduces pain. It often occurs in conjunction with impingement syndrome or rotator cuff tear.
4. **Superior Labral Anterior Posterior (SLAP) Lesions:** This involves injury to the superior aspect of the labrum, the cuff of cartilage that extends from the glenoid cavity, where the biceps tendon attaches. As a result, symptoms often mimic impingement syndrome, biceps tendinitis, and AC joint pain, thus a high level of suspicion is necessary for diagnosis. Lesions usually result from trauma, such as falling onto outstretched arms or sudden upward or pulling motion of the shoulder, as well as repetitive shoulder movements. Movements of the shoulder may cause clicks or grinding and signs of instability.
5. **Acromioclavicular Joint Arthrosis:** This is a degenerative condition that destroys the articular cartilage of the AC joint. It typically will cause superior shoulder pain at the area of the AC joint and cross-body adduction reproduces pain.
6. **Subacromial Impingement Syndrome (SAIS):** This makes up the most common cause of shoulder pain. It involves impingement between the humeral head and acromion of tendons from the rotator cuff or biceps. It is characterized by anterior shoulder pain and difficulty with overhead activity.

From: Auckland Bone and Joint Surgery NZ

History and Physical Examination

Shoulder kinematics requires the coordinated action of multiple muscles at four different articulation points, making it essential to acquire the appropriate information that will aid in establishing a diagnosis. A good understanding of the muscles that comprise the shoulder and their role in allowing movements of the shoulder and arm will enable the clinician to build a solid differential diagnosis.

The first and most important aspect of evaluating shoulder pain is to complete a thorough history and physical exam. Appropriate history taking includes the patient's age, recreational factors, mechanism of injury, location, radiation, type of pain, onset, progression and duration, relieving and exacerbating factors. Associated symptoms such as stiffness, weakness, instability, clicking and sensory changes should also be noted. After completing a thorough history, a methodical physical exam of the shoulder must include the following components:

1. **Inspection:** Both extremities should be visualized from all angles with the patient exposed and muscle atrophy, swelling, deformities, skin findings (redness, ecchymosis) should be noted. The presence of atrophy suggests nerve entrapment or neuropathy. In addition, atrophy of the supraspinatus and infraspinatus implies a chronic rotator cuff injury.
2. **Palpation:** Numerous anatomical spots must be palpated in order to identify tender points, masses, warmth, and muscular integrity. Those include the clavicle, sternoclavicular and acromioclavicular joints, long head of the biceps and rotator cuff. Tenderness over the AC joint (the anterior, superior aspect of the shoulder) implies AC joint arthrosis. Lateral deltoid pain often implies a rotator cuff disorder whereas diffuse tenderness is more common in glenohumeral joint osteoarthritis. Tenderness over the bicipital groove suggests biceps tendinitis.
3. **Range of Motion (ROM):** The patient first performs active movements of the shoulder to determine the painful positions and to minimize further discomfort when passive range of motion is evaluated next. Those include abduction (0-180°), adduction (0-30°), flexion (0-180°), extension (0-60°), internal rotation (0-70°) and external rotation (0-90°) of the arm. Limited ROM, both active and passive, often accompanies glenohumeral joint osteoarthritis. However, preserved passive but absent active ROM implies rotator cuff involvement.
4. **Strength Testing:** Based on the movement that is painful or unable to be performed, having a sensible understanding of the shoulder girdle's anatomy and muscle involvements will allow clinicians to narrow their differential diagnosis. Weakness is often seen with rotator cuff disorders and glenohumeral osteoarthritis.
5. **Sensation:** Sensory testing involves light and deep touch, pain, temperature, vibration and proprioception. If any of these components are affected, involvement of the nervous system is probable. Next, distribution of the sensory deficit over dermatomes must be determined. A cervical etiology often produces numbness, tingling and pain that may radiate past the elbow. It is often difficult to differentiate between weakness as a result of pain or from a disturbance in the nerves innervating muscles of the shoulder. In these situations, anesthetic injections of the shoulder will only ameliorate pain if the cause is musculoskeletal in origin, helping to confirm diagnosis. It should not be expected to improve in the presence of nerve involvement.
6. **Provocative Testing:** This involves isolating specific shoulder muscles to diagnose pathology (see table on the following page).

Diagnostics

Diagnostic Workup of Common Shoulder Injuries Encountered in Space Medicine

POSSIBLE CAUSES	KEY FEATURES on HISTORY or PHYSICAL EXAMINATIOIN	PROVOCATIVE TESTING
Glenohumeral Joint Osteoarthritis	> 40 Years Crepitus, "Catching" Gradual Pain	Loss of Full ROM
Rotator Cuff Tear	Supraspinatus/Infraspinatus Muscle Atrophy Weakness Pain on Abduction Pain at Night	Empty-Can Test Lift-Off Test Drop-Arm Test
Biceps Tendonitis	Anterior Shoulder Pain / Aching Pain on Repetitive Overhead Motion, Pulling or Lifting	Point Tenderness Over Bicipital Groove
Superior Labral Anterior-Posterior (SLAP) Lesions	Anterior Glenohumeral Joint Pain Shoulder Instability	Crank Test O'Brien Test
Acromioclavicular (AC) Joint Arthropathy	Superior Shoulder Pain AC Joint Tenderness	Cross-Body Adduction Test
Subacromial Impingement	Pain with Overhead Activity Pain at Night	Hawkin's Test

Provocative Tests*

Cross-Body Adduction Test	**The affected arm is passively adducted across the chest towards the opposite shoulder. A positive test will reproduce the pain.**
Crank Test	The shoulder is abducted to 160°, then force is applied to the glenohumeral joint while externally rotating the arm. A test is positive if pain is reproduced and/or presence of clicking is noted.
Drop-Arm Test	The shoulder is abducted at 90°, then the patient is asked to slowly adduct the arm to the side of the body. A positive test will elicit pain or the patient will be unable to perform this maneuver slowly.
Empty-Can Test	Place both shoulders at 90° with the arms at a 30° internal rotation and thumbs pointing to the floor. Downward force is then applied to the arms as the patient resists movement. A positive test is indicated by pain or inability to keep the shoulder at 90° compared to the unaffected side.
Hawkin's Test	The humerus is flexed forward at 90°, the shoulder is then internally rotated by the examiner. A positive test will reproduce pain.
Lift-Off Test	The affected arm is internally rotated behind the back then the patient is asked to move the forearm away from the back against the examiner's force. A positive test is indicated by pain or inability to move the arm forward against resistance.
O'Brien Test	The shoulder is flexed at 90° and adducted to 15°. With the arm internally rotated and thumb pointing towards the floor, the patient resists downward force from the examiner. This is repeated with the arm externally rotated. A positive test is implied by pain with internal rotation and relieved during the external rotation maneuver.

**These tests are not pathognomonic for any one type of shoulder injury but should be used as a useful tool in the diagnostic process of identifying a cause.*

Treatment Guidelines

All astronauts complaining of shoulder pain should immediately notify their flight surgeon at the onset of symptoms in order to initiate prompt therapy and prevent disability. In addition to a proper history and physical exam, a shoulder ultrasound should be obtained as part of the initial work-up for early diagnosis and to tailor appropriate management of shoulder injuries. Conservative management, such as rest, ice, oral analgesics, physical rehabilitation, and anesthetic injections, should be the initial steps in managing shoulder injuries. Further imaging modalities should be postponed until several weeks of these modalities have been completed if no improvements are made or if the diagnosis remains unclear.

Indications for Diagnostic Imaging

Multiple imaging modalities are available to aid in diagnosing shoulder injuries, however, costs and timing of these studies must be taken into consideration. Musculoskeletal ultrasound has shown promise in evaluating shoulder pain and should be considered the initial imaging modality of choice when evaluating the cause of shoulder pain. For example, ultrasound is the best modality to diagnose biceps tendinitis. In addition, ultrasound is the most readily available imaging tool in space as a result of its compact nature and immediate diagnostic implications. In order to minimize radiation exposure in the astronaut population from routine shoulder x-rays and high costs associated with MRI, shoulder ultrasound has been a promising imaging alternative. In combination with a thorough history and physical exam, this imaging modality allows for the greatest likelihood of correctly diagnosing the etiology of shoulder pain.

Indications for Referral

Conservative management over a minimum period of 6 to 8 weeks should be prescribed prior to obtaining expert consultation, unless potentially serious conditions are implicated such as fractures, complete tear, nerve entrapment or septic joint in which case prompt workup and referral would be necessary. Prognosis of using a conservative approach is expected to decrease pain and improve shoulder function in the long run. If pain has not improved or worsens despite conservative care, or if the diagnosis remains unclear a shoulder MRI should be obtained. Orthopedic consultation should be sought after carefully reviewing available imaging results in addition to fully exhausting other forms of non-surgical management for the presumed diagnosis if conservative therapy alone is not sufficient.

Most patients with shoulder pain improve without requiring surgery or invasive testing by conservative management alone. Several therapeutic options are available in the management of shoulder injuries and treatment type will depend on the history and physical exam. The initial steps include conservative care and pain modulation. The application of ice immediately following musculoskeletal injuries or with chronic inflammation has proven effective in numerous studies as it diminishes edema, pain and inflammation. Other forms of therapy include anti-inflammatory medications, short-duration opiates, local anesthetics and activity modifications such as rest and avoiding activities that worsen the pain. In addition, special instructions from Astronaut Strength, Conditioning, and Rehabilitation Specialists (ASCRs) may be given based on the most likely mechanism of injury. These measures must be fully exhausted before surgical correction is pursued.

The ultimate goal is to control pain and restore complete function.

Treatment Guidelines

Shoulder Pain/Shoulder Care Recommendations:

Recommendation 1: Clinicians should conduct a focused history and physical exam.

Recommendation 2: Clinicians should not routinely obtain imaging or other diagnostic tests in patients with nonspecific shoulder pain. If history suggests possibility of fracture, proceed immediately to recommendation 3.

Recommendation 3: Clinicians should perform diagnostic imaging starting with a shoulder ultrasound and other appropriate tests when significant decrease in strength are present or when serious underlying conditions, such as septic joint, are suspected on the basis of history and physical exam. If shoulder pain has persisted after 8 weeks of appropriate conservative measures, an MRI of the shoulder should be obtained.

Recommendation 4: Clinicians should advise patients with evidence-based information on shoulder pain, self care options and to remain active.

Recommendation 5: Clinicians should consider the use of medications such as acetaminophen, non-steroidal anti-inflammatory drugs (NSAIDs) and/or injectable anesthetics as first line agents. Assess severity of pain, functional deficits in conjunction with potential benefits, risks and lack of long-term efficacy and safety data before initiating pharmacologic therapy.

Recommendation 6: Clinicians should consider providing non-pharmacologic therapy for those who did not improve with self-care options. In acute shoulder pain, therapy involves physical therapy and massage. For chronic should pain, intensive interdisciplinary rehabilitation is recommended.

Interventions

The specific type of intervention are to be made at the discretion of the clinical provider.

INTERVENTIONS	SHOULDER PAIN Duration:	ACUTE < 4 Weeks	CHRONIC > 4 Weeks
SELF CARE (Recommendation 4)	Activity Modification*	☑	☑
	ICE*	☑	
	Therapeutic Exercises*	☑	☑
PHARMACOLOGIC THERAPY (Recommendation 5)	Acetaminophen/NSAIDs*	☑	☑
	Muscle Relaxants	☑	
	Tramadol, Opioids	☑	☑
	Injectable Corticosteroids	☑	☑
NON-PHARMACOLOGIC THERAPY (Recommendation 6)	Physical Rehabilitation*	☑	☑
	Massage	☑	
	Transcutaneous Electrical Nerve Stimulation (TENS)*	☑	
	Phonophoresis*	☑	
	Intensive Interdisciplinary Rehabilitation		☑

**These therapeutic modalities are part of the Astronaut Strength and Conditioning Rehabilitation Specialist (ASCRS) standing orders*

History of Shoulder Injuries in Astronauts

There are currently no reported incidences of shoulder injuries occurring in-flight. However, a combination of the robust physical training regimen that NASA astronauts follow, as well as the potential cumulative musculoskeletal deconditioning effects of long-duration spaceflight missions, emphasizes the importance of monitoring and treating shoulder pain and injuries swiftly and appropriately.

Shoulder Injury Cases – Neutral Buoyance Laboratory (NBL) EVA Training

In 2002, a tiger team was formed to evaluate a potential correlation between shoulder injuries and EVA training at the NBL. A survey of 22 astronauts participating in EVA training at the NBL found that 64% experienced shoulder pain attributed to EVA training in the EMU, 14% with shoulder pain had injuries requiring surgical treatment, and 45% of the astronauts had preexisting remote shoulder injuries. Another evaluation of queried astronaut medical records (n=330) found that 40 injuries met the definition of shoulder injury associated with EVA training by the end of 2012. The overall shoulder injury incidence rate was 9.67 injuries per 100 astronauts over 10 years. It is important to note that the number of EVA training runs increased from 1.96 runs/year per astronaut from 1982-1996; to 5.08 runs/year per astronaut from 2003-2009.

Factors contributing to shoulder injuries suspected to be due to EVA training included:

- Limitations to shoulder mobility in the extravehicular mobility unit (EMU) hard upper torso (HUT)
- Performing overhead tasks
- Repetitive motion
- Heavy tools
- Performing tasks in inverted body positions
- Suboptimal suit fit
- Frequency of NBL training runs

Restricted scapulothoracic motion
From: *EMU Shoulder Injury Tiger Team Report (2003)*

Design of the EMU Planar HUT

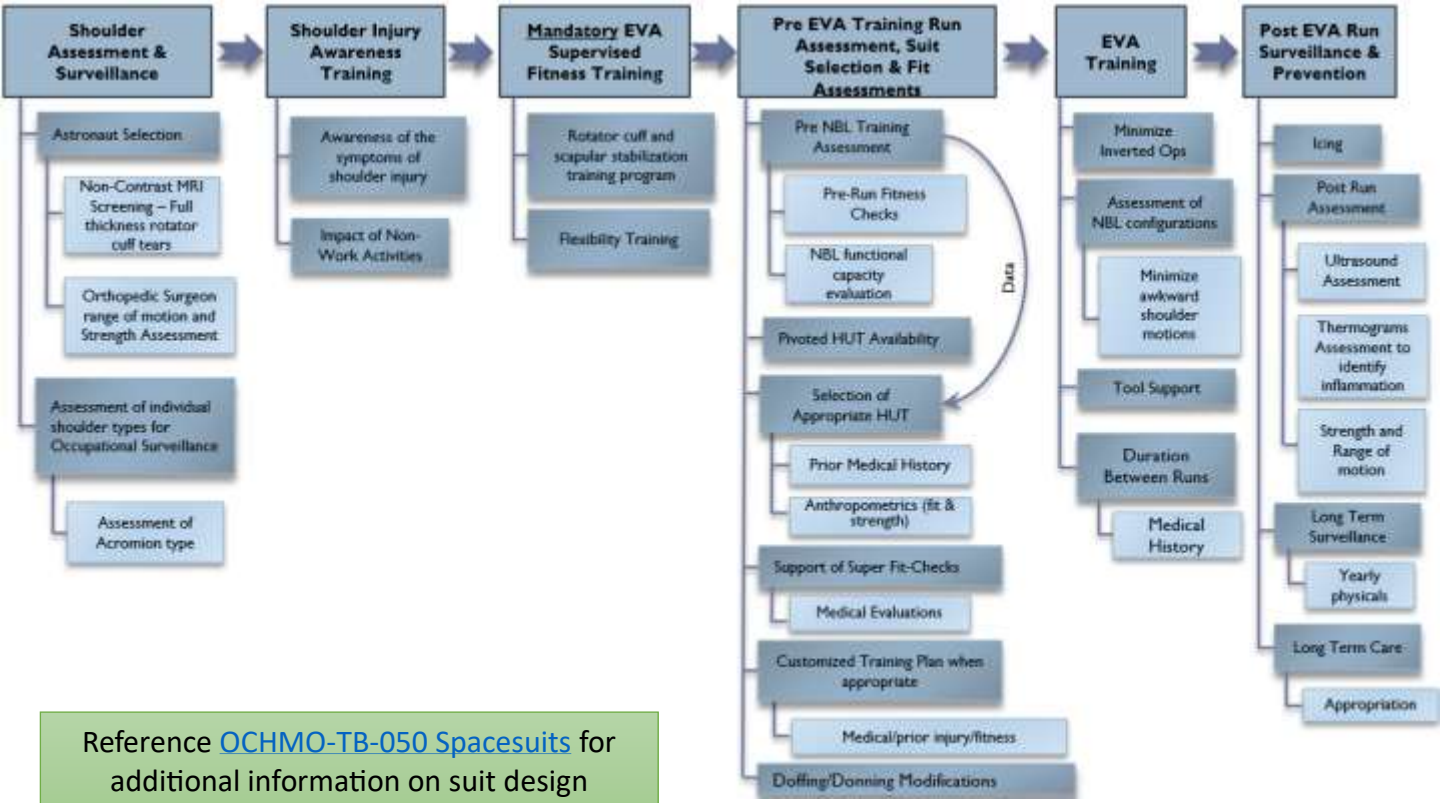
- The HUT shoulder design restricts the normal scapulothoracic motion of the shoulder joint, resulting in rotator cuff impingement in certain arm positions.
- Increases in internal rotation of the crewmember's shoulder joint leads to possible destabilization of the shoulder and limiting the rage of motion in certain arm positions.
- The Planar HUT design uses a standardized body seal closure and scye bearing. The size of these components restricts don/doff and mobility envelopes, and can increase the risk of shoulder injuries.
- The suit sizing algorithm, which was developed for the Pivoted HUT two decades ago, does not include all relevant measurements for fitting the crew and does not reflect the sizing requirements for the Planar HUT. Additionally, the suits were developed to accommodate the largest segment of the 5th to 95th percentile anthropometric standards.

Prevention of Shoulder Injuries

A multi-disciplinary team of experts at NASA generated a plan for prevention of crew shoulder injury with the primary goal "to have no more suit attributable shoulder injuries before the end of ISS" and a secondary goal to provide design criteria for future suit designs to greatly reduce the risk of injury attributable to the suit.
The resulting ***Integrated Shoulder Injury Prevention Project*** included the following areas of consideration and future work depicted in the graphic below.

A U.S. astronaut trains for an EVA at the NBL
Image: *NASA*

Integrated Shoulder Injury Prevention



Reference OCHMO-TB-050 Spacesuits for additional information on suit design considerations.

Level of Evidence for Recommendations

After a comprehensive literature review regarding the management and treatment of shoulder injuries, clinical recommendations made within these guidelines reached an evidence rating of B, Class IIa based on overall consensus, disease-oriented evidence, usual practice, expert opinion and case series. There is a lack of well-designed clinical trials proving the efficacy of the most commonly practiced treatments for shoulder pain. However, the primary approach of activity modification, ice, physical rehabilitation, medications, and injectable anesthetics continues to be the mainstay for managing shoulder injuries as it produces satisfactory results in the majority of patients.

Levels of Evidence

A: Date derived from multiple randomized clinical trials or meta-analyses
B: Data derived from a single randomized trial, or nonrandomized studies
C: Only consensus opinion of experts, case studies, or standard-of-care

Size of Treatment Effect

Estimate of Certainty (Precision) of Treatment Effect	Class I	Class IIa	Class IIb	Class III
	Benefit >>> Risk **Procedure/Treatment SHOULD be performed/ administered**	Benefit >> Risk Additional studies with focused objectives needed **IT IS REASONABLE to perform procedure/ administer treatment**	Benefit≥ Risk Additional studies with broad objectives needed; Additional registry data would be helpful **IT IS NOT UNREASONABLE to perform procedure/ administer treatment**	Risk ≥ Benefit No additional studies needed **Procedure/Treatment should NOT be performed/ administered SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**
Level A Multiple (3-5) population risk strata evaluated General consistency of direction and magnitude of effect	o Recommendation that procedure or treatment is useful/effective o Sufficient evidence from multiple randomized trials or meta-analyses	o Recommendation in favor of treatment or procedure being useful/effective o Some conflicting evidence from multiple randomized trials or meta-analyses	o Recommendation's usefulness/efficacy less well established o Greater conflicting evidence from multiple randomized trials or meta-analyses	o Recommendation that procedure or treatment not useful/effective and may be harmful o Sufficient evidence from multiple randomized trials or meta-analyses
Level B Limited (2-3) population risk strata evaluated	o Recommendation that procedure or treatment is useful/effective o Limited evidence from single randomized trial or non-randomized studies	o Recommendation in favor of treatment or procedure being useful/effective o Some conflicting evidence from single randomized trial or non-randomized studies	o Recommendation's usefulness/efficacy less well established o Greater conflicting evidence from single randomized trial or non-randomized studies	o Recommendation that procedure or treatment not useful/effective and may be harmful o Limited evidence from single randomized trial or non-randomized studies
Level C Very limited (1-2) population risk strata evaluated	o Recommendation that procedure or treatment is useful/effective o Only expert opinion, case studies, or standard-of-care	o Recommendation in favor of treatment or procedure being useful/effective o Only diverging expert opinion, case studies, or standard-of-care	o Recommendation's usefulness/efficacy less well established o Only diverging expert opinion, case studies, or standard-of-care	o Recommendation that procedure or treatment not useful/effective and may be harmful o Only expert opinion, case studies, or standard-of-care

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