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Untwining the intertwined: a comprehensive review on differentiating pathologies of the shoulder and spine

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Background: The anatomic interplay and overlap between the cervical spine and the shoulder constitutes a challenge for shoulder and spine surgeons, as symptoms of spine and shoulder pathologies are often similar and may lead to entity misdiagnosis.
Methods: PubMed, Cochrane, and Google Scholar (page 1-20) searches were updated to October 2023 in search of the qualified papers. Boolean Operators were used with a combination of the keywords “spine” OR “neck” And “Shoulder”. Furthermore, reference lists from papers were also searched to find literature.
Results: It is of pivotal importance to conduct comprehensive preoperative clinical investigation to appropriately evaluate and assess the source of the pathology and the leading causes behind it. Certain markers can help guide surgeons towards etiologies, and these include areas of pain and physical exam findings with the arm squeeze test having the highest sensitivity and specificity for diagnosing cervical radiculopathy. As for the shoulder, despite its low sensitivity, the Yergason test had the highest specificity for diagnosing subacromial impingement. Local anesthetic injection can help as well in the diagnostic approach. Moreover, the interplay between these anatomic locations is not solely related to preoperative diagnosis. Studies have shown that previous surgery for cervical spine pathology may negatively affect the outcomes of shoulder procedures like arthroplasties.
Conclusion: Shoulder and spine surgeons should be wary and vigilant of accurately diagnosing the etiology of the presenting symptoms to ensure proper management and optimize prognosis.

There is a close relationship between the shoulder and the spine. All the muscles around the shoulder are innervated by peripheral nerves that originate from the cervical spine, save for the trapezius, which is innervated by cranial nerve XI. Specifically, the deltoid and the rotator cuff are innervated by nerves that receive contributions from the fifth (C5) and sixth (C6) cervical nerve roots[25,48] As a result, the clinical presentation of C5 or C6 radiculopathy typically includes shoulder pain and weakness. On the other hand, a rotator cuff tear involving the supraspinatus and infraspinatus, muscles which are innervated by the suprascapular nerve that branches from the C5 and C6 nerve roots, may present with similar symptoms.[2] This interplay and overlap between both pathologies make it difficult to differentiate the origin of symptoms and correctly diagnose patients.

In a study by Sembrano et al, it is estimated that about 1 in 25 patients who present with shoulder or neck symptoms may exhibit a crossover between the shoulder and neck.[46] The patient may attribute mistakenly their symptoms to the wrong anatomy or both pathologies may coexist. Shoulder pain may arise from cervical spine pathology, and conversely neck pain may arise from shoulder pathology,[31] underscoring the need to examine the cervical spine and shoulder concurrently, rather than individually.

The purpose of this review is to explore the interaction between shoulder and cervical spine symptoms and pathologies and to present some of the physical examination and diagnostic strategies that can be helpful in differentiating the various diagnoses, and propose a management algorithm. In addition, we aim to evaluate the effect of cervical spine pathologies and surgery on the

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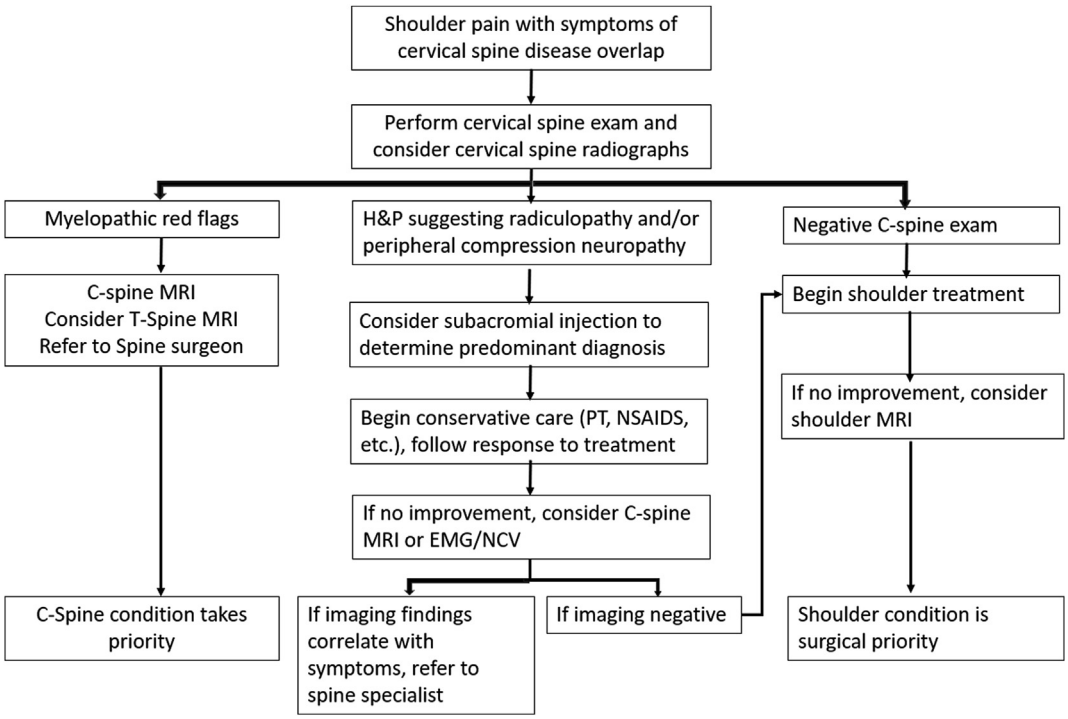

Figure 1 Algorithm on how to approach patients with both shoulder and spine symptoms. *H&P*, history and physical exam; *PT*, physical therapy; *NSAIDS*, non-steroidal anti-inflammatory drugs; *MRI*, magnetic resonance imaging; *EMG/NCV*, electromryography/nerve conduction velocity.

treatments and outcomes following surgery for various shoulder conditions.

Patient approach

Shoulder and cervical spine pathologies may be difficult to differentiate as they may present similarly with overlapping symptoms encompassing pain, weakness, and stiffness in the shoulder, neck, or both concurrently (Fig. 1). A thorough history and a careful complete physical examination of both shoulder and cervical spine is critical, and often helps differentiate the 2 pathologies.

History

Several factors including the location, character, and timing of the pain can help guide diagnosis.[11] Pain that is intrinsic to the shoulder most commonly localizes to the lateral deltoid region, the acromioclavicular joint, and/or the biceps tendon and bicipital groove[11]; whereas cervical radiculopathy more commonly presents with arm pain in conjunction with motor and sensory deficits originating from the neck and radiating beyond the elbow[11,57] (Table I).

Pain originating from a shoulder condition or injury is more likely to be dull and aching, whereas pain from the cervical spine is often characterized as shooting, electric, and burning.[11] Shoulder abduction often exacerbates pain caused by intrinsic shoulder pathology such as rotator cuff disease,[31] but shoulder abduction often relieves pain in cervical spine conditions by reducing traction on a cervical nerve root.[18] In contrast, pain resulting from cervical spine pathology worsens with neck motion[41] and Valsalva maneuvers.[44] Loss of hand dexterity, unstable gait, and bladder or bowel incontinence are additional symptoms seen in cervical myelopathy.[11] Painless shoulder weakness may suggest suprascapular nerve entrapment.[13] Importantly, nocturnal pain is highly indicative of shoulder pathology.[7] In a case series by Austin et al, almost 90% of patients with symptomatic rotator cuff tears reported nocturnal pain and generalized sleep disturbance.[7]

Shoulder pathology can arise insidiously and slowly over time, but symptoms frequently are triggered by injury such as a fall resulting in a rotator cuff tear or biceps pulley injury. In contrast, cervical pathology is usually degenerative and infrequently related to trauma. An epidemiological study by Radhakrishnan et al found that only 15% of cervical radiculopathy occurred with traumatic onset, suggesting that a history of trauma is less suggestive of a cervical spine etiology.[43]

Physical exam

A complete and thorough physical examination is paramount to differentiating cervical spine and shoulder pathologies, starting with a thorough neurological examination. Cervical etiologies may be characterized by abnormal neurological exams, including sensory and motor deficits in the dermatomes of the upper extremities as well as long tract signs suggestive of myelopathy.[31] An absent biceps muscle stretch reflex is highly indicative and nearly pathognomonic for cervical radiculopathy.[55] Patients with shoulder pathology may present with weakness in abduction and elbow flexion; they are otherwise neurologically intact and have normal biceps tendon reflexes.[31]

Provocative maneuvers may also help isolate the pathology. Spurling's test (Fig. 2) and the arm squeeze test (Fig. 3) are 2 maneuvers that are strongly indicative of cervical radiculopathy. Spurling's test has demonstrated low sensitivity ranging from 30% to 50% but a high specificity of 93%[53]; whereas the arm squeeze test has demonstrated a sensitivity of 96% and a specificity of 90%.[24] On the other hand, a positive drop arm test or impingement sign is strongly indicative of shoulder pathology. The drop arm test (Fig. 4)

Table I
Clinical and physical findings of shoulder and cervical spine pathologies.

Clinical and physical exam findings	
Shoulder	Cervical spine
Pain localized to lateral deltoid region, acromioclavicular joint and biceps tendon.	Pain classically originates from neck and radiates beyond elbow.
Pain is dull and aching	Pain is electric and burning
No pain with neck deviation and Valsalva maneuvers	Pain with neck deviation and Valsalva maneuvers
Shoulder weakness and pain	Shoulder weakness without pain (suprascapular nerve impingement)
Nocturnal pain highly indicative	Nocturnal pain not highly indicative
Pain with arm abduction	Relief of pain with arm abduction
Weakness in abduction or biceps strength	Absence of biceps muscle stretch reflex
Positive provocative exams: Drop Arm test, Yergason test, Painful arc test, Jobe's test, Hawkin's test, Belly press test…etc.	Positive provocative exams: Spurling's test.
Pain relief after a subacromial, acromioclavicular joint, or biceps tunnel injection.	Pain relief after a cervical transforaminal injection

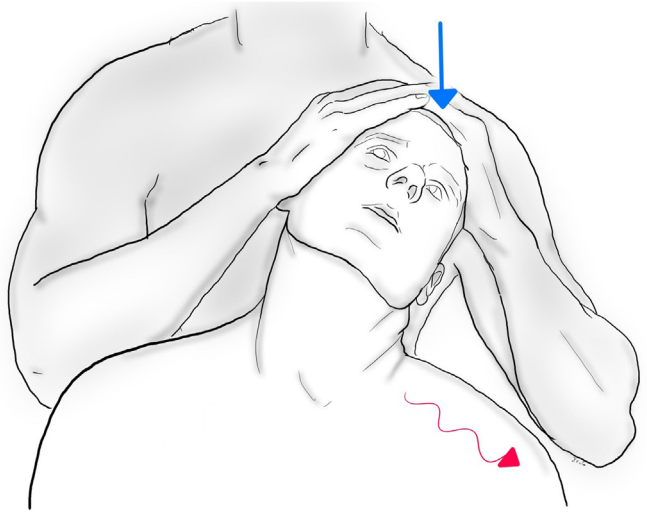

Figure 2 Illustration of Spurling's test.

was shown to have the highest specificity for subacromial impingement (97.2%) (Fig. 5), followed by the Yergason test (86.1%) (Fig. 6) and painful arc test (80.5%) (Fig. 7).[14] However, all 3 had low sensitivities of 7.8%, 37%, and 32.5%, respectively.[14] As mentioned earlier, another method to differentiate the cervical spine and shoulder pathology is to provoke pain via shoulder abduction. A positive shoulder abduction sign in which the pain is exacerbated with abduction is indicative of shoulder pathology, and a negative sign is indicative of cervical spine pathology.[18] In a case series by

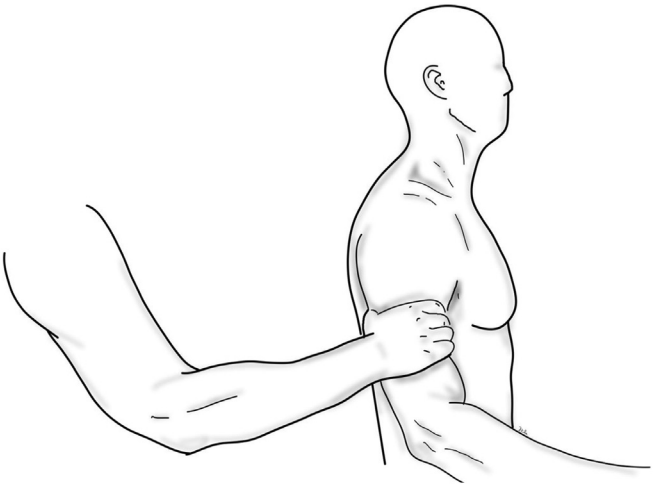

Figure 3 Illustration of the arm squeeze test.

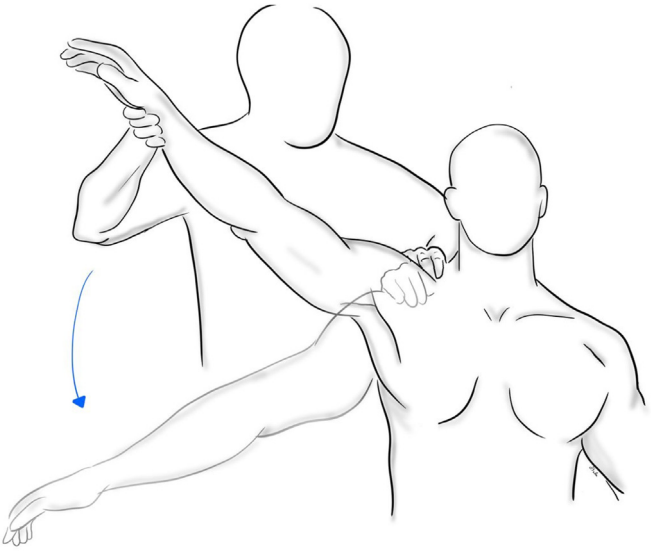

Figure 4 Illustration of the drop arm test.

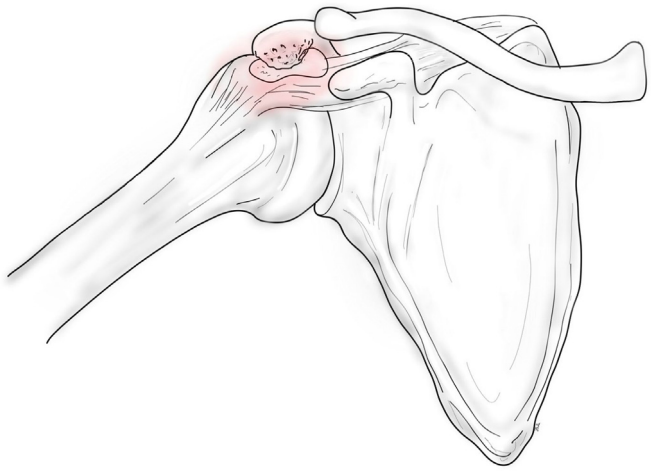

Figure 5 Illustration of showing the subacromial impingement.

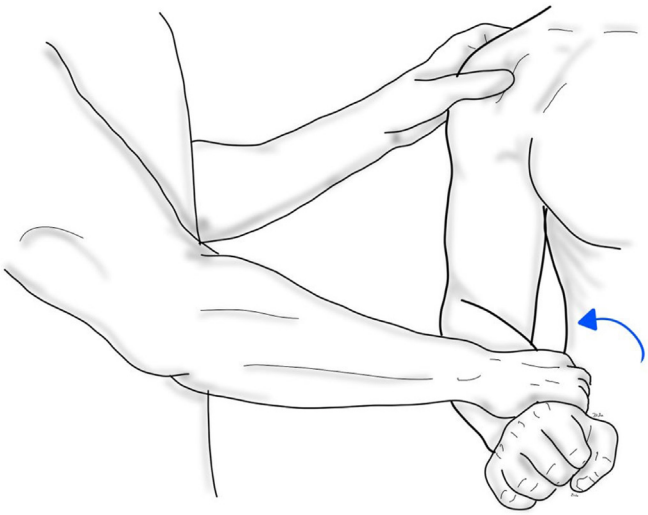

Figure 6 Illustration of Yergason's test.

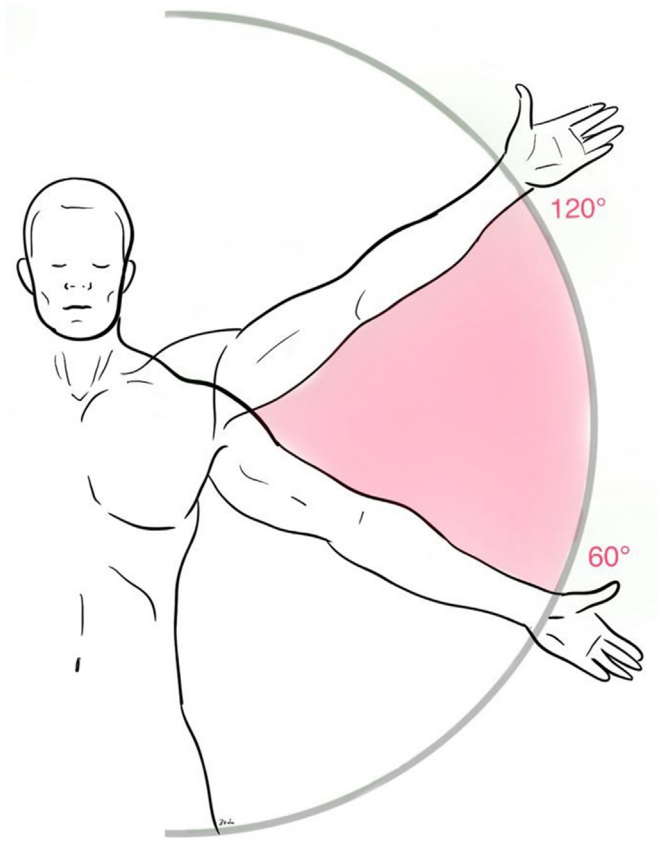

Figure 7 Illustration of the painful arc test.

Davidson et al, 68% of patients with cervical radiculopathy experienced pain relief with arm abduction.[18] Moreover, injections of local anesthetic with or without corticosteroid may play a role in helping with the diagnosis.[31] Some authors have opined that if a cervical transforaminal injection relieves more than 50% of the pain, then attention must shift towards the neck whereas if the pain relief occurred after a subacromial, acromioclavicular joint, or a bicipital groove injection, then the shoulder is the more likely culprit.[31]

Atypical pain

Discerning between the shoulder and neck pathology when the constellation of symptoms and examination findings are typical is often achieved with ease; however, sometimes the presentation is atypical which increases the chances of misdiagnosis and may delay the time to reach a diagnosis. In such cases, both physical examination and imaging are crucial to help reach the diagnosis.[52]

Atypical in location

The pain could be atypical based on its location, such as being present in the sternoclavicular joint, the acromion, the periscapular area, the upper trapezius, or the clavicle. When faced with a pain in the sternoclavicular area, some of the potential diagnoses include sternoclavicular instability or hypermobility, osteoarthritis, osteitis condensans claviculi, or osteonecrosis of the medial clavicle otherwise known as Friedrich disease.[52] Clinical examination may reveal instability, tenderness, or fluctuance of this joint[26] (Table II).

Pain around the acromion may be caused by an os acromiale, which is a fusion failure in the acromial process and is most often asymptomatic but can become painful.[23] A symptomatic os acromiale is often misdiagnosed as subacromial impingement but this can be differentiated from the latter by performing an imaging-guided local anesthetic injection at the os acromiale which will completely relieve the pain[8] (Table II).

In the periscapular region, the list of differential diagnoses is exhaustive. The cause may be benign, such as trigger points where the pain is common in the upper and middle trapezius, typically present in fibromyalgia and other syndromes.[39] Other causes may be related to the scapular kinematics such as scapular dyskinesia and scapular winging which can be diagnosed with history taking to see if there were any previous surgery causing nerve damage and scapular tests such as scapular assist test, wall push-ups, and resisted elevation.[52] Trauma-related etiologies include scapular fracture as well as post-traumatic scapular muscle detachment.[35] A sporadic entity to be considered is an elastofibroma dorsi, which is a tumor that usually presents as a swelling of the inferior scapular angle and is rarely painful[10] (Table II).

Pain at the upper trapezius, could be muscular such as muscle strain and fatigue or referred pain originating from the neck or the subacromial space.[52] Another etiology to be considered in this location is the Parsonage-Turner syndrome or brachial neuritis, which can be diagnosed with the aid of an electromyogram.[3] Pain over the clavicle shaft can be referred from the acromioclavicular joint, sternoclavicular joint, neck, and shoulder. Nevertheless, an occult or stress fracture must always be ruled out, even in the absence of a trauma, and especially in elderly people[1] (Table II).

Atypical in intensity

Some shoulder pathologies present with very intense pain, which may confuse or mislead physicians. In the early stages of adhesive capsulitis, patients may present with maintained passive range of motion but pain-inhibited active motion so that the shoulder pain is out of proportion to the physical findings.[17] The diagnosis of adhesive capsulitis may remain elusive until global shoulder stiffness sets in and pain improves in stage II adhesive capsulitis.[17] Another condition that sometimes overlaps with adhesive capsulitis is calcific tendinitis which is also a very painful condition. Plain radiographs or advanced imaging demonstrate the calcific deposits to help establish the diagnosis.[36] Severe shoulder

Table II
Different areas of pain in the shoulder and neck region and potential diagnoses.

Area of pain	Potential diagnoses
Sternoclavicular area	Sternoclavicular instability or hypermobility Osteoarthritis Osteonecrosis of medial clavicle (Friedrich disease)
Acromion	Os acromiale
Periscapular area	Fibromyalgia Scapular dyskinesis Scapular winging Scapular fracture/post-traumatic scapular muscle detachment Elastofibroma dorsi
Trapezius	Muscle strain or fatigue Referred pain from neck or subacromial space Parsonage-Turner syndrome
Clavicle shaft	Referred from acromioclavicular joint, sternoclavicular joint, neck, or shoulder Trauma

pain is also frequently seen in patients with humeral head osteonecrosis, caused by impaired humeral head perfusion which may be post-traumatic, related to chronic steroid use, sickle cell disease, or other conditions.[45] Early stages of osteonecrosis may not be visible on plain radiographs so that magnetic resonance imaging should be obtained if there is a high index of suspicion based on history and examination.[45]

A few conditions may present with pain that is atypical due to its low intensity. One such condition is suprascapular nerve entrapment which can be caused by an ossified ligament, a paralabral cyst, and other etiologies.[54] Patients experiencing suprascapular nerve entrapment may manifest supraspinatus and infraspinatus weakness when compression occurs at the suprascapular notch. Alternatively, isolated infraspinatus weakness may be evident when the compression is at the spinoglenoid notch. Importantly, in both scenarios, the presence of associated pain is minimal to nonexistent, serving as a key distinguishing factor from weakness associated with a rotator cuff tear or cervical radiculopathy.

Positional pain

Other etiologies may present with atypical pain in terms of its radiations and associated findings. One such condition is thoracic outlet syndrome which may relate to scapular dyskinesis, clavicle fracture malunion, anomalous muscle tissue or a cervical rib. Patients with thoracic outlet syndrome typically present with positional pain worse with neck extension and shoulder abduction, extension, and external rotation, with a diminished radial pulse.[42] Furthermore, this syndrome may either be neurogenic, venous, or arterial, each with a different set of associated symptoms.[42] Elbow pain may also result from neck and shoulder pathologies.[52] However, physical exam is usually sufficient to discern between elbow and shoulder/neck pathologies.

The shoulder in spine surgery

Cervical spine

In cervical spine disease, one of the most predominant symptoms is impairment of upper limb function.[28] In fact, Kholinne et al found that cervical disorders causing axial neck pain may mask various shoulder pathologies, such as rotator cuff disease followed by adhesive capsulitis and calcific tendinitis. However, these concurrent conditions may be diagnosed by careful examination preoperatively.[34] Another study found an association between cervical spine surgery and postoperative adhesive capsulitis.[30] This association may be explained by patients overlooking their shoulder pain and self-limiting their shoulder movement because of the severity of their cervical spine complaint.[34] Therefore, a thorough evaluation must be conducted preoperatively to establish if the symptoms originate largely from the cervical spine, the shoulder, or both.[34] Moreover, it is advised to focus on the shoulder without ignoring any potential contributions from the cervical spine.[34]

Risk factors for the persistence of postoperative shoulder symptoms have been identified.[29,34] One of these risk factors is surgery on the lower cervical spine. However, most cervical pathologies occur between C5 and C7, so this finding must be taken in the proper context.[19,22] A posterior surgical approach to C5-C7 has also been found to negatively affect the postoperative relief of shoulder symptoms.[29,34,56] This may result from detaching muscles that insert onto the cervicothoracic spinous process, which acts as the fulcrum for the shoulder suspensory muscles. Detaching these muscles therefore increases the fatigability of the remaining muscles and lowers the pain threshold.[34]

Another risk factor for persistent pain is the type of cervical spine surgery and associated conditions. Myelopathy has been found to negatively impact the attainment of minimal clinically important difference (MCID) and substantial clinical benefit (SCB) of the Disabilities in the Arm, Shoulder, and Hand (DASH) score following cervical spine surgery.[28] Other studies as well[50,51] showed that when compared to radiculopathy, myelopathy was associated with a failure to achieve MCID and SCB in spine-related symptoms more frequently than surgery for radiculopathy.[5,51] Other risk factors that negatively influenced the achievement of MCID and SCB of the DASH score were older age and a duration of symptoms $\geq$6 months.[28] This may be explained by the presence of more severe degenerative changes, axonal damage, and cord compression, such as in elderly patients with long-standing symptoms.[49,51]

Thoracic spine

The thoracic spine and shoulder exhibit a noteworthy anatomical correlation, although it is less pronounced compared to the cervical spine. While thoracic spine deformities have not been linked to any kind of shoulder pain, deformity correction may improve shoulder range of motion.[9] However, their main impact of deformity correction resides in shoulder balance and symmetry. In adolescent idiopathic scoliosis surgery, shoulder balance plays an increasingly crucial role in surgical decision-making and evaluating clinical outcomes.[47] Moreover, it has been demonstrated that achieving proper shoulder balance is essential for enhancing patient-perceived body image, postoperative satisfaction, and surgical success.[6] In a retrospective case series by Miyanji et al, postoperative shoulder balance was evaluated 2 years following anterior vertebral body tethering of the spine in patients with Lenke type 1 and 2 idiopathic scoliosis.[40] It was shown that the absolute shoulder height, as well as the number of patients with shoulder deformity, was reduced on 2-year postoperative follow-up. This suggests a potential spontaneous correction of shoulder deformity following anterior vertebral body tethering.[40] Furthermore, another retrospective review by Amir et al equally showed that all measures of shoulder imbalance were reduced postoperatively following anterior or posterior spinal fusions.[4] However, it was demonstrated that leveling the upper thoracic spine does not

Table III
Red flags.

Gait disturbance
Bowel/bladder changes
Positive Hoffman's sign
Hyperreflexia
Progressive motor deficit

necessarily ensure the presence of clinically balanced shoulders or clavicles; only the trapezial prominence and medial shoulder balance seemed to be significantly impacted by leveling T1 and the first rib and by minimizing the upper thoracic curve.[4] Taken together, this suggests that shoulder balance and its relationship with thoracic spine deformities is a complex mechanism that is influenced by numerous factors. More research is therefore needed to further determine the exact role and utility of adolescent idiopathic scoliosis surgery in correcting shoulder balance and achieving satisfactory clinical results.

Postoperative patient approach

Because shoulder pain can persist after cervical spine surgery, the postoperative evaluation of the shoulder is as important as the preoperative evaluation. These patients have complex interrelated pathologies, so that a thorough history, physical examination, and diagnostic tests are all needed. During history taking, the clinician must explore the common differential diagnoses while looking for "red flags" (Table III) that suggest a spinal origin of the pain such as motor deficits or myelopathy.[20,31]

Concerning the physical examination, numerous tests, as discussed earlier, can be employed.[31] Additionally, the DASH score has been recently validated, demonstrating correlation with both the Neck Disability Index and visual analog scale.[27,32] Furthermore, a separate study determined the MCID and the SCB of the DASH score, corresponding to −8 and −18, respectively.[28]

Diagnostic testing can encompass a wide spectrum from advanced imaging modalities such as magnetic resonance imaging or computed tomography to electromyography, particularly when neurological symptoms are evident, along with the use of diagnostic injections. However, one must note that for patients with nominal physical examination findings, advanced imaging studies may produce false positives and wrongly guide some unnecessary treatment modalities where otherwise continued conservative management can be successful.[12]

Impact of spine pathology on shoulder surgery

Several studies explored the effects of spine pathologies on the outcomes of shoulder surgery. A retrospective study by Colasanti et al assessed the difference in outcomes of patients after total shoulder arthroplasty with and without a history of cervical arthrodesis (CA).[15] The authors evaluated 573 cases, including 48 with a history of CA and 525 without.[15] Patients with a history of CA had significantly lower postoperative functional outcome scores (Constant, American Shoulder and Elbow Surgeons (ASES), and Shoulder Function score) ($P < .05$), along with a more limited postoperative external rotation ($P < .05$) and lower overall satisfaction rate ($P < .05$).[15] The CA cohort was also noted to have a higher overall complication rate.[15] Another study by Griswold et al retrospectively reviewed all records of primary reverse shoulder arthroplasty in a single institution, and evaluated these cases for the presence of any medical or surgical history of cervical pathology.[21] The authors then compared the outcomes of 50 arthroplasty patients with cervical spine pathology to 108 without cervical spine pathology.[21] Patients with cervical spine pathology had significantly lower postoperative functional scores (University of California Los Angeles, ASES, and Simple Shoulder Test scores) when compared to the patients with no cervical spine pathology.[21] Patients with no cervical spine pathology were also noted to have a significant improvement in preoperative and postoperative University of California Los Angeles and ASES scores.[21] These studies demonstrate that the presence of cervical spine pathology has a substantial impact on shoulder surgery outcomes.[15,21] Given the fact that coexisting shoulder and cervical pathologies are common, it is important to educate surgeons on the importance of a comprehensive clinical exam and history taking.

The frequency with which patients present with concurrent surgical problems of both shoulder and cervical spine had led many surgeon–scientists to explore the influence of operative sequence on clinical outcomes. D'Antonio et al conducted a retrospective analysis for patients who had overlapping shoulder and cervical spine symptoms and who underwent both primary anterior cervical discectomy and fusion (ACDF) and rotator cuff repair (RCR).[16] The cohort was divided into 2 groups: patients who had ACDF first and patients who had RCR first.[16] The authors conducted a multivariate analysis to evaluate whether the operative order of the procedures affected improvements in functional scores at 1 year following the second procedure.[16] The authors reported no significant differences in rate of 90-day readmission, rotator cuff reoperations, and spine reoperations.[16] They concluded that the operative order of procedures does not affect patients with overlapping shoulder and spine symptoms.[16] However, another study by Neil et al studied the effect of ACDF on RCR.[37] The latter showed that having a prior ACDF almost doubled the risk of revision surgery within 2 years postoperatively as well as worsened the outcomes, increased postoperative pain, opioid use, and complications.[37] Furthermore, sometimes shoulder surgery before spine surgery in overlapping rotator cuff arthropathy and neck radiculopathy can relieve the latter.[38] To further support the shoulder first approach, Khan et al[33] found that preoperative shoulder pathologies were associated with a visual analog scale score of more than 7 after cervical spine surgery.

Nevertheless, individualized patient education remains a key component when addressing patients with both shoulder and cervical spine symptomatology. Explaining to each patient the causes of their symptoms, delineating the goals of surgery, and setting up realistic expectations are all imperative for a satisfactory patient prognosis.

Conclusion

The relationship between the cervical and thoracic spine and the shoulder is a close and complex one that cannot be ignored. Spine surgery whether cervical or thoracic can affect the function of the shoulder and unmask shoulder pathologies that were not apparent preoperatively making both preoperative and postoperative shoulder examination a must. Furthermore, cervical spine pathology and surgery can negatively affect the outcome of subsequent shoulder surgery, such as RCR or shoulder arthroplasty. Patients presenting with cervical and/or thoracic spine pathology should always undergo thorough shoulder examination to improve their outcomes, in the event of subsequent shoulder or spine surgery.

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