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The painful shoulder arthroplasty: appropriate work-up and review of interventional pain treatments

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Shoulder arthroplasty is a successful surgical procedure for several conditions when patients become refractory to conservative management modalities. Unfortunately, some patients experience persistent chronic pain after shoulder arthroplasty. These individuals should undergo a comprehensive evaluation by an orthopedic surgeon to determine whether structural pathology is responsible for the pain and to decide whether reoperation is indicated. At times, a surgical solution does not exist. In these circumstances, a thorough and specific plan for the management of persistent chronic pain should be developed and instituted. In this article, we review common reasons for persistent pain after shoulder arthroplasty and outline the evaluation of the painful shoulder arthroplasty. We then provide a thorough review of interventional pain management strategies. Finally, we hypothesize developments in our field that might provide better outcomes in the future for patients suffering with chronic intractable pain after shoulder arthroplasty.

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Shoulder arthroplasty is a common and successful surgical procedure for a number of conditions when they become refractory to conservative management strategies.[38,67] The most common conditions managed with shoulder arthroplasty include glenohumeral osteoarthritis, rotator cuff tear arthropathy, selected functionally irreparable rotator cuff arthropathy, inflammatory arthropathy, osteonecrosis, and certain proximal humerus fractures and its sequelae.[67,68] The utilization of shoulder arthroplasty continues to increase. In the United States, between 2012 and 2017, the population-adjusted incidence of primary anatomic total shoulder arthroplasty (TSA) increased from 9.5 to 12.5 procedures per 100,000 and that of reverse arthroplasty increased from 7.3 to 19.3 procedures per 100,000 for a total surgical procedure volume in 2017 of well more than 100,000 procedures per year.[6]

Although many shoulder arthroplasty procedures lead to resolution of pain and improved function, a number of patients continue to experience shoulder pain after arthroplasty.[26,41,69] In many painful shoulders after arthroplasty, a careful evaluation by an orthopedic surgeon identifies correctable structural pathology; however, there is a subset of patients with pain after shoulder arthroplasty for which a surgical solution does not exist. In those circumstances, establishment of a thorough and specific pain management strategy by a board-certified pain specialist may be a good option to provide these individuals with an improved quality of life.

Differential diagnosis

Persistent pain after shoulder arthroplasty may be due to multiple factors.[78] Some may be extrinsic to the shoulder joint, whereas others may be intrinsic. Furthermore, certain intrinsic causes for pain after shoulder arthroplasty are specific to either anatomic (TSA) or reverse (reverse shoulder arthroplasty [RSA]) implants, whereas other causes are common for both implant styles (Table I; Fig. 1). Evaluation of the painful shoulder arthroplasty typically involves a thorough history and physical examination as well as careful review of sequential radiographs. Investigations for possible deep periprosthetic joint infection (PJI) often include blood laboratory analyses and joint aspiration with subsequent culture and laboratory analyses of the fluid. Additional investigations may

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Table I
Possible causes of pain after shoulder arthroplasty.

	Intrinsic			Extrinsic
	Both anatomic and reverse	Reverse	Anatomic	
Prostheses	• Loosening • Wear with particulate-induced synovitis and/or osteolysis • Metal allergy (?)	• Humeral bearing overhang/ protrusion • Component disassociation or fracture		• ACJ, SCJ, and periscapular conditions • Cervical spine conditions • Complex regional pain syndrome • Vascular conditions • Psychiatric conditions • Fibromyalgia • Narcotic dependence
Bone	• Periprosthetic fractures	• Acromion or scapular spine fracture • Coracoid impingement • Scapular notching	• Glenoid erosion/pain after hemiarthroplasty	
Soft tissues	• Dislocation • Capsular contracture/stiffness • Heterotopic ossification	• Deltoid dehiscence • Excessive deltoid stretching/ pain • Conjoined tendon impingement/pain	• Cuff insufficiency, subscapularis failure • Biceps tenosynovitis/pain	
Infection	• Deep periprosthetic joint infection (PJI) • Superficial (incisional) infection			
Other	• Brachial plexopathy • Axillary nerve injury • Neuroma • Recurrent hemarthrosis or seroma • Neoplasm	• Suprascapular nerve injury by screw		

ACJ, acromioclavicular joint; *SCJ*, sternoclavicular joint.

include computed tomography, ultrasound, magnetic resonance (MR), scintigraphy, and electromyography with nerve conduction studies. Occasionally, diagnostic injections are considered. Diagnostic arthroscopy may also be selectively recommended.

Evaluation of the painful shoulder arthroplasty

History, psychosocial assessment, and physical examination

When assessing a patient with persistent pain after shoulder arthroplasty, details obtained through thorough history taking may be invaluable. The severity of pain and overall impact on daily activities may be quantitated using a visual analog scale and the subjective shoulder value, respectively.[29] The location of pain is important too, especially in regard to excluding extrinsic causes of pain (ie, cervical spine pain may manifest at the neck or over the trapezius region, whereas intrinsic pain typically is centered over the deltoid region). Cervical radiculopathy, brachial plexopathy, and complex regional pain syndrome tend to cause pain in the whole upper extremity, typically associated with numbness, tingling, and various degrees of hyperesthesia or weakness.

The temporal course of pain with the index procedure provides important insight as well. If the pain never improved after the arthroplasty, particularly if the pain is in the same location and has the same characteristics, extrinsic causes could be the reason for persistent pain, but infection, persistent glenoid pain after hemiarthroplasty, painful capsular contracture, iatrogenic brachial plexopathy, and other nerve injuries may also follow this same temporal relationship. On the contrary, implant loosening or wear and chronic infection typically manifest years after the procedure. Stress fractures of the scapular spine and acromion classically manifest as acute onset of pain a few months after an RSA.[47] Any correlation between pain and activity is important too: pain at rest may be indicative of infection or neuropathic pain, whereas pain with activity may be related to mechanical causes such as implant loosening or painful glenoid erosion after hemiarthroplasty.

The details of the surgical procedure are extremely important too. How severe was the pain before surgery? Did the patient undergo one or more procedures or corticosteroid injections before surgery? Was there prolonged drainage, fever, chills, redness, or need for a course of antibiotics after the index arthroplasty? What was the physical therapy program prescribed after surgery? A copy of the operative report should be reviewed carefully to determine how the biceps tendon and subscapularis muscles were managed. Components implanted should be noted because some may have a poor track record with known instances of early unexpected failure.[4]

The psychosocial assessment of the patient is extremely important too. As with other orthopedic surgical procedures, mood disorders, excessive use of preoperative narcotic pain medication, and Worker's Compensation status with potential secondary gains may lead patients to report pain that cannot be explained or is out of proportion with their condition.[13,42,51]

Physical examination should be performed with the torso uncovered. The prior skin incision should be assessed for possible signs of infection, including redness and drainage. The deltoid, rotator cuff, and biceps should be inspected for deformity or atrophy. Gross shoulder deformity may be present in cases of anterosuperior escape after anatomic arthroplasty or dislocation after reverse arthroplasty. Palpation may identify painful structures, which might include the sternoclavicular joint, the acromioclavicular joint, the acromion and spine of the scapula, the bicipital groove, and the superomedial pole of the scapula and periscapular muscles. Active and passive range of motion in elevation, external rotation, and internal rotation should be carefully evaluated. The strength of the deltoid and rotator cuff should be assessed with manual testing and performance of dedicated tests (belly press, external rotation lag in adduction, and abduction). A thorough neurovascular examination of the upper extremity should be completed to identify evidence of radiculopathy, brachial plexopathy, nerve injuries, or complex regional pain syndrome. Finally, the scapulothoracic region and the cervical spine should be evaluated as potential sources of referred pain.

Imaging studies

Radiographs

Image evaluation of the painful shoulder arthroplasty should always begin with radiographs, including an anteroposterior x-ray in the scapular plane and an axillary radiograph. The interface

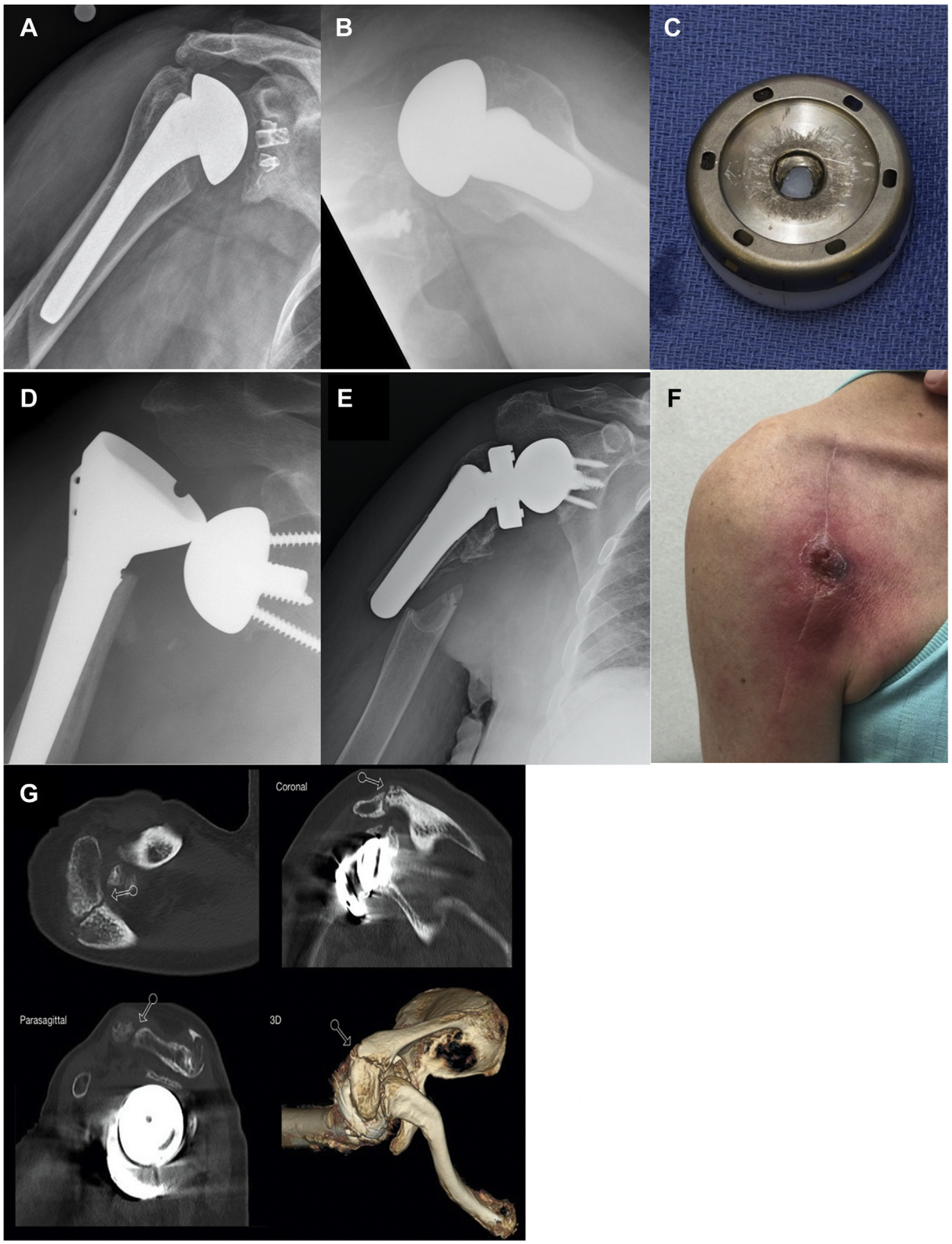

Figure 1 Common reasons for intrinsic pain after shoulder arthroplasty include loosening (**A**), rotator cuff insufficiency (**B**), component disassociation or fracture (**C**), dislocation (**D**), periprosthetic humeral fracture (**E**), periprosthetic joint infection (**F**), and scapular spine fracture after reverse arthroplasty (**G**).

between the implant and surrounding bone or cement is best visualized when radiographs are obtained under fluoroscopic positioning. In some patients, radiographs may clearly reveal the problem (bone or component fracture, dislocation, and gross loosening), and certain degrees of component malposition can be a source of persistent pain. However, many painful shoulder arthroplasties look well positioned and well fixed on radiographs. Radiographic assessment of glenoid component fixation after anatomic shoulder arthroplasties using all-polyethylene components may be very difficult to assess unless sequential

radiographs that have been obtained over time are compared.[49] Radiolucent lines and change in component position are commonly used to identify component loosening. Fractures of the acromion and spine after reverse arthroplasty may also be difficult to visualize on radiographs.[11]

Computed tomography

Computed tomography with intra-articular injection of contrast (CT arthrogram) may be particularly helpful to identify cuff failure, subscapularis insufficiency, or glenoid loosening after anatomic arthroplasty.[44] Computed tomography is also useful to assess for fractures of the spine of the scapula or acromion after reverse arthroplasty and to determine whether any of the screws used for baseplate fixation is in dangerous proximity to the suprascapular nerve (SSN). Finally, computed tomography may be used to assess the degree of muscle atrophy and fatty infiltration of the rotator cuff and other muscles and also to identify wear, notching, and osteolysis.

Ultrasound

Ultrasound evaluations of the shoulder have become increasingly popular, especially in regard to the assessment of the condition of the rotator cuff after shoulder arthroplasty.[77] Ultrasound allows dynamic evaluation of the shoulder, and it is relatively inexpensive compared with other advanced imaging studies. However, it is operator dependent and sometimes difficult to interpret by the orthopedic surgeon. Ultrasound is also extremely useful to assist with aspiration of articular fluid and diagnostic injections.

MR and scintigraphy

Although MR is considered by many to be the most useful advanced imaging modality for the painful native shoulder, MR after arthroplasty is much less useful because of metal artifact, even when dedicated metal subtraction techniques are used.[56] Scintigraphy may be useful to diagnose deep infection and occult stress fractures of the acromion or scapular spine; also, complete absence of uptake on scintigraphy may reinforce the need to look for extrinsic causes of shoulder pain.[24] However, scintigraphy is not very commonly used in the evaluation of the painful shoulder arthroplasty. Single-photon emission computed tomography has been reported to be of value for the evaluation of the painful shoulder arthroplasty.[74]

Laboratory analysis and cultures

Sedimentation rate and C-reactive protein are the serum inflammatory markers most commonly used when evaluating for infection after shoulder arthroplasty.[61] When infection is suspected, articular fluid (typically obtained under ultrasound guidance) may be analyzed for cell count with cell differential and sent for cultures.

The Musculoskeletal Infection Society recommends specific cutoff values for identifying PJI after knee arthroplasty (>3000 cells/μL with >80% polymorphonuclear for chronic infection; >10,000 cells/μL with >90% [polymorphonuclear] for acute infection).[58] However, a substantial percentage of deep infections after shoulder arthroplasty are caused by *Cutibacterium acnes*; infections by this slow-growing bacterium oftentimes will *not* lead to elevated serum inflammatory markers or elevated articular fluid cell counts. In addition, *Cutibaterium acnes* is more difficult to isolate in culture and may require 14 days of incubation. To reach consensus in the diagnosis of infection complicating shoulder arthroplasty, the International Consensus Meeting on Orthopedic Infections published criteria for the definition of periprosthetic shoulder infection, including a scoring system for definite, probably, possible, and unlikely infection (Table II).[28] Culture of sonicate fluid from explanted prostheses may provide additional diagnostic value.[60]

Table II
Definition of infection according to the International Consensus Meeting on Orthopedic Infections.[24]

Major criteria that define definite periprosthetic shoulder infection (meeting one of these criteria is diagnostic)
• Presence of a sinus tract from the skin surface to the prosthesis
• Gross intra-articular pus
• Two positive tissue cultures with phenotypically identical virulent organisms
Minor criteria to be considered for the scoring system below
• Unexpected wound drainage—4 points
• Single positive tissue culture with virulent organism—3 points
• Single positive tissue culture with low-virulence organism—1 point
• Second positive tissue culture (identical low-virulence organism) —3 points
• Humeral loosening—3 points
• Positive frozen section (5 PMNs in ≥high-power fields)—3 points
• Positive preoperative aspirate culture (low or high virulence)—3 points
• Elevated synovial neutrophil percentage (>80%)*—2 points
• Elevated synovial WBC count (>3000 cells/μL)* —2 points
• Elevated ESR (> 30 mm/h)*—2 points
• Elevated CRP level (> 10 mg/L)*—2 points
• Elevated synovial α-defensin level—2 points
• Cloudy fluid—2 points
Probable infection
• Organism identified in at least one culture *and* 6 or more points
Possible infection
• Single positive culture with virulent organism
• 6 or more points with no organism identified
• 2 positive cultures with low-virulence organism
Unlikely infection
• Less than 6 points and negative cultures or only a single culture with low-virulence organism

PMN, polymorphonuclear leukocyte; *WBC*, white blood cell; *ESR*, erythrocyte sedimentation rate; *CRP*, C-reactive protein.
*Beyond 6 weeks from most recent surgery.

The relationship between metal allergy and pain or failure after shoulder arthroplasty continues to be debated, but selected patients may be assessed for adverse immune reactions to the materials used in shoulder arthroplasty.[40,43]

Electromyography and nerve conduction studies

Persistent pain after shoulder arthroplasty may be secondary to a number of neurologic conditions, including brachial plexopathy and complex regional pain syndrome. Brachial plexopathy may be secondary to a stretch injury during surgery, present as a complication of nerve blockade (secondary to toxicity or mechanical injury), or occur in the form of postsurgical inflammatory plexopathy. Electromyography and nerve conduction studies may aid in the diagnosis of these conditions and can also be used to assess for severity and possibility of recovery.

Diagnostic injections

As a general rule, diagnostic injections into the glenohumeral joint space after arthroplasty are not recommended for fear of iatrogenic infection, as detailed below. However, diagnostic injections of a local anesthetic with or without corticosteroids may be useful to confirm physical and imaging findings that may suggest an alternative painful structure, such as the acromioclavicular joint, the sternoclavicular joint, or the tendon of the long head of the biceps (Table I).

Diagnostic arthroscopy

As the diagnosis of PJI after shoulder arthroplasty may be elusive and it does require cultures from tissue samples, diagnostic arthroscopy to obtain tissue biopsies is considered for certain painful shoulder arthroplasties with no alternative clear explanation for ongoing pain.[66] Samples obtained arthroscopically have been reported to provide high diagnostic yield.[18] Arthroscopy also allows assessment of glenoid component fixation, polyethylene wear, synovitis, and the condition of the rotator cuff and tendon of the long head of the biceps.[19]

Interventional treatments for the painful shoulder arthroplasty

Intra-articular steroids

Intra-articular steroids (IAS) are hypothesized to decrease inflammation within arthritic joints, thereby reducing pain. After arthroplasty, the joint articular surface is replaced with an artificial joint, potentially limiting the effectiveness of IAS and increasing the risk of a periprosthetic infection. Interestingly, a recent retrospective study of 4790 TSA patients was published. A total of 958 TSA patients underwent an IAS injection at some point after TSA, whereas 3832 TSA patients had not. After controlling for demographics and comorbidities, the rate of infection in patients who had an IAS injection was significantly higher than in those who had not undergone the injection. The authors concluded that IAS injections in patients with pre-existing TSA increase the risk of infection and should be avoided.[10] Similar data can be found in the total knee arthroplasty literature.[53,65] Given the risks, the authors of this article recommend against IAS injections into the painful TSA.

Radiofrequency ablation

The use of radiofrequency ablation (RFA) for the treatment of chronic large joint pain has emerged as a very promising treatment option, particularly of the shoulder region, where conservative and surgical efforts may fail to manage pain and associated disability. It is well established that shoulder pain stems from a variety of musculoskeletal structures, involving potential pathology of the glenohumeral joint, acromioclavicular joint, and rotator cuff musculotendinous structures. RFA involves creation of a distinct thermal lesion to specific nervous tissue, resulting in decreased pain perception of the innervated, painful area. The prevalence and functional disability that results from shoulder pain are quite common, potentially as high as 30% of the population.[62] In the post shoulder arthroplasty population, reports of persistent shoulder pain may be as high as 10%.[25] Candidates for shoulder RFA after TSA or RSA are those individuals who are not candidates for revision surgery and have failed more conservative pain management strategies. Importantly, the relative risks associated with RFA of peripheral sensorimotor nerves are low and include vascular injury, nerve impairment, musculoskeletal damage, septic arthritis, and cutaneous burns.[36] It must be stated, however, that there have been no studies to date researching the use of RFA for chronic TSA or RSA pain.

RFA of the shoulder joint is typically preceded by diagnostic local anesthetic blocks targeting the sensory nerves of the shoulder region. Articular branch nervous input of the anterior and posterior glenohumeral joint is divided into 3 primary sensorimotor branches: (1) SSN, which serves the posterolateral aspect; (2) axillary nerve (AN), which serves the anterolateral, inferior, and posterolateral aspect; and (3) lateral pectoral nerve, which serves the anterosuperior aspect.[21,55] Ablation of the primary sensory nerves is described using traditional (tRFA), pulsed (pRFA), and cooled (cRFA) RFA techniques. The vast majority of studies to date focus primarily on the SSN, as it is thought to supply more than 70% of the sensory innervation to the shoulder joint.[3] One of the first successful uses of percutaneous minimally invasive tRFA lesioning of the sensorimotor nerves was described in a 2012 retrospective case series, where Simopoulos et al used continuous tRFA in 9 patients with chronic unremitting shoulder pain who responded with at least 50% reduction in pain intensity during anesthetic phase SSN block and no additional motor weakness of the shoulder. The patients selected previously had less than 2 months relief from conservative efforts, including prior corticosteroid therapy and pRFA treatments. Continuous tRFA lesioning of the SSN at 80°C for 60 seconds resulted in reduction of pain scores 7/10 to 3/10 approximately 6 weeks after the procedure that was sustained anywhere from 3 to 18 months. In addition, patients had improved range of motion, and all chose to have the procedure repeated again, given the perceived benefits.[72] In 2015, Chang et al reported another small case series of 6 patients with metastatic malignancy-associated shoulder pain that had continuous tRFA of the SSN, 80°C for 75 seconds, with immediate relief of pain, improved active range of motion, and >60 days of pain relief during the terminal phase of life. Both these small studies suggest that continuous tRFA of the SSN appear to confer meaningful pain relief for chronic shoulder pain, unrelated to prior TSA or RSA, with minimal side effect or motor deficit.[12]

Given that the sensorimotor pattern of the SSN supplies 2 of the 4 rotator cuff muscles (eg, supraspinatus and infraspinatus), the vast majority of the studies to date have focused on the use of pulsed RFA. Pulsed RFA is unique, given its perceived benefit of avoiding tissue destruction, as it uses short, high-voltage bursts of electrical current followed by longer periods without energy, allowing for heat to dissipate in the surrounding tissue and never getting warmer than 42°C.[9] One of the earliest case reports by Shah et al in 2003 demonstrated the effectiveness of pRFA at the SSN (42°C for 3 cycles of 120 seconds, 2 Hz and 20 ms pulse width) that resulted in nearly 4 months of pain relief (7/10 baseline and 2-3/10 at follow-up) and improved shoulder range of motion.[71] Subsequent randomized control trial by Gofeld et al in 2013 examined 22 patients with chronic shoulder pain and compared local anesthetic blocks (10 patients) to pRFA (12 patients) of the SSN (42°C for 120 seconds). When assessing the numeric rating scale, they demonstrated that the pRFA group (6.4/10 baseline, 3.1/10 and 2.7/10, 1 and 3 months, respectively) were more satisfied than the local anesthetic control group (6.3/10 baseline, 5.1/10 and 4.3/10 at 1 and 3 months, respectively). The authors concluded that significant trends in the reduction of pain favored the pRFA group and that patient satisfaction and Shoulder Pain and Disability Index scores were sustained for at least 3 months postprocedure in both groups.[31]

More recently, the application of cRFA around the shoulder joint has shown promise by targeting several of the known sensory nerves beyond the SSN.[7] Similar to tRFA that targets neurodestructive tissue temperatures of 80 degrees C, the use of monopolar cRFA is accomplished with a constant flow of water around the electrode that results in a larger lesion and projects a spherical isotherm around and distal to the probe tip.[80] A recent retrospective case series published by Eckmann et al reviewed 34 patients with chronic refractory shoulder pain. Patients selected to undergo RFA of the shoulder region were screened with local anesthetic blocks resulting in >50% reduction of typical pain and had either tRFA or cRFA of the articular branch SSN, AN and lateral pectoral nerve. Six of the 10 with cRFA had a mean duration of >50% pain relief of 6.6 months with a statistically significant decrease in

numeric rating scale at the first follow-up visit (6/10 baseline vs. 1.1/10 follow-up visit). Three of 9 patients treated with tRFA reported a mean duration of >50% pain relief of 5.3 months. There was no statistical difference in responder rates between tRFA and cRFA, and importantly, no major complications or motor deficits reported. Overall, the use of cRFA and tRFA in this challenging population demonstrated approximately a 50% responder rate with a success of >50% pain relief for greater than 3 months.[22]

In summary, nonsurgical management of shoulder pain after TSA/RSA refractory to conservative treatments of therapy and medications should include consideration of RFA of the articular branch nerves, given the supporting literature on chronic shoulder pain. We are optimistic that RFA, if considered earlier in the care plan, may improve range of motion and allow participation in continued rehabilitation efforts after arthroplasty with improvements in pain scores and patient-reported outcomes.[57] Future studies focused on the use of RFA in post-TSA/RSA pain are needed to better support its regular use.

Peripheral nerve stimulation

Peripheral nerve stimulation (PNS) is a surgical technique that involves percutaneous or open surgical placement of small stimulating electrodes in close proximity to a specific peripheral nerve. Electrical impulses are then delivered from the electrodes to the peripheral nerve to reduce pain related to the targeted nerve(s) or their anatomic distributions. Similar to stimulation techniques involving the central nervous system, stimulation of the peripheral nerves has been shown to interrupt pain signaling and improve chronic pain states. The exact mechanism of action continues to be debated, but it is believed that both central and peripheral factors are affected.[11] There have been recent technological advances in PNS that have led to a resurgence of interest in this approach. Indeed, the technique has been widely applied to chronic pain syndromes and anatomical targets, including chronic headache, back pain, and pain of the extremities.[30,63,73]

There is no specific literature addressing PNS in post-TSA/RSA patients. However, PNS has been applied in a variety of shoulder pain etiologies.[45,46,50] The evidence supports the stimulation of the suprascapular and/or NSs.[48] In a retrospective review, Mansfield and Desai describe 8 patients with a variety of chronic shoulder pain etiologies (excluding poststroke shoulder pain), with 88% of the patients reporting >50% reduction of pain.[45] Interestingly, the data are most robust for successful PNS therapy for poststroke shoulder pain.[35,48] Although the pathologies and etiologies described previously are undoubtedly different from post-TSA/RSA pain, these successful cases may provide a framework to consider PNS for post-TSA/RSA pain. Hopefully, this can be further explored in future research and clinical reports.

Spinal cord stimulation

Spinal cord stimulation (SCS) is a minimally invasive procedure that involves placement of 1 or 2 epidural dorsal column leads either percutaneously or in an open surgical procedure. The leads are connected to an implantable pulse generator that supplies electrical signals to the spinal cord to interfere with central nervous system pain transmission and processing.[35]

After reviewing the published literature to date, we were unable to find any studies on the successful use of SCS for chronic pain following TSA or RSA. In 2010, Williams et al published a case report describing the use of traditional cervical SCS for the treatment of right glenohumeral degenerative joint disease in a 67-year-old female. Following a successful trial with leads placed at C3, the patient underwent a paddle lead implant. Eighteen months after implant, the patient reported 50% pain relief, had discontinued oxycodone, and was utilizing tramadol as needed.[58,79] Similarly, Susa et al described the use of traditional cervical SCS in an 84-year-old female for the treatment of glenohumeral arthritis pain. The leads were implanted to span from C3 to T1. At 3 months post-implantation, the patient reported greater than 90% reduction in pain, she had decreased her overall opioid use, and had improvement in arm function.[75] Other publications have described SCS for chronic neck and upper extremity pain, but whether any of these patients had prior TSA or RSA is not reported, and it does not appear that shoulder pain was the primary pain complaint.[1,15,17,20,37]

Dorsal root ganglion stimulation

Dorsal root ganglion (DRG) stimulation involves targeted stimulation at specific neuroforaminal levels to target the DRG at that location. In doing so, there is enhancement of the T-junction within the DRG, which increases pain signal filtering and decreases pain transmission.[34]

Similar to SCS, the use of DRG stimulation for the treatment of chronic pain after TSA or RSA has not been described in the literature. This is partially explained by its Food and Drug Administration approval for use between T10-S2, whereas treatment of TSA/RSA-related pain would require DRG stimulator lead placement at levels cephalad to T10.[16] However, in Australia and Europe, physicians have described safe cervical and high-thoracic DRG stimulator lead placement, and in the United States, unintentional cervical DRG stimulation with an SCS lead has been safely described.[2,27,59]

Future directions

The evidence for RFA and neurostimulation technologies in the treatment of other chronic pain conditions is increasing, and it is likely the use of interventional pain techniques for chronic pain after TSA and RSA will increase as well. Although studies are limited regarding the use of RFA for post total knee and post total hip arthroplasty pain, future publications will likely point to the benefits of RFA in these related patient populations.[39,52,64,76] Certainly, directed studies using RFA for post-TSA/RSA pain will be necessary, but with specific nerve targets around the glenohumeral implants and evidence in other postarthroplasty pain states, one could foresee the use of RFA for post-TSA/RSA chronic pain becoming increasingly popular.

There are a number of publications suggesting the use of DRG stimulation for chronic postsurgical pain and should further evidence be published regarding the safety of cervical and upper thoracic DRG placement, this may be a potential treatment option in the future.[5,8,23,54,70] Regarding SCS, prospective studies have suggested that both 10 kHz and burst SCS are beneficial for neck and upper extremity pain.[1,32] In addition, chronic postsurgical pain of multiple areas has been shown to respond to 10 kHz SCS.[33] It is possible that chronic pain after TSA or RSA may be treatable with SCS, particularly 10 kHz programming. Finally, PNS has proven to be very beneficial for other shoulder conditions, and it is likely that with additional study, specific anatomical targets will be found to provide pain relief for post-TSA/RSA chronic pain patients.[14,17]

Regardless, additional research and evidence are needed before definitive recommendations can be made regarding current interventional pain techniques and chronic pain after TSA or RSA.

Conclusion

The treatment of end-stage shoulder conditions with TSA or RSA is generally safe and effective and has been increasingly used in recent years. Unfortunately, a small subset of patients will continue

to experience ongoing pain after TSA or RSA. In these situations, referral to a board-certified chronic pain specialist and formulation of a patient-specific treatment plan may be beneficial. As we have outlined, there are an array of potentially effective treatment options, but further research is necessary to make definitive recommendations for this patient population.

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