Radiofrequency in arthroscopic shoulder surgery: a systematic review

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Background: Radiofrequency has seen an increase in use in orthopedics including cartilage lesion debridement in the hip and knee as well as many applications in arthroscopic shoulder surgery. The purpose of this systematic review is to evaluate the safety and usage of radiofrequency in the shoulder.

Methods: This systematic review was registered with PROSPERO (international registry) and followed the preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) guidelines. Embase and PubMed were searched using: “shoulder,” “rotator cuff,” “biceps,” “acromion” AND “monopolar,” “bipolar,” “ablation,” “coblation,” and “radiofrequency ablation.” The title and abstract review were performed independently. Any discrepancies were addressed through open discussion.

Results: A total of 63 studies were included. Radiofrequency is currently utilized in impingement syndrome, fracture fixation, instability, nerve injury, adhesive capsulitis, postoperative stiffness, and rotator cuff disease. Adverse events, namely superficial burns, are limited to case reports and case series, with higher-level evidence demonstrating safe use when used below the temperature threshold. Bipolar radiofrequency may decrease operative time and decrease the cost per case.

Conclusions: Shoulder radiofrequency has a wide scope of application in various shoulder pathologies. Shoulder radiofrequency is safe; however, requires practitioners to be cognizant of the potential for thermal burn injuries. Bipolar radiofrequency may represent a more efficacious and economic treatment modality. Safety precautions have been executed by institutions to cut down patient complications from shoulder radiofrequency. Future research is required to determine what measures can be taken to further minimize the risk of thermal burns.

Keywords: Radiofrequency; Plasma energy; Arthroscopic shoulder surgery; Safety; Efficiency

INTRODUCTION

Radiofrequency (RF) refers to application of thermal energy to reorganize tissue on a molecular level and restore normal structure and function [1]. Traditional RF or electrocauterization refers to the use of thermal energy to treat surgical pathology by passing electrical current directly through tissue [1]. RF can be delivered through a monopolar or bipolar device [1-3]. Bipolar RF represents a safer alternative at lower temperatures, voltages, contact pressures, and contact times [1]. These devices create high-energy free radicals that can break molecular bonds and excise soft tissue at relatively low temperatures (40°C–70°C) [2]. RF systems are widely used in arthroscopic orthopedic procedures for ablation, resection, and coagulation of soft tissues [3]. RF en-
ergy is not without its risks and does exhibit time-dependent effects that need to be considered by surgeons [4]. Next-generation RF devices utilize plasma energy fields to deliver thermal energy to minimize damage to the surrounding soft tissues [1,5].

The safety profile of RF has been studied in the knee in the context of low-grade cartilage lesions [2]. The safety of RF has also been well-studied in the hip for ablating soft tissues [6]. In the glenohumeral joint, RF was first studied in the context of instability but resulted in overtreatment [7], permanent tissue damage [7], and high failure rates necessitating capsular plication [8,9]. However, there are limited reports on the temperature profile and complications in shoulder joint RF.

In recent years, there have been many studies published regarding the use of RF energy in the surgical treatment of many shoulder pathologies. In the existing publications regarding RF use in the shoulder, the purpose of the equipment is to split and partially remove soft tissues [10-20]. However, the safety and complications of RF use to debride soft tissue have not been established. The purpose of this investigation is to conduct a systematic review of the currently available literature to evaluate the safety and complication profile of RF devices for use in the shoulder.

METHODS

General
This systematic review was registered in an international prospective register of systematic reviews (PROSPERO No. CRD 42021288444.) The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines were followed.

Literature Search
The literature search was performed using Embase and PubMed with the keywords displayed in Table 1. The initial literature search revealed 1,531 studies. After removal of duplicate articles, title and abstract screening was performed on 1,374 studies. Of these, 537 studies did not pertain to the use of RF in arthroscopic shoulder surgery. Finally, the full-text of 837 studies was screened (Fig. 1).

Study Selection
Studies were selected according to the inclusion and exclusion criteria presented in Table 2. Of note, studies related to shoulder capsulorrhaphy usage were excluded, given the high complication rates of axillary nerve dysfunction, articular cartilage damage, and capsular necrosis [21]. Application of our inclusion and exclusion criteria resulted in a total of 63 studies.

Qualitative Synthesis
Due to a limited number of high-level clinical studies on the topic and heterogeneous reporting of data, the included studies were qualitatively synthesized. The included studies were grouped into those that contained data regarding the performance profile of RF and those that did not. The performance profile was defined as any mention of the temperature profile, safety profile and

![Table 1. Search keywords used in the literature search](#)

| Search term category       | Keywords used                                      |
|----------------------------|----------------------------------------------------|
| Anatomic location          | 'shoulder,' 'rotator cuff,' 'biceps,' 'acromion'   |
| Radiofrequency modality    | 'monopolar,' 'bipolar,' 'ablation,' 'coblation,' 'turbovac,' 'radiofrequency ablation' |

![Fig. 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) flow diagram for our study.](#)
complication rate, or clinical outcomes. These studies were grouped accordingly and descriptively summarized in the tables.

RESULTS

General
Of our 59 included articles, 39 did not include RF performance in terms of temperature profile or complications. The remaining 20 studies did include at least one of these measures. The studies in this review that discuss RF for shoulder arthroscopic orthopedic procedures without data on performance profile do provide insight regarding the breadth of shoulder RF use and are summarized in Table 3 [10,12-19,22-51]. Table 3 revealed bipolar RF as the most commonly used modality. Of the 39 studies depicted in Table 3, only 17 (43.6%) specified the RF modality, all of which were bipolar. The remaining 22 studies (56.4%) were unspecified.

Performance Profile
Studies that disclosed the performance profile of RF usage in the shoulder were further analyzed. These studies were grouped by temperature profile (Table 4) [3,20,52-62] and complications (Table 5) [21,63-68].

Temperature Profile
Our literature review identified two randomized controlled trials, two prospective cohort studies, two case series, three cadaveric studies, two animal studies, and two basic science studies exploring the temperature profile of RF ablation devices in the shoulder (Table 4).

While comparing RF instruments, Huynh et al. [3] found few differences in temperature characteristics. The peak temperature during RF usage in subacromial decompression was 32.0°C (range, 29.3 °C–43.1°C) [55]. The mean peak temperature of outflow fluid was 71.6°C, assumed to mimic wand tip temperature, which should be between 40 and 70°C [55]. During the study, Barker et al. [55] found the most crucial factor in subacromial temperature to be fluid irrigation temperature. For this reason, they recommended against the use of warmed irrigation fluid in RF. Davies et al. [56] also suggested that irrigation fluid be cooled before RF usage. In their case series of 30 patients, subacromial bursa temperature during RF with a monopolar device was assessed. Mean (27.8°C) and maximum (41.8°C) temperatures were observed well below the chondrocyte damage threshold temperature. The authors explained the isolated reading of 41.8°C to be due to blockage of the RF suction probe [56].

Good et al. [58] performed a cadaveric study regarding intraarticular temperatures during shoulder RF use. Intraarticular temperatures increased above 45°C in each trial. The highest peak temperatures were observed when the fluid flow rate was 0%, while the lowest peak temperatures were observed when the fluid flow rate was 100% [58]. No statistical differences in mean temperature were observed whether the device was immersed in fluid or in direct contact with tissue [58]. Zoric et al. [57] demonstrated three factors that were critical for maintaining safe intra-articular temperature: rate of flow, distance of device application, and duration of usage. This study also suggested that maximization of irrigation flow, shorter duration of device use, and adequate suction techniques further prevent temperature-related patient complications and injuries.

Safety and Complications
Overall, reports of postoperative complications following RF methods were lacking (Table 5). Our literature search revealed one prospective controlled trial, one case series, and five case reports that provided significant complication rates or commented on the safety profile. The small number of reported complications from RF usage within the literature was related to increased irrigation fluid temperature and was limited to case reports [55] and case series [65]. Four cases of second-degree burns were reported by Troxell et al. [65] due to a bipolar RF device being used in an unreported number of patients over 4 years. The authors [65] attributed these four cases to lack of outflow tubing. Since changing their practice, further burn cases have not occurred.

The most common adverse events of RF use are thermal injuries due to high temperature of the fluid and surrounding tissue [3]. Many studies involve novel arthroscopic techniques with RF devices, yet parameters of its use such as safety, complications, and outcome profiles are poorly detailed within the majority of
Table 3. Studies included within this review article where RF device usage occurred without performance outcome disclosure by authors

| Study                        | Use                              | Study purpose                                                                 | Device used                                           | Radiofrequency mode | Amount of radiofrequency use |
|------------------------------|----------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------|---------------------|------------------------------|
| Baumgarten et al. [22]       | Acromioclavicular joint reconstruction | To propose a novel technique for the reconstruction of acromioclavicular joint | Unspecified                                          | Unspecified         | Minor                        |
| Cvetanovich et al. [10]      | Adhesive capsulitis               | To report outcomes after 360° arthroscopic capsular release for glenohumeral adhesive capsulitis performed in the lateral decubitus position | Super Turbovac 90 (Arthrocare; Smith & Nephew, Austin, TX, USA) | Coblation           | Major                        |
| Cvetanovich et al. [14]      | Adhesive capsulitis               | Description of an arthroscopic 360° capsular release method                   | Super Turbovac 90 (Arthrocare)                       | Coblation           | Major                        |
| Arce et al. [13]             | Adhesive capsulitis               | To detail an arthroscopic capsular release for primary frozen shoulder syndrome | VAPR III (DePuy Mitek, Raynham, MA, USA)             | Bipolar             | Major                        |
| Katthagen et al. [23]        | Anterior instability              | Presentation of a novel technique in open Latarjet procedure along with an arthroscopic Hills-Sachs remplissage | Super Turbovac 90 (Arthrocare)                       |                     |                              |
| Ganokroj et al. [24]         | Anterior instability              | To propose a novel arthroscopic technique called the "double row-double pulley" in the restoration of a bony Bankart lesion | Super Turbovac 90 (Arthrocare)                       | Coblation           | Minor                        |
| Lewington et al. [25]        | Anterior shoulder instability     | To present a method for shoulder instability using lateral decubitus arthroscopic Latarjet procedure | StarVac 90 (Arthrocare)                             | Coblation           | Minor                        |
| Gomes et al. [26]            | Anterior shoulder instability     | To present a Marfan’s Syndrome patient with recurrent anterior shoulder dislocation due to hyperlaxity requiring arthroscopic treatment | Unspecified                                          |                     | Major                        |
| Saithna et al. [17]          | Biceps pathology                 | Description of a novel technique to transilluminate the bicipital groove and identify long head biceps tendon | Unspecified                                          |                     | Minor                        |
| Shih et al. [27]             | Biceps pathology                 | Introduction of a novel technique for arthroscopic suprapectoral biceps tenodesis utilizing an all suture method | Unspecified                                          |                     | Minor                        |
| Valenti et al. [19]          | Biceps pathology                 | To present a novel technique for arthroscopic biceps tenodesis                | VAPR Coolpulse 90 (DePuy Mitek)                     | Bipolar             | Major                        |
| Daggett et al. [28]          | Biceps pathology                 | To describe a novel arthroscopic technique for bicep tenodesis, the “loop lock” technique | Unspecified                                          |                     | Minor                        |
| Saithna et al. [29]          | Biceps pathology                 | To present a novel method to identify the long head biceps tendon within the subacromial space | Unspecified                                          |                     | Major                        |
| Su et al. [18]               | Biceps pathology                 | To introduce a novel technique utilizing a double knotless screw for tenodesis of the long head of the biceps | Unspecified                                          |                     | Minor                        |

(Continued to the next page)
| Study                   | Use                         | Study purpose                                                                 | Device used                                                                 | Radiofrequency mode | Amount of radiofrequency use |
|------------------------|-----------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------|-----------------------------|
| Armangil et al. [30]   | Brachial plexopathy         | To describe a recollection of obstetrical brachial plexus palsy released with arthroscopic technique | Unspecified                                                                | Unspecified         | Minor                       |
| Li et al. [31]         | Coracoclavicular ligament repair | Description of a novel technique for coracoclavicular ligament repair arthroscopically | Unspecified                                                                | Unspecified         | Major                       |
| Yalizis et al. [32]    | Impingement syndrome        | To describe the acquisition of a panoramic view of the subacromial space arthroscopically | Unspecified device                                                       | Unspecified         | Major                       |
| Pagán Conesa et al. [33]| Impingement syndrome       | Presentation of intramuscular lipoma of supraspinatus muscle causing impingement syndrome treated arthroscopically | Unspecified device                                                       | Unspecified         | Minor                       |
| O’Brien et al. [34]    | Impingement syndrome        | To introduce a novel technique of the “subdeltoid approach” for anterior shoulder arthroscopy | Unspecified “radiofrequency ablation device”                               | Unspecified         | Minor                       |
| Mellano et al. [35]    | Impingement syndrome        | To propose an optimized technique for arthroscopic acromioplasty              | Unspecified                                                                | Unspecified         | Minor                       |
| Valenti et al. [36]    | Impingement syndrome        | To describe a novel technique in arthroscopic subacapularis assessment after removal of the coracoid process for shoulder impingement prophylaxis | VAPR (DePuy Mitek)                                                       | Bipolar             | Minor                       |
| Hendrix et al. [37]    | Other                       | To describe a novel arthroscopic technique for Pec Minor release to treat shoulder pain and dysfunction | Unspecified                                                                | Unspecified         | Minor                       |
| Theopold et al. [38]   | Other                       | To evaluate the accuracy of arthroscopic placement versus conventional placement of coracoclavicular tunnels | Unspecified                                                                | Unspecified         | Minor                       |
| Scheibel et al. [39]   | Other                       | To present cases of gracilis tendon transclavicular-transcoracoid loop technique via arthroscopic Tight-Rope | Unspecified                                                                | Unspecified         | Minor                       |
| Almazan et al. [40]    | Other                       | To compare and detail the results of the indirect bursal technique with the direct superior approach (the arthroscopic trans-articular distal clavicle resection) | VAPR 2 Side Effect (DePuy Mitek)                                          | Bipolar             | Minor                       |
| Boileau et al. [41]    | Posterior instability       | To introduce data from a novel arthroscopic posterior bone block technique    | Unspecified                                                                | Unspecified         | Minor                       |
| Parada et al. [15]     | Posterior instability       | Description of novel graft transfer technique during arthroscopic posterior glenoid reconstruction | Super Turbovac (Arthrocare)                                               | Coblation           | Minor                       |
| Rausch et al. [42]     | Postoperative stiffness     | To describe a novel arthroscopic method for restoration of shoulder mobility treatment of scapula neck fractures | Ambient Super TurboVac 90 (Arthrocare)                                     | Coblation           | Major                       |
| Bhatia et al. [43]     | Proximal humerus fracture   | Introduction of proximal humeral plate removal via arthroscopy                | Unspecified                                                                | Unspecified         | Minor                       |

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Table 3. Continued

| Study                        | Use                        | Study purpose                                                                 | Device used                     | Radiofrequency mode | Amount of radiofrequency use |
|------------------------------|----------------------------|-------------------------------------------------------------------------------|---------------------------------|---------------------|-----------------------------|
| Park et al. [44]             | Rotator cuff disease       | Introduction of a novel technique within arthroscopic rotator cuff repair     | Unspecified                     | Unspecified         | Minor                       |
| Shon et al. [45]             | Rotator cuff disease       | To describe a novel tenodesis performed via an arthroscopic suture anchor technique | Bisector Arthro Wand (Arthrocare) | Coblation           | Minor                       |
| Petri et al. [46]            | Rotator cuff disease       | To describe a novel technique for open reduction internal fixation for posterosuperior rotator cuff repair and latissimus dorsi transfer | Super TurboVac 90 (Arthrocare)  | Coblation           | Minor                       |
| Laskovski et al. [47]        | Rotator cuff disease       | To introduce a novel technique in arthroscopic augmentation of rotator cuff repair with an acellular human dermal allograft | Unspecified                     | Unspecified         | Minor                       |
| Cabarcas et al. [48]         | Rotator cuff disease       | To describe the surgical technique of a “double-row” arthroscopic subscapularis repair | Super TurboVac 90 (Arthrocare)  | Coblation           | Minor                       |
| Chernchujuj et al. [49]      | Rotator cuff disease       | To present a novel arthroscopic technique for the management of high graded bursal sided rotator cuff tears | Super TurboVac 90 (Arthrocare)  | Coblation           | Minor                       |
| Boutsiadis et al. [16]       | Rotator cuff disease       | To propose a modification of superior capsular reconstruction with a long head bicep autograft | Super TurboVac 90 (Arthrocare)  | Coblation           | Minor                       |
| Warth et al. [50]            | Sternoclavicular joint disease | To describe a novel technique for arthroscopic sternoclavicular joint resection | Unspecified                     | Unspecified         | Minor                       |
| Yamakado et al. [51]         | Suprascapular nerve entrapment | To quantify the learning curve using the log-linear model for arthroscopic suprascapular nerve decompression | Unspecified                     | Unspecified         | Minor                       |
| Thompson et al. [12]         | Adhesive capsulitis        | To propose a novel technique for performing an arthroscopic capsular release   | DYONICS EFLEX (Arthrocare)      | Monopolar           | Major                       |

DISCUSSION

In this systematic review of the literature, 63 studies demonstrated the safety and efficacy of RF devices within the shoulder. Of these, 25 studies explicitly studied the temperature profile, safety profile, or clinical outcomes. Though the temperature and safety profile were reasonably well described, functional or patient-reported outcomes after RF treatment were sparse [10,11,13-19, 22,23,25-27,29-33,35,39-45,49,51].

Our study demonstrated that the landscape of shoulder RF has changed significantly since it was originally studied in the context of shoulder instability [1,7,9]. Given the unanimous findings of poor outcomes in this setting, RF is largely used for debriding soft tissue (Table 3). Yasura et al. [70] demonstrated that bipolar RF resulted in significantly less chondrocyte death than unipolar RF in the knee. The results of our systematic review seem to be in concordance with this and demonstrate a general trend toward

studies [16,44-49,69]. All four studies reporting these adverse events specify second-degree burns as related to direct contact of the irrigation fluid from outflow tubing rather than from contiguous, elevated intraarticular temperatures [65-68]. Dermal burns have been reported during subacromial decompression [66]. Surgeons, however, plugged fluid outflow to increase the joint tamponade effect for better visibility, resulting in overheated irrigation fluid that burned the patient [66]. To decrease the burn risk, it is recommended that suction surveillance and high fluid outflow be maintained by surgeons [68].
| Study          | Radiofrequency device used                                                                 | Radiofrequency mode               | Study type                 | Level of evidence | Number of patients | Use                | Purpose                                                                 | Main outcome                                                                                           | Conclusion                                                                                           |
|---------------|------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------|-------------------|--------------------|--------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Faruque et al. [52] | Stryker Endoscopy Radio Frequency Ablation System (SERFAS) (Stryker, Portage, MI, USA) or Super Turbovac 90 (Arthrocare, Smith & Nephew, Austin, TX, USA) | Bipolar and Coblation              | Randomized control trial | I                 | 40                 | Rotator cuff repair | To compare intraarticular temperature profile in standard ablation versus plasma ablation RF devices for arthroscopic rotator cuff repair | Although 7 patients registered temperatures above 45 °C, no significant differences in intraarticular temperature were found between standard and plasma RF devices (P = 0.433). | Plasma ablation radiofrequency may be equivalent to standard radiofrequency. Further study is needed to determine the safety profile of plasma radiofrequency. |
| Gereli et al. [53] | Super Turbovac 90 (Arthrocare)                                                                 | Coblation                         | Prospective cohort study  | II                | 41                 | Subacromial decompression | To investigate the effect of irrigation fluid temperature on joint temperatures during shoulder surgery | The measured maximum temperature between the group receiving irrigation fluid of 34 °C and the group receiving 24 °C irrigation fluid was not statistically significantly different with a mean rise of 7.34 °C ± 0.7 °C with concurrent RF use. | Irrigation fluid temperature may not influence intraarticular temperature during shoulder surgery. New generation coblation devices may have a safe temperature profile. |
| Chivot et al. [54] | Ambient Super Turbovac 90 (Arthrocare)                                                     | Coblation                         | Prospective cohort study  | II                | 22                 | Subacromial decompression/rotator cuff surgery | To determine the effect of surgery site, radiofrequency modality, and other surgical details on intraarticular temperature during arthroscopic shoulder surgery | Additional portal sites reduced the temperature elevation by 3.8 °C (P < 0.05) when concurrent radiofrequency was used. Arthropump pressure plays a significant role in the intraarticular temperature as well (P < 0.05). No significant difference was found regarding radiofrequency modality choice. | It is important to be cognizant of the variables that can affect intraarticular temperature during arthroscopic shoulder surgery. Radiofrequency modality may or may not be as important as other factors. |

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| Study                      | Radiofrequency device used                        | Radiofrequency mode | Study type                  | Level of evidence | Number of patients | Use                      | Purpose                                                                 | Main outcome                                                                 | Conclusion                                                                 |
|---------------------------|---------------------------------------------------|---------------------|-----------------------------|-------------------|--------------------|------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Huynh et al. [3]          | Super Turbovac 90 (Arthrocare) and VAPR Mitek (DePuy Mitek, Raynham, MA, USA) | Coblation           | Prospective controlled trial | II                | 13                 | Subacromial decompression | To investigate the temperature profile during arthroscopy within the subacromial space | No difference in temperature profile was demonstrated between VAPR and coblation within the first 40 seconds (P > 0.05). After 40 seconds, coblation temperatures were higher than VAPR (P < 0.05). All trials displayed temperatures below the chondrocyte threshold damage of 45 °C. | There is minimal concern for temperature violation with both VAPR and coblation. |
| Barker et al. [55]        | Super Turbovac 90 (Arthrocare)                    | Coblation           | Case series                 | IV                | 15                 | Subacromial decompression | To investigate if the bipolar RF ablation wand causes excess heating   | The mean peak temperature was 32.0 °C in the subacromial bursa and 71.6 °C in the outflow fluid during arthroscopic subacromial decompression. Baseline temperature of irrigation fluid most influenced bursal temperature | Bipolar RF can be safely used below the temperature threshold in the shoulder. |
| Davies et al. [56]        | Ablator-S (Arthrocare)                            | Monopolar           | Case series                 | IV                | 30                 | Impingement syndrome    | To assess subacromial space temperatures during RF ablation of subacromial bursa | Both the mean and maximum temperatures reached in 30 case series patients were below the experimental thresholds for chondrocyte damage. | Radiofrequency can be used safely in the shoulder below the temperature limit. |

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Table 4. Continued

| Study | Radiofrequency device used | Radiofrequency mode | Study type | Level of evidence | Number of patients | Use | Purpose | Main outcome | Conclusion |
|-------|-----------------------------|--------------------|------------|-------------------|--------------------|-----|---------|--------------|------------|
| Zoric et al. [57] | Super Turbovac (Arthrocare) | Coblation | Cadaveric study (10 cadavers) | NA | NA | NA | To investigate factors that impact joint temperature profiles with RF usage | Three factors are crucial in influencing joint capsule temperature: application duration, application distance, and flow rate, with the flow rate being the most important factor. | Maintaining appropriate joint temperature during shoulder radiofrequency treatment is important. These factors better enable clinicians to do so. |
| Good et al. [58] | VAPR3 (DePuy Mitek) | Bipolar | Cadaveric study (30 cadavers) | NA | NA | NA | To assess glenohumeral fluid temperature during shoulder arthroscopy and the effect RF energy has upon it | In this cadaveric study using VAPR3, joint temperatures rose above 45 °C in all trials. A flow rate of 100% had reduced temperatures compared to a flow rate of 0%. | Bipolar radiofrequency has the potential to raise the intraarticular temperature, which can be detrimental to chondrocyte viability. Clinicians must keep this in mind while pursuing radiofrequency treatment in the shoulder. |
| Edwards et al. [59] | ArthroCare System 2000 (Arthrocare) and Vulcan EAS | Monopolar | Animal study | NA | NA | NA | To compare and contrast cartilage matrix temperatures between the monopolar and bipolar RF energy devices | Monopolar RF devices were associated with lower temperatures and at greater depths within the cartilage. | Monopolar radiofrequency can be safely used without violating the temperature limit of the shoulder. |

(Continued to the next page)
| Study | Use | Main outcome | Conclusion |
|-------|-----|--------------|------------|
| Valet et al. [60] | SuperTurbo Vac 90 (Arthrocare) Coblation | To determine an optimal technique for prevention of damaging suture material in RF tissue ablation | High-strength ultra-high molecular weight polyethylene sutures were less sensitive to RF treatment than polyester sutures. By maintaining the distance between the probe and suture, damage can be reduced to sutures. Suture choice can affect the safety of radiofrequency treatment in the shoulder. |
| Shah et al. [61] | Orthopedic Procedure Electrosurgical System (Arthrex, Naples, FL, USA) | To evaluate different sutures and the effect RF energy exerts on their mechanical properties | This study demonstrates that exposure to electrocautery damages and weakens sutures. Radiofrequency has the potential to affect the integrity of all sutures tested and should be used with care around sutures. |
| Lemos et al. [20] | Ambient Super Turbo Vac 90 (Arthrocare) | To describe a novel technique of outlet biceps tenodesis or tenotomy | In comparison to traditional tenotomy on cadavers, biomechanical testing showed favorable pullout force results from this technique. Radiofrequency use was used in a novel biceps tenodesis technique that did not result in any adverse effects. |
| Ficklscherer et al. [62] | OPES CoolCut (Arthrex) | To investigate footprint preparations in rotator cuff repair alone with their histological and biomechanical outcomes | RF in comparison to spongialisation of the footprint was associated with poorer biomechanical and histological outcomes. RF cannot be advised in place of spongialisation for rotator cuff repair. |

RF: radiofrequency, NA: not applicable.
Table 5. Studies included within the review article that investigated complications and safety profile of radiofrequency use in the shoulder

| Study         | Radiofrequency device                  | Radiofrequency mode | Study type              | Level of evidence | Number of patients | Use     | Purpose                                                                 | Main outcome                                                                 | Conclusion                                                                 |
|---------------|----------------------------------------|---------------------|-------------------------|-------------------|-------------------|---------|------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Nho et al. [21] | VAPR Mitek (DePuy Mitek, Raynham, MA) and OraTec Vulcan EAS (OraTec, Manassas, VA, USA) | Bipolar             | Prospective randomized clinical trial | I                 | 50                | Varied  | To investigate if RF energy devices originally from coagulation and soft tissue ablation cause thermal injury to the bone | With MRI, no cases of osteonecrosis or bone edema occurred with monopolar or bipolar RF devices. | There may not be any injury or insult that is detectable on imaging studies after utilization of radiofrequency in the shoulder. |
| Jerosch et al. [63] | VAPR (DePuy Mitek) | Bipolar             | Case report             | IV                | 1                 | Capsular release | To present a case of chondrolysis post arthroscopic capsular release for adhesive capsulitis with a bipolar VAPR RF energy probe | Glenohumeral chondrolysis occurred after treatment with the bipolar VAPR RF probe, although rare. A surface replacement was required. | Chondrolysis can occur as a complication of bipolar radiofrequency in the shoulder. |
| Bonsell et al. [64] | Unspecified device | Bipolar             | Case report             | IV                | 1                 | Subacromial decompression | To present a case of deltoid detachment that occurred during arthroscopic subacromial decompression | Overaggressive use of the bipolar RF was attributed to deltoid detachment by the authors. | Bipolar radiofrequency use is not without its risks. The practicing shoulder surgeon needs to be aware of these risks. |
| Troxell et al. [65] | SuperTurbo Vac 90 (Arthrocare; Smith & Nephew, Austin, TX, USA) | Coblation            | Case series             | IV                | 4                 | Subacromial decompression | To present reports of shoulder arthroscopy bipolar RF-induced burn injuries within patients | Four patients over 4 years suffered second-degree burns after irrigation fluid from outflow tubing contacted the patients. | Orthopedic surgeons need to be cognization of burn risk during radiofrequency of the shoulder. |
| Chahar et al. [66] | VAPR (DePuy Mitek) | Bipolar             | Case report             | IV                | 1                 | Rotator cuff repair | To present a dermal burn case that occurred after a radiofrequency procedure | The suction device was removed leading intraarticular fluid temperature to increase. Dermal burns occurred as a consequence of RF subacromial decompression. | Practitioners need to be aware of the complication of thermal burns. |

(Continued to the next page)
Radiofrequency

Table 5. Continued

| Study                | Radiofrequency device       | Radiofrequency mode | Study type        | Level of evidence | Number of patients | Use                          | Purpose                                                                 | Main outcome                                                              | Conclusion                                                                 |
|----------------------|----------------------------|---------------------|-------------------|-------------------|--------------------|------------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Talati et al. [67]   | Stryker endoscopy Ablation System (SERCAS; Stryker, Portage, MI, USA) | Bipolar             | Case report       | IV                | 1                  | Impingement syndrome         | To describe a report of skin burn from contact with an RF device with a spinal needle during arthroscopic subacromial decompression. | A patient received skin burns from the contact of the spinal needle with the RF device during an arthroscopic subacromial decompression. | Orthopedic surgeons should use caution when using radiofrequency in order to minimize the risk of superficial dermal burns.          |
| Kouk et al. [68]     | Super Turbo Vac 90 (Arthrex) | Coblation           | Case report       | IV                | 1                  | Subacromial decompression    | To report a case of overheating irrigation fluid from RF causing second-degree burns on the patient's chest wall and shoulder | Author details forgetting to close the valve and place the suction, thus allowing heated irrigation fluid to drip onto the patient and cause second-degree burns. | Bipolar radiofrequency use is not without its risks, which are increased by user error.                                       |

RF: radiofrequency, MRI: magnetic resonance imaging.
CONCLUSIONS

Shoulder RF has a wide scope of application in various shoulder pathologies. Although shoulder RF is safe, it requires practitioners to be cognizant of the potential for thermal burn injuries. Protocols regarding irrigation fluid temperature and outflow rates should be set by individual institutions to further reduce minor patient complications of shoulder RF. Future research is required to determine measures to minimize further the risk of thermal burn injuries.

NOTES

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Author contributions
Conceptualization: NV, JNL, NA. Data curation: NV, JNL, NA. Formal Analysis: NV, JNL, NA. Investigation: NV, JNL, NA. Methodology: NV, JNL, NA. Project administration: JNL, NA. Resources: NV, JNL, NA. Software: NV, JNL, NA. Supervision: JNL, NA. Validation: NV, JNL, NA. Visualization: NV, JNL, NA. Writing – original draft: NV, JNL, NA. Writing – review & editing: NV, JNL, NA.

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REFERENCES

1. Anderson SR, Faucett SC, Flanagan DC, Gmabardella RA, Amin NH. The history of radiofrequency energy and Coblation in arthroscopy: a current concepts review of its application in chondroplasty of the knee. J Exp Orthop 2019;6:1.
2. Lu Y, Zhang Q, Zhu Y, Jiang C. Is radiofrequency treatment effective for shoulder impingement syndrome?: a prospective randomized controlled study. J Shoulder Elbow Surg 2013;22:1488–94.
3. Huynh V, Barbier O, Bajard X, Bouchard A, Ollat D, Versier G. Subacromial temperature profile during bipolar radiofrequency use in shoulder arthroscopy: comparison of Coblation® vs. VAPR®. Orthop Traumatol Surg Res 2017;103:489–91.
4. Peng L, Li Y, Zhang K, et al. The time-dependent effects of bipolar radiofrequency energy on bovine articular cartilage. J Orthop Surg Res 2020;15:106.
5. Kosy JD, Schranz PJ, Toms AD, Eyres KS, Mandalaria VI. The use of radiofrequency energy for arthroscopic chondroplasty in the knee. Arthroscopy 2011;27:695–703.
6. Schenker ML, Philippon MJ. The role of flexible radiofrequency energy probes in hip arthroscopy. Tech Orthop 2005;20:37–44.
7. Hayashi K, Markel MD. Thermal capsulorrhaphy treatment of shoulder instability: basic science. Clin Orthop Relat Res 2001; (390):59–72.
8. Hawkins RJ, Krishnan SG, Karas SG, Noonan TJ, Horan MP. Electrothermal arthroscopic shoulder capsulorrhaphy: a minimum 2-year follow-up. Am J Sports Med 2007;35:1484–8.
9. D’Alessandro DF, Bradley JP, Fleischl JE, Connor PM. Prospective evaluation of thermal capsulorrhaphy for shoulder instability: indications and results, two- to five-year follow-up. Am J Sports Med 2004;32:21–33.
10. Cvetanovich GL, Leroux TS, Bernardoni ED, et al. Clinical outcomes of arthroscopic 360° capsular release for idiopathic adhesive capsulitis in the lateral decubitus position. Arthroscopy 2018;34:764–70.
11. Li T, Yang ZZ, Deng Y, Xiao M, Jiang C, Wang JW. Indirect transfer of the sternal head of the pectoralis major with autogenous semitendinosus augmentation to treat scapular winging secondary to long thoracic nerve palsy. J Shoulder Elbow Surg 2017;26:1970–7.
12. Thompson SR, Lebel ME. Use of a hip arthroscopy flexible radiofrequency device for capsular release in frozen shoulder. Arthrosc Tech 2012;1:e75–8.
13. Arce G. Primary frozen shoulder syndrome: arthroscopic capsular release. Arthrosc Tech 2015;5:e717–20.
14. Cvetanovich GL, Leroux T, Hamamoto JT, Higgins JD, Romeo AA, Verma NN. Arthroscopic 360° capsular release for adhesive capsulitis in the lateral decubitus position. Arthrosc Tech 2016;5:e1033–8.
15. Parada SA, Shaw KA. Graft transfer technique in arthroscopic posterior glenoid reconstruction with distal tibia allograft. Arthrosc Tech 2017;6:e1891–5.
16. Boutsiadis A, Chen S, Jiang C, Lenoir H, Delsol P, Barth J. Long head of the biceps as a suitable available local tissue autograft for superior capsular reconstruction: “the Chinese way”. Arthrosc Tech 2017;6:e1559–66.
17. Saithna A, Longo A, Leiter J, MacDonald P, Old J. Biceps tenoscopy: arthroscopic evaluation of the extra-articular portion of the long head of biceps tendon. Arthrosc Tech 2016;5:e1461–5.
18. Su WR, Ling FY, Hong CK, Chang CH, Chung KC, Jou IM. An arthroscopic technique for long head of biceps tenoscopy with double knotless screw. Arthrosc Tech 2015;4:e375–8.
19. Valenti P, Benedetto I, Maqdes A, Lima S, Moraiti C. “Relaxed” biceps proximal tenodesis: an arthroscopic technique with decreased residual tendon tension. Arthrosc Tech 2014;3:e639–41.
20. Lemos D, Esquivel A, Duncan D, Marsh S, Lemos S. Outlet biceps tenoscopy: a new technique for treatment of biceps long head tendon injury. Arthrosc Tech 2013;2:e83–8.
21. Nho SJ, Freedman KB, Bansal SL, et al. The effect of radiofrequency energy on nonweight-bearing areas of bone following shoulder and knee arthroscopy. Orthopedics 2005;28:392–9.
22. Baumgarten KM, Altchek DW, Cordasco FA. Arthroscopically assisted acromioclavicular joint reconstruction. Arthroscopy 2006;22:228.
23. Katthagen JC, Anavian J, Tahal DS, Millett PJ. Arthroscopic remplissage and open latarjet procedure for the treatment of anterior glenohumeral instability with severe bipolar bone loss. Arthrosc Tech 2016;5:e1135–41.
24. Ganokroj P, Keyurapan E. Arthroscopic bony bankart repair using a double-row double-pulley technique. Arthrosc Tech 2018;8:e31–6.
25. Lewington MR, Urqhart N, Wong IH. Lateral decubitus all-arthroscopic Latarjet procedure for treatment of shoulder instability. Arthrosc Tech 2015;4:e207–13.
26. Gomes N, Hardy P, Bauer T. Arthroscopic treatment of chronic anterior instability of the shoulder in Marfan’s syndrome. Arthroscopy 2007;23:110.
27. Shih CA, Chiang FL, Hong CK, et al. Arthroscopic transtendinous biceps tenodesis with all-suture anchor. Arthrosc Tech 2017;6:e705–9.
28. Daggett M, Stepanovich B, Meyers A, Geraghty B. Arthroscopic on-lay biceps tenodesis: the loop-lock technique. Arthrosc Tech 2019;8:e935–9.
29. Saithna A, Longo A, Leiter J, MacDonald P, Old J. Safety of the “inside-out” radiofrequency ablation technique for rapid localization of the biceps tendon in the subacromial space. Tech Shoulder Elbow Surg 2016;17:98–9.
30. Armangil M, Akan B, Basarir K, Bilgin SS, Gürcan S, Demirtas M. Arthroscopic release of the subscapularis for shoulder contracture of obstetric palsy. Eur J Orthop Surg Traumatol 2012;22:25–8.
31. Li X, Padmanabha A, Koh J, Cusano A. All-arthroscopic coracoclavicular ligament reconstruction surgical technique using a semitendinosus allograft and tenodesis screws. Arthrosc Tech 2017;6:e413–7.
32. Yalızis M, Kruse K 2nd, Godenèche A. Arthroscopic “panorama” view of the subacromial space via deltoid fascia release. Arthrosc Tech 2015;5:e935–9.
33. Pagán Conesa A, Verdú Aznar C, Herrera MR, Lopez-Prats FA. Arthroscopic marginal resection of a lipoma of the supraspinatus muscle in the subacromial space. Arthrosc Tech 2015;4:e371–4.
34. O’Brien SJ, Taylor SA, DiPietro JR, Newman AM, Drakos MC, Voos JE. The arthroscopic “subdeltoid approach” to the anterior shoulder. J Shoulder Elbow Surg 2013;22:e6–10.
35. Mellano CR, Virk MS, Shin JJ, Aiyash S, Romeo AA. Tips and technical pearls for performing an arthroscopic acromioplasty in a reproducible and accurate manner. Tech Shoulder Elbow Surg 2015;16:59–62.
36. Valenti P, Maroun C, Schoob B, Arango SO, Werthel JD. Arthroscopic Trillat coracoid transfer procedure using a cortical button for chronic anterior shoulder instability. Arthrosc Tech 2019;8:e199–204.
37. Hendrix ST, Hoyle M, Tokish JM. Arthroscopic pectoralis minor release. Arthrosc Tech 2018;7:e589–94.
38. Theopold J, Marquass B, von Dercks N, et al. Arthroscopically guided navigation for repair of acromioclavicular joint dislocations: a safe technique with reduced intraoperative radiation exposure. Patient Saf Surg 2015;9:41.
39. Scheibl M, Ifesanya A, Pauly S, Haas NP. Arthroscopically assisted coracoclavicular ligament reconstruction for chronic acromioclavicular joint instability. Arch Orthop Trauma Surg 2008;128:1327–33.
40. Almazan A, Sierra L, Cruz F, et al. Arthroscopic transarticular distal clavicle resection. Tech Shoulder Elbow Surg 2006;7:206–9.
41. Boileau P, McClelland WB Jr, O’Shea K, et al. Arthroscopic Hill-Sachs remplissage with Bankart repair: strategy and technique. JBJS Essent Surg Tech 2014;4:e4.
42. Rausch V, Königshausen M, Schildhauer TA, Seybold D, Gessmann J. Arthroscopic lateral border resection in medialized clavical neck fractures. Arthrosc Tech 2017;6:e1619–23.
43. Bhatia DN, de Beer JF, van Rooyen KS, du Toit DF. Arthroscopic suprascapular nerve decompression at the suprascapular notch. Arthroscopy 2006;22:1009–13.
44. Park YB, Park YE, Koh KH, Lim TK, Shon MS, Yoo JC. Subscapularis tendon repair using suture bridge technique. Arthrosc Tech 2015;4:e133–7.
45. Shon MS, Koh KH, Lim TK, Lee SW, Park YE, Yoo JC. Arthroscopic suture anchor tenodesis: loop-suture technique. Ar-
throsr Tech 2013;2:e105–10.
46. Petri M, Greenspoon JA, Millett PJ. Arthroscopic superior cap- 
sule reconstruction for irreparable rotator cuff tears. Arthrosc 
Tech 2015;4:e751–5.
47. Laskovski J, Abrams J, Bogdanovska A, Taliwal N, Taylor M, 
Fisher M. Arthroscopic rotator cuff repair with allograft aug-
mentation: making it simple. Arthrosc Tech 2019;8:e597–603.
48. Cabarcas BC, Garcia GH, Liu JN, Gowd AK, Romeo AA. Dou-
ble-row arthroscopic subacapularis repair: a surgical technique. 
Arthrosc Tech 2018;7:e805–9.
49. Chernchujit B, Shahul Hamid MA, Aimprasitthichai S. Knotless 
suture bridge technique in high-grade bursal-sided rotator cuff 
tears: is this the way forward. Arthrosc Tech 2017;6:e2259–63.
50. Warth RJ, Lee JT, Millett PJ. Figure-of-eight tendon graft recon-
struction for sternocavicular joint instability: biomechanical 
rational, surgical technique, and a review of clinical outcomes. 
Oper Tech Sports Med 2014;22:260–8.
51. Yamakado K. Quantification of the learning curve for ar-
throscopic suprascapular nerve decompression: an evaluation of 
300 cases. Arthroscopy 2015;31:191–6.
52. Faruque R, Matthews B, Bahlo Z, et al. Comparison between 2 
types of radiofrequency ablation systems in arthroscopic rotator 
cuff repair: a randomized controlled trial. Orthop J Sports Med 
2019;7:232596719835224.
53. Gereli A, Kocaoglu B, Guven O, Turkmen M. Warm irrigation 
fluid does not raise the subacromial temperature to harmful 
levels while using radiofrequency device. Int J Shoulder Surg 
2015;9:99–100.
54. Chivot M, Airaudi S, Galland A, Gravier R. Analysis of param-
ters influencing intraarticular temperature during radiofre-
cuency use in shoulder arthroscopy. Eur J Orthop Surg Trau-
matol 2019;29:1205–10.
55. Barker SL, Johnstone AJ, Kumar K. In vivo temperature mea-
surement in the subacromial bursa during arthroscopic sub-
acromial decompression. J Shoulder Elbow Surg 2012;21:804–7.
56. Davies H, Wynn-Jones H, De Smet T, Johnson P, Sampath S, 
Sjoelin S. Fluid temperatures during arthroscopic subacromial 
decompression using a radiofrequency probe. Acta Orthop 
Belg 2009;75:153–7.
57. Zoric B, Horn N, Braun S, Millett PJ. Factors influencing in-
tra-articular fluid temperature profiles with radiofrequency ab-
lation. J Bone Joint Surg Am 2009;91:2448–54.
58. Good CR, Shindle MK, Griffith MH, Wanich T, Warren RF. Ef-
fect of radiofrequency energy on glenohumeral fluid temperature 
during shoulder arthroscopy. J Bone Joint Surg Am 2009; 
91:429–34.
59. Edwards RB 3rd, Lu Y, Markel MD. The basic science of ther-
mally assisted chondroplasty. Clin Sports Med 2002;21:619–47.
60. Valet S, Weisse B, Fischer B, Meyer DC. Mechanical effects of 
heat exposure from a bipolar radiofrequency probe on suture 
under simulated arthroscopic conditions. Arthroscopy 2016; 
32:1985–92.
61. Shah AA, Kang P, Deutsch A. Radiofrequency and its effect on 
suture strength. Orthopedics 2009;32:894.
62. Ficklscherer A, Serr M, Loitsch T, et al. The influence of differ-
ent footprint preparation techniques on tissue regeneration in 
rotator cuff repair in an animal model. Arch Med Sci 2017; 
13:481–8.
63. Jerosch J, Aldawoudy AM. Chondrolysis of the glenohumeral 
joint following arthroscopic capsular release for adhesive capsu-
litis: a case report. Knee Surg Sports Traumatol Arthrosc 2007; 
15:292–4.
64. Bonsell S. Detached deltid during arthroscopic subacromial 
decompression. Arthroscopy 2000;16:745–8.
65. Troxell CR, Morgan CD, Rajan S, Leitman EH, Bartolozzi AR. 
Dermal burns associated with bipolar radiofrequency ablation 
in the subacromial space. Arthroscopy 2011;27:142–4.
66. Chahar D, Chawla A, Verma N, Mittal A, Pankaj A. Dermal 
burn: an unusual complication of radio frequency probe in 
shoulder arthroscopy. J Arthrosc Joint Surg 2017;4:38–40.
67. Talati RK, Dein EJ, Hur J, McFarland EG. Cutaneous burn 
caused by radiofrequency ablation probe during shoulder ar-
throscopy. Am J Orthop (Belle Mead NJ) 2015;44:E58–60.
68. Kouk SN, Zoric B, Stetson WB. Complication of the use of a ra-
diofrequency device in arthroscopic shoulder surgery: sec-
ond-degree burn of the shoulder girdle. Arthroscopy 2011;27: 
136–41.
69. Jang JS, Choi HJ, Kang SH, Yang JS, Lee JJ, Hwang SM. Effect of 
pulsed radiofrequency neuromodulation on clinical improve-
ments in the patients of chronic intractable shoulder pain. J Ko-
nor Neurosurg Soc 2013;54:507–10.
70. Yasura K, Nakagawa Y, Kobayashi M, Kuroki H, Nakamura T. 
Mechanical and biochemical effect of monopolar radiofre-
cuency energy on human articular cartilage: an in vitro study. Am J 
Sports Med 2006;34:1322–7.
71. Taverna E, Battistella F, Sansone V, Perfetti C, Tasto JP. Radiofre-
cuency-based plasma microtenotomy compared with ar-
throscopic subacromial decompression yields equivalent out-
comes for rotator cuff tendinosis. Arthroscopy 2007;23:1042– 
51.
72. Diab MA, Fernandez GN, Elsorayf K. Time and cost savings in 
arthroscopic subacromial decompression: the use of bipolar 
versus monopolar radiofrequency. Int Orthop 2009;33:175–9.