Systematic Review

Heat-Related Complications from Radiofrequency and Electrocautery Devices Used in Arthroscopic Surgery: A Systematic Review

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Purpose: To investigate the occurrence of heat-related complications from radiofrequency and electrocautery devices in patients undergoing arthroscopic surgery. **Methods:** A systematic review was performed using the PubMed/Medline, Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Cochrane databases, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. All studies reporting complications after arthroscopy using electrosurgery devices were included. Only English- and Dutch-language articles were included. Basic science/nonclinical studies/human cadaveric studies and animal studies were excluded. Article selection was performed by 2 separate reviewers. Interobserver agreement of the selection procedure was determined by Cohen's kappa. All included articles were critically appraised using an adapted version of the ROBINS-I tool. **Results:** Twenty-five studies were included in this systematic review. A total of 309 cases of heat-related complications were identified. Chondrolysis was present in 45 cases and dermal burns in 15 cases. Axillary nerve injuries were reported in 197 cases of arthroscopic adhesive capsulitis release. However, it was unclear whether these injuries were directly related to the overheating of the arthroscopic fluid. No one specific risk factor for thermal complications was identified, but related factors included the leakage of the arthroscopy fluid, use of a thermal device continuously for a long period of time, proximity of the thermal device to the tissue, intra-articular local anesthetic injection or the use of intra-articular pain pumps, and certain surgical procedures, such as thermal capsulorrhaphy, capsular release, and synovectomy. **Conclusions:** The most common heat-related complications in arthroscopy are dermal burns and chondrolysis. Risk factors include leakage of arthroscopy fluid, use of a thermal device, intra-articular anesthetics/pain pumps, and performing specific surgical procedures. **Level of Evidence:** Systematic review of level III-IV studies.

Arthroscopy is one of the most frequently performed surgeries in orthopaedics.[1,2] Electrosurgery devices such as electrocautery, radiofrequency, and laser can be helpful when performing arthroscopic surgery, as they produce heat when cutting or ablating tissues, aiding in hemostasis and visualization. Radiofrequency devices use an electrical current that is led through the tissue. There are monopolar and bipolar radiofrequency devices.[3] Monopolar devices use an alternating current between the electrode and the grounding pad, whereas bipolar devices have an individual positive and a negative electrode. The energy is propagated through liquid (saline). Since it has individual electrodes, the radiofrequency is kept in a much smaller area, which can make it safer to use.[3] With electrocautery devices, the electric current passes through an electrode that is placed on or near the tissue. The tip of the electrode is heated by the electric current to cut, coagulate, or remove the tissue.[4] Laser is an optical device that can transmit energy in the form of an intense beam of light. The light gets absorbed by the tissues (composed mainly of water), and heat is generated. The energy absorbed by the tissue is

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 2, 2020; accepted December 20, 2020.

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2666-061X/20421

https://doi.org/10.1016/j.asmr.2020.12.002

controlled by the power density, the spot size, and the duration of application.[5]

As these arthroscopic instruments can reach up to 1200°C, the fluid may attain too high of a temperature in a short period of time, especially when the irrigation flow is not regulated properly.[6] This can result in intra- and extra articular complications. Soft-tissue damage can occur above 43°C and cartilage damage above 50°C.[7] Complications include chondrolysis,[8-10] adhesive capsulitis and dermal blistering,[6] as well as damage to the suture materials used in the repair.[11]

Recent studies have focused mostly on temperature thresholds for safe surgery.[11-14] These have found that fluid temperatures within the space with is being scoped increase on average 10°C, whereas the outflow fluid from the device increases on average 50°.[13] Use of room temperature inflow fluid, maintenance of flow, avoiding long uninterrupted use, and increasing the distance between the device and the tissue and the radiofrequency/electrocautery have been suggested to prevent heat complications during arthroscopy.[12,13]

However, the true incidence and spectrum of heat-related complications is not known. This is most likely because isolated studies on the topic are too small. The purpose of this systematic review was to investigate the occurrence of heat-related complications from radiofrequency and electrocautery devices in patients undergoing arthroscopic surgery. It was hypothesized that heat-related complications would be clinically significant and could have permanent consequences for the patient.

Methods

Search Method

A literature search was conducted on April 23, 2019, using the PubMed/Medline, Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Cochrane databases, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, to identify all potentially relevant studies. Data extraction was already started and therefore PROSPERO registration was not possible. The search terms used were "arthroscopy" combined with "thermal complications" as well as corresponding synonyms and terms. The full list of search terms used for PubMed is enclosed in Appendix 1, available at www.arthroscopyjournal.org. An updated search was repeated before submission to obtain any additional articles published in the period of time between the initial search and completion of this review.

Eligibility Criteria

All studies mentioning any type of heat-related complications following any type of arthroscopic treatment of any joint in living human subjects employing electrocautery and radiofrequency devices were included. Conference abstracts and reviews were excluded. Only English- and Dutch-language articles were included. No publication year limit was applied. Heat-related complications were defined as complications linked to the employed thermal device by the author or a complication known as a heat-related complication, for example, chondrolysis, and clearly mentioned in the article. Basic science/nonclinical studies/ human cadaveric studies and animal studies were excluded.

Article Selection

All articles were independently screened on title and abstract by 2 reviewers (T.A.C.M. − orthopaedic resident, M.P.J.B. − orthopaedic surgeon). No distinction was made between study types during the article selection procedure. After title and abstract screening, the remaining articles were screened using full-text review by the same reviewers. Disagreements during the selection procedure were resolved by consensus or third-party adjudication (B.J. − orthopaedic surgeon). The reference list of all included studies was screened for potentially missed studies. The flowchart of the article selection procedure is summarized in Fig 1.

Data Extraction

Data extraction was performed by 1 reviewer (T.A.C.M. − orthopaedic resident) and audited by another reviewer (J.A.C.Z. − orthopaedic surgeon). The following data were collected from the included studies: database search from which the study was retrieved, authors, year of publication, journal of publication. Regard heat-related complications, the following information was recorded: surgical procedure(s) performed, type of thermal device used (i.e., radiofrequency vs electrocautery, and monopolar vs bipolar), type of health-related complication(s) that occurred, incidence/frequency of heat-related complication, etiology of the injury, treatment rendered, and outcome. With regards to the included patients, the sex and age were recorded.

Critical Appraisal Tool

The included articles were graded on quality by using an adapted version of the ROBINS-I (Risk Of Bias In Non-randomized Studies - of Interventions) tool.[15] An overall low risk of bias score was classified as a maximum of one intermediate risk score on any of the subscores, a medium risk as a maximum of 1 high score or 2 intermediate scores, and a high risk of bias as more than 1 high-risk score or more than 2 intermediate risk scores.

Statistical Analysis

Cohen's kappa (κ), including a 95% confidence interval (95% CI), was calculated to describe interobserver agreement of the screening and article selection procedure using IBM SPSS Statistics for Macintosh, Version 25.0 (IBM Corp., Armonk, NY). A κ

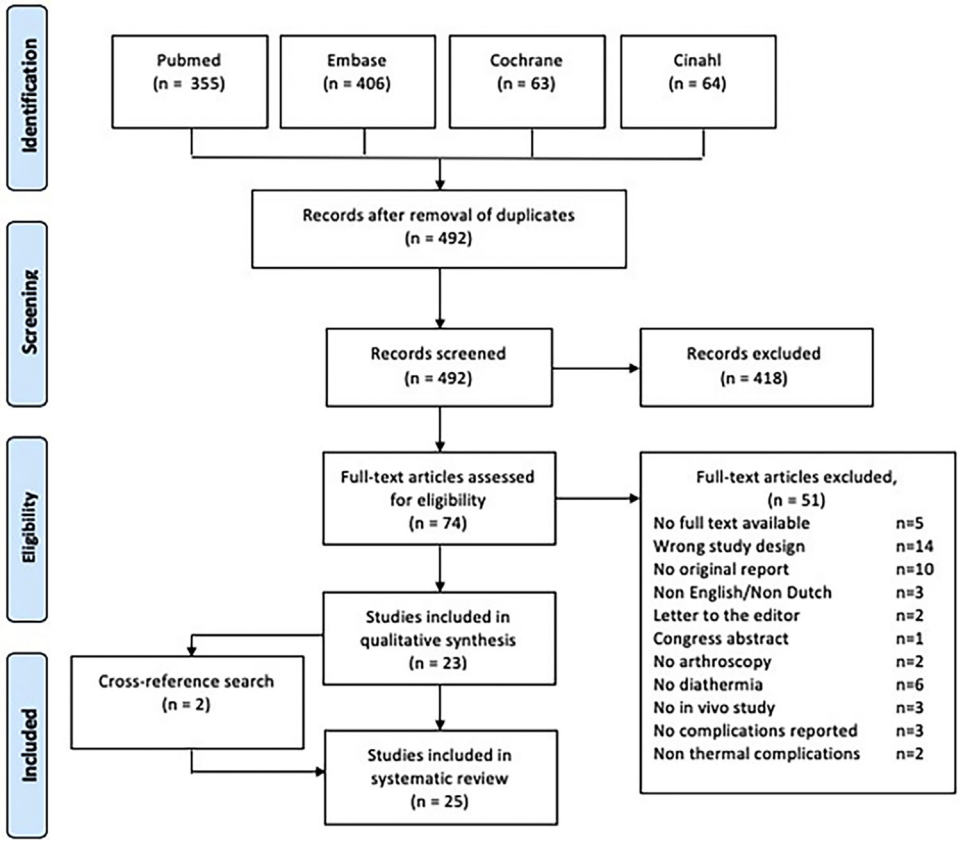

Fig 1. Flowchart of the article selection process. A total of 492 papers were identified from the 4 databases that were searched. Of those, 74 articles were identified for full-text review. After review of the full text, 23 articles remained for inclusion in the study. After we checked the reference lists of these papers, an additional 2 articles were identified, bringing the total number of included studies to 25.

of 0 to 0.20 reflects poor interobserver agreement, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, 0.61 to 0.80 substantial, and 0.80 to 1.00 near-perfect agreement.[16] Pooling of the results was not able to be performed due the heterogeneity of the data.

Results

Search Results

A total of 25 full-text articles was included (Fig 1).[5,6,8,14,17-37] Reviewer interobserver agreement was substantial for title and abstract screening ($\kappa = 0.61$ [95% CI 0.53-0.70]) and high for full-text screening ($\kappa = 0.88$ [95% CI 0.76-1.0]).

Study Characteristics

The characteristics of all included studies are summarized in Table 1. None of the studies were of high quality. Three studies were retrospective cohort studies,[18,32,37] and the remaining studies consisted of case reports, case series, and a survey.[5,6,8,14,17,19-31,33-36] The overall risk of bias score was high based on the employed appraisal tool (Table 2).

All Complications

The 25 included papers included 297 shoulder arthroscopies, 5 knee arthroscopies, 3 hip arthroscopies, 1 temporomandibular joint arthroscopy, and 3 wrist arthroscopies.[5,6,8,14,17-37] Electrocautery was used in 6 cases,[22,29,30,34,35] radiofrequency in 236 cases,[5,6,18-21,23-27,30-33,36,37] and laser in 3 cases.[5] In 1 study, a combination of radiofrequency and electrocautery was used.[30] The type of thermal device was not specified in 63 cases.[5,8,14,17,28] There were 309 complications described in total (Table 1).

Dermal Burns

Fifteen cases of dermal burns were reported, involving 8 shoulder, 3 knee, 2 hip, 1 wrist, and 1 temporomandibular joint arthroscopy.[6,20-22,29,32,34-37] Radiofrequency devices were used in 9 cases[6,20,21,32,36,37] and electrocautery devices in 6 cases.[22,29,34,35] Leakage of the arthroscopy fluid was the most commonly described cause of dermal burns, specifically, failure to switch the suction from the shaver to the radiofrequency wand when the instruments were switched. Leaving the outflow open without suction led to a superficial second-degree burn from the outflow irrigant.[6,21] An example described is one of the hot arthroscopy fluid leaking from the open radiofrequency wand onto the chest and arm of patient during shoulder arthroscopy. The authors reported second-degree burns, which were treated conservatively with cool compresses.[6,21] Overaggressive resection of (bursal)

Table 1. Study Characteristics

Author	Year of Publication	Level of Evidence: Study Type	Cases, n	Joint	Device Used	Complication	Suture Anchors	Pain Pump
Akgun et al[17]	2007	Level IV: case-series	2	Knee	Not specified	Other (osteonecrosis)	−	−
Bailie and Ellenbecker[18]	2009	Level III: retrospective cohort study	7	Shoulder	RF device	Chondrolysis	+	+
Beauthier et al.[19]	2010	Level IV: case report	1	Shoulder	RF device	Osteonecrosis	+	−
Chahar et al.[20]	2017	Level IV: case report	1	Shoulder	RF device	Dermal burn	NA	NA
Coobs et al.[8]	2009	Level IV: case-series	2	Shoulder	Not specified	Chondrolysis	+	−
Curtin and Friebe[21]	2014	Level IV: case report	1	Hip	RF device	Dermal burn	NA	NA
Gomide et al.[22]	2011	Level IV: case report	1	Shoulder	Electrocautery	Dermal burn	NA	NA
Good et al.[14]	2007	Level IV: case-series	8	Shoulder	Not specified	Chondrolysis	−	−
Greis et al.[23]	2001	Level IV: case-series	4	Shoulder	RF device	Other (axillary nerve damage)	NA	NA
Hanypsiak et al.[24]	2004	Level IV: case-series	2	Shoulder	RF device	Other (long head of biceps tear)	NA	NA
Jerosch and Aldawoudy[26]	2007	Level IV: Case report	1	Shoulder	RF device	Chondrolysis	−	−
Kouk et al.[6]	2011	Level IV: case-report	1	Shoulder	RF device	Dermal burn	NA	NA
Levine et al.[27]	2005	Level IV: case-series	2	Shoulder	RF device	Chondrolysis	−	−
Levy et al.[28]	2008	Level IV: case-series	10	Shoulder	Not specified	Chondrolysis	−	+
Lord et al.[29]	1991	Level IV: case-series	3	Knee	Electrocautery	Dermal burn	NA	NA
Mas Martinez et al.[30]	2015	Level IV: case report	1	Hip	Electrocautery + RF device	Chondrolysis	+	−
McKnickle et al.[31]	2009	Level IV: case-series	5	Shoulder	RF device	Chondrolysis	+	+
Park et al.[32]	2014	Level III: Retrospective cohort study	1	Hip	RF device	Dermal burn	NA	NA
Pell et al.[37]	2004	Level III: Retrospective cohort study	3	Wrist	RF device	Dermal burn + wrist tendon ruptures	NA	NA
Petty et al.[33]	2004	Level IV: case-series	3	Shoulder	RF device	Chondrolysis	−	+
Rey et al.[25]	2009	Level IV: case-series	7	Shoulder	RF device	Chondrolysis	+	−
Sanders et al.[34]	2009	Level IV: case-report	1	Shoulder	Electrocautery	Dermal burn	NA	NA
Segami et al.[35]	2004	Level IV: case report	1	TMJ	Electrocautery	Dermal burn + paresthesia of the buccal area	NA	NA
Troxell et al.[36]	2011	Level IV: case-series	4	Shoulder	RF device	Dermal burn	NA	NA
Wong et al.[5]	2001	Level IV: survey	237	Shoulder	3 laser 193 RF device 41 not specified	Other (axillary nerve damage + adhesive capsulitis)	NA	NA

NA, not applicable; RF, radiofrequency; TMJ, temporomandibular joint.

tissue using only the thermal device, keeping it on for a long period of time, was named as a potential cause of burns of the adjacent skin.[6]

Dermal burns also were noticed underneath grounding pads,[22] which are only used in monopolar and electrocautery devices.[6,20-22,29,32,34-37] Three cases described third-degree burns, 7 cases second-degree burns, and in 5 cases, the degree of the burn was not specified.[22,29,34,35]

Chondrolysis

Chondrolysis was diagnosed in 36 cases.[8,14,18,25-28,30,31,33] Forty-five cases involved the shoulder joint, and 1 case involved the hip.[8,14,18,25-28,30,31,33] A bipolar radiofrequency device was used in 14 cases, a monopolar device in 6 cases, and an electrocautery device in 1 case.[8,14,18,25-28,30,31,33] The type of radiofrequency device was not specified in 5 cases.[8,14,18,25-28,30,31,33] In 23 cases, no intra-articular local anesthetic pumps or suture anchors were used.[14,17,26,27] In 18 cases, intra-articular local anesthetic pumps were used.[18,28,31,33] Suture anchors were placed in 16 cases.[8,18,19,25,30,31] In 12 cases, both intra-articular local anesthetic pumps and suture anchors were used.[18,31] Although no papers were able to determine a single cause for the occurrence of chondrolysis, suggested factors included intra-articular injection of a local anesthetic at the time of surgery, use of a high-volume intra-articular pain pump for 48 hours after surgery, and use of a thermal probe during the surgery.[18] Index procedures in the shoulder with a high incidence of chondrolysis included

Table 2. Critical Appraisal Table Using the Adapted ROBINS-I Tool[9]

	Study Type	Bias Due to Confounding	Bias in Classification of Intervention	Bias Due to Deviations From Intended Interventions	Bias Due to Missing Data	Overall Risk of Bias	Overall Applicability	Overall Risk for Bias
Bailie and Ellenbecker[18]	−	−	+/−	+	+	−	+	High
Coobs et al.[8]	−	+/−	+/−	+	+	−	+	High
Good et al.[14]	−	+/−	+/−	+	+	−	+	High
Jerosch and Aldawoudy[26]	−	+/−	+	+	+	−	+	High
Levine et al.[27]	−	+/−	+	+	+	−	+	High
Levy et al.[28]	−	−	+/−	+	+/−	−	+/−	High
McKnickle et al.[31]	−	−	+/−	+	+	−	+	High
Petty et al.[33]	−	−	+/−	+	+	−	+/−	High
Rey et al.[25]	−	−	+/−	+	-	−	+	High
Chahar et al.[20]	−	+/−	+	+/−	+	−	+	High
Gomide et al.[22]	−	+/−	+	+/−	+	−	+/−	High
Kouk et al.[6]	−	+/−	+	+/−	+	−	+	High
Sanders et al.[34]	−	+/−	+	+	+	−	+	High
Troxell et al.[36]	−	+/−	+/−	+	+	−	+	High
Beauthier et al.[19]	−	+/−	+/−	+	+	−	+	High
Greis et al.[23]	−	+/−	+	+	+	−	+	High
Wong and Williams[5]	−	+/−	-	+	+	−	+/−	High
Hanypsiak et al.[24]	−	+/−	+	+	+	−	+/−	High
Mas Martinez et al.[30]	−	+/−	+	+	+	−	+	High
Curtin and Friebe[21]	−	+/−	+	+	+	−	+	High
Park et al.[32]	−	+/−	+	+	+	−	+	High
Akgun et al.[17]	−	+/−	+	+/−	+	−	+	High
Lord et al.[29]	−	+/−	+	+	+	−	+	High
Segami et al.[35]	−	+/−	+	+	+	−	+	High

ROBINS-I, Risk Of Bias In Non-randomized Studies - of Interventions.

thermal capsulorrhaphy, capsular release,[26] and extensive glenohumeral synovectomy.[14] No specific risk factors were provided in the papers involving hip and knee arthroscopy.

Other Complications

A total of 248 cases of other complications were identified and are mentioned separately, as they cannot clearly be linked to overheated arthroscopic fluid.[5,6,8,14,17-36] Two hundred of these were axillary nerve injuries,[5,23] of which 196 were extracted from 1 study, a survey among 379 surgeons regarding thermal capsulorrhaphy of the shoulder.[5] Of the 196 axillary nerve injuries, 95% were temporary, whereas 10 cases resulted in permanent axillary nerve damage.[5]

Adhesive capsulitis was reported in 41 cases,[5] postoperative long head of biceps tears in 3 cases,[24] osteonecrosis in 2 cases,[17,19] tendon rupture in 1 case,[37] and persisting paresthesia of the buccal area in 1 case.[34]

Discussion

In this systematic review on heat-related complications in arthroscopic surgery, the most frequently described complications were dermal burns and chondrolysis. Although no one specific cause was identified, the following factors were indicated to cause the risk for dermal burns: leakage of hot arthroscopy fluid onto the skin, usually due to failure to attach the suction to the thermal device, and aggressive tissue resection with the thermal device where it is kept on for long periods of time. Potential causes for chondrolysis that were identified in the included studies were the associated use of intra-articular local anesthetic injection or intra-articular pain pump, use of a thermal probe, and certain index procedures, such as thermal capsulorrhaphy,[3] capsular release, and synovectomy.

Zoric et al.[38] reported 3 main factors that influence heat generation during arthroscopy using a radiofrequency device: the flow of the irrigation fluid, the duration of activation of the radiofrequency device, and the distance between the tissue and the probe tip. A way to monitor the intra-articular temperature is the use of a temperature probe. Arthroscopic fluid temperature measurement warns the surgeon about potentially dangerous temperatures and may thus protect the surrounding tissues (skin, cartilage, and nerves) against damage if the fluid temperature is lowered in response to the alarm.[39] The latter can be done by increasing the irrigation flow and/or by temporarily not using the device.

Multiple studies have been conducted to identify safe temperature thresholds for different tissues. Derriks et al.[7] showed that the lowest temperature threshold was for soft tissues, at 43°C. They found nerve damage occurred from temperatures greater than 60°C and skin damage after short exposure (30 seconds) to a

temperature of 60°C and prolonged exposure to a temperature of 50°C.[7]

Chondrocyte death, resulting in chondrolysis, may occur from temperatures greater than 50°C.[40] Kaplan et al.[41] observed morphologic changes in healthy cartilage at a temperature of 61°C, whereas arthritic cartilage showed changes at a temperature of 57°C. The fluid temperature at which skin damage occurs is currently unknown. However, if dermal burns arise following arthroscopy, it may be assumed that the joint cartilage will have suffered heat damage as well. This review found that a thermal device was the only causative factor present in around 25% (11 of 45) of chondrolysis cases. Radiofrequency devices were used in 26 cases. Chondrolysis occurred more than twice as much after the use of bipolar radiofrequency devices compared to monopolar devices. This is in line with findings of an ex vivo study by Edwards et al.[42] They harvested 30 osteochondral sections from patients undergoing knee arthroplasty. The specimens then underwent arthroscopy where the designated area was treated until smooth using either a monopolar or bipolar device. The bipolar devices produced significantly greater depths of chondrocyte death as well as death to subchondral bone significantly more often than monopolar devices. However, others suggest that bipolar devices have advantages when compared with monopolar devices because they have positive and negative electrodes located on the wand. This allows the current to be directed from the tip of the wand into the tissue and back through the ground without flowing through the patient.[43] This implies that bipolar devices might have more risk of chondrolysis, but less risk of dermal burns when compared with monopolar devices.

Electrocautery was described in only 1 case of chondrolysis. In almost one half the cases involving chondrolysis, the used thermal device was not specified. Furthermore, in 35 of 45 cases of chondrolysis, an intra-articular local anesthetic pump or suture anchors were used. Previous studies implied both of these modalities could be a cause of chondrolysis.[44-47]

Strategies identified in this review to prevent heat-related complications include limiting the duration the thermal device is used, placing it further from the tissue, ensuring there is suction attached to it and the hot arthroscopy fluid is not leaking onto the patient's skin. Another potential solution is the use of tranexamic acid to aid in hemostasis, such that the use of thermal devices can be limited.[48]

Noticeably more complications were identified in shoulder arthroscopy than in other joint arthroscopies. A clear explanation for this cannot be provided based on this systematic review. However, it can be hypothesized that radiofrequency and electrocautery devices are more frequently used in shoulder arthroscopy due to the inability to use a tourniquet for hemostasis.[49,50] Also, subacromial bursectomies may require relatively long electrocautery times. Furthermore, the choice of irrigation system could be a potential influence, as the shoulder is a relatively small joint without a structure that limits extravasation of fluid from the joint, resulting in different flow dynamics of the irrigation fluid compared with knee arthroscopy.[50] Also, no outflow cannulas are used in the shoulder, in contrast to the knee, because this would cause turbulence, increasing bleeding and decreasing visualization.[51,52]

Limitations

This review does have limitations. First, PROSPERO registration was not performed before starting this study. There might be a publication bias. Surgeons who experience complications may be more likely to report their results than surgeons who did not have any complications. When a devastating complication is encountered, the surgeon may want to write about this in a paper as to prevent other surgeons and patients from experiencing the same problem. Second, statistical pooling of the data into a meta-analysis was not possible secondary to the heterogeneity of the included studies. In addition, there is a lack of high-level prospective studies on this topic. Furthermore, nearly all included studies were either case reports, case series or retrospective database studies. Another limitation is the quality of the data extracted from the included studies. The majority of the studies did not fully specify, or in a few cases did not specify at all, the device that was being used. In addition, there is no consensus concerning the definition of a heat-related complication. Complications such as tendon ruptures and adhesive capsulitis also can occur due to reasons unrelated to temperature after or during surgery. More importantly, axillary nerve damage also can be caused by using the radiofrequency device too close to the axillary nerve, rather than by overheated arthroscopic fluid. Therefore, in this review these complications were not treated as truly heat-related. Similarly, intra-articular local anesthetic pumps were used in some of the studies.[18,28,31,33] In this setting, it is difficult to determine whether chondrolysis was caused by thermal injury or inappropriate usage of the intra-articular anesthetic pump.

Conclusions

The most common heat-related complications in arthroscopy are dermal burns and chondrolysis. Axillary nerve injuries are associated with adhesive capsulitis release; it is unclear whether nerve injury is directly related to thermal injury. Risk factors include leakage of arthroscopy fluid, use of a thermal device continuously for long periods of time, proximity of the device to the tissue, associated intra-articular local

anesthetic injection or intra-articular pain pumps, and procedures such as thermal capsulorrhaphy, capsular release, and synovectomy.

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Appendix 1

Searchstring PubMed: ((((((blister*[Title/Abstract]) OR chondrolysis[Title/Abstract]) OR ((adhesive[Title/Abstract]) AND capsulitis[Title/Abstract])) OR (((((((damage[Title/Abstract]) OR wound[Title/Abstract]) OR complication[Title/Abstract]) OR injur*[Title/Abstract]) OR necrosis[Title/Abstract])) AND (((thermal[Title/Abstract]) OR burn*[Title/Abstract]) OR heat[Title/Abstract]))) OR chondrolysis[Title/Abstract])) AND ((((arthroscopic[Title/Abstract]) OR arthroscop*[Title/Abstract]) OR scopic[Title/Abstract])).