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Selective denervation of the wrist for chronic pain: a systematic literature review

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Abstract

Selective denervation of sensory nerve branches to the wrist is a palliative surgical treatment option for patients with chronic wrist pain when preserving the range of motion and function is preferred. Treatment varies from partial isolated denervation of the posterior interosseous nerve to extensive 'complete' denervations. This study aimed to provide an overview of the literature regarding treatment outcomes in the domains of pain, grip strength, patient satisfaction and return to work. MEDLINE (PubMed), EMBASE and Cochrane databases were systematically searched and identified 993 studies, of which 12 were eligible for analysis. Denervation resulted in high 'return to work' rates (up to 94%), patient satisfaction (up to 92%), increased grip strength (7%–64%) and improved average pain scores (36%–92%). Treatment outcomes of both partial and complete denervations were favourable; however, variations in outcomes suggest the need for improving evidence regarding surgical technique and nerve identification.

Keywords

Wrist denervation, chronic pain, anterior interosseous nerve, posterior interosseous nerve, neurectomy

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Introduction

Chronic pain in the hand and wrist is a common problem. In the UK, the prevalence of chronic (>3 months) pain was present in 13% of the surveyed population who had pain in multiple locations in the hand or wrist (Carnes et al., 2007). Patients eligible for denervation should have chronic wrist pain (>3 months) and be skeletally mature (Hofmeister et al., 2006). This procedure is a palliative option when preservation of the range of motion and function are preferred and conservative treatment has been inadequate (Hofmeister et al., 2006; Le Nen et al., 2011).

Denervation techniques of the wrist have been modified over the years from Wilhelm's 'complete' denervation in 1959 (Wilhelm, 2001) to less invasive 'partial' denervation using only a single incision (Berger, 1998; Grechenig et al., 2017). Partial denervation focuses on specific articular nerves, especially the anterior interosseous nerve (AIN) and posterior interosseous nerve (PIN). To determine the potential effect of denervation, the patient's response to a preoperative anaesthetic nerve block has been evaluated (Hofmeister et al., 2006; Ishida et al., 1993; Riches et al., 2016; Storey et al., 2011). However, other authors refrain from using diagnostic blocks because the analgesic response after the local block poorly correlated with the postoperative change in pain scores (Patil and Arenas-Prat, 2016; Weinstein and Berger, 2002). Surgical scarring, incomplete surgical denervation and/or re-innervation of the joint may lead to reduced pain reduction. Furthermore, the local analgesic might spread to smaller terminal nerve branches to the wrist joint that are not divided during surgery. The procedure is contraindicated in

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chronic conditions that are still treatable with conservative methods and in a dysfunctional joint due to a structural deformity (Hofmeister et al., 2006; Patil and Arenas-Prat, 2016).

We systematically reviewed the literature describing therapeutic effects of nerve denervation in the domains of wrist pain, grip strength, patient satisfaction and return to work (RTW).

Methods

Literature search

A systematic search of the available literature in MEDLINE using PubMed, EMBASE and Cochrane CENTRAL databases was performed in March of 2019. In PubMed, the title and abstract (tiab) and medical subject headings (MeSH Terms) were added to the keywords of the search to expand the scope of the search. For EMBASE, the title (ti) and abstracts (ab) and further keywords (kw) were also added to the primary search terms that were used for the queries. The primary search terms included 'wrist', 'denervation', 'neurectomy', 'neurotomy', 'nerve tissue', 'anterior interosseous nerve' and 'posterior interosseous nerve'. A search for additional trials was done in Cochrane CENTRAL. The complete search strategy is provided in the supplementary data (Table S1; Appendix S1). References in selected studies were screened for eligibility.

Inclusion and exclusion criteria

All clinical studies with their own patient cohort reporting outcomes on both complete and/or partial wrist denervation techniques on chronic wrist pain, regardless of the origin of the pain, were included. There was no limit for publication date. Non-English studies and studies on patients who underwent concomitant surgical procedures were excluded. Studies containing both patients with and without concomitant procedures were only included if the treatment and outcomes of the 'denervation only' group was reported separately.

Selection procedure

All studies from the search were screened on title and abstract for eligibility for analysis by two independent assessors (KC and AE) using an online referencing tool (Ouzzani et al., 2016). After selection based on title and abstract, full texts were screened for relevance of outcomes. In case of disagreement, both assessors discussed the eligibility of the study with the senior author (SS) acting as a referee until consensus was reached on final inclusion or exclusion.

Quality of selected studies

Guidelines from the Oxford Centre for Evidence-Based Medicine (CEBM) were followed to assess the quality of the included studies. Furthermore, the online GRADEpro Guideline Development Tool (McMaster University/Evidence Prime Inc., Hamilton, Ontario, Canada) was used to give an overall indication of the risk of bias and quality of the included studies according to guidelines set by the Cochrane Handbook for each outcome measure discussed.

Outcomes

Full text manuscripts were screened to obtain the detailed patient characteristics including age, follow-up time and denervation technique. The primary outcome was postoperative pain using the visual analogue scale (VAS) on a 0–10 (or 0–100) scale or pre- and postoperative grip strength (in kilograms). Secondary outcomes included, 'return to work' (RTW) rate, patient satisfaction and patient recommendation rates.

Results

Study selection

The literature search yielded a total of 993 studies (Figure 1). After removing duplicates, screening titles and abstracts, 969 studies were excluded from further analysis. After screening full texts of 24 studies, another 12 studies were excluded based on incomplete presentation of outcomes, such as the absence of both pre- and postoperative VAS scores or grip strength outcomes. Results from 12 studies were included for analysis (Table 1).

Indications for selective denervation

The 12 included studies reported a range of conditions for which patients were treated with selective denervations. These are summarized in Table 1.

Surgical techniques for selective denervation

The studies included can be subdivided according to surgical technique; (modified) complete denervation techniques and less invasive partial denervations (Table 1) (Berger, 1998; Wilhelm, 1965, 2001). The complete denervation, according to Wilhelm, targets the PIN, articular branch of the first interosseous space, articular branches of the lateral antebrachial cutaneous nerve, articular branch of the superficial radial nerve, articular fibres of the palmar branch of

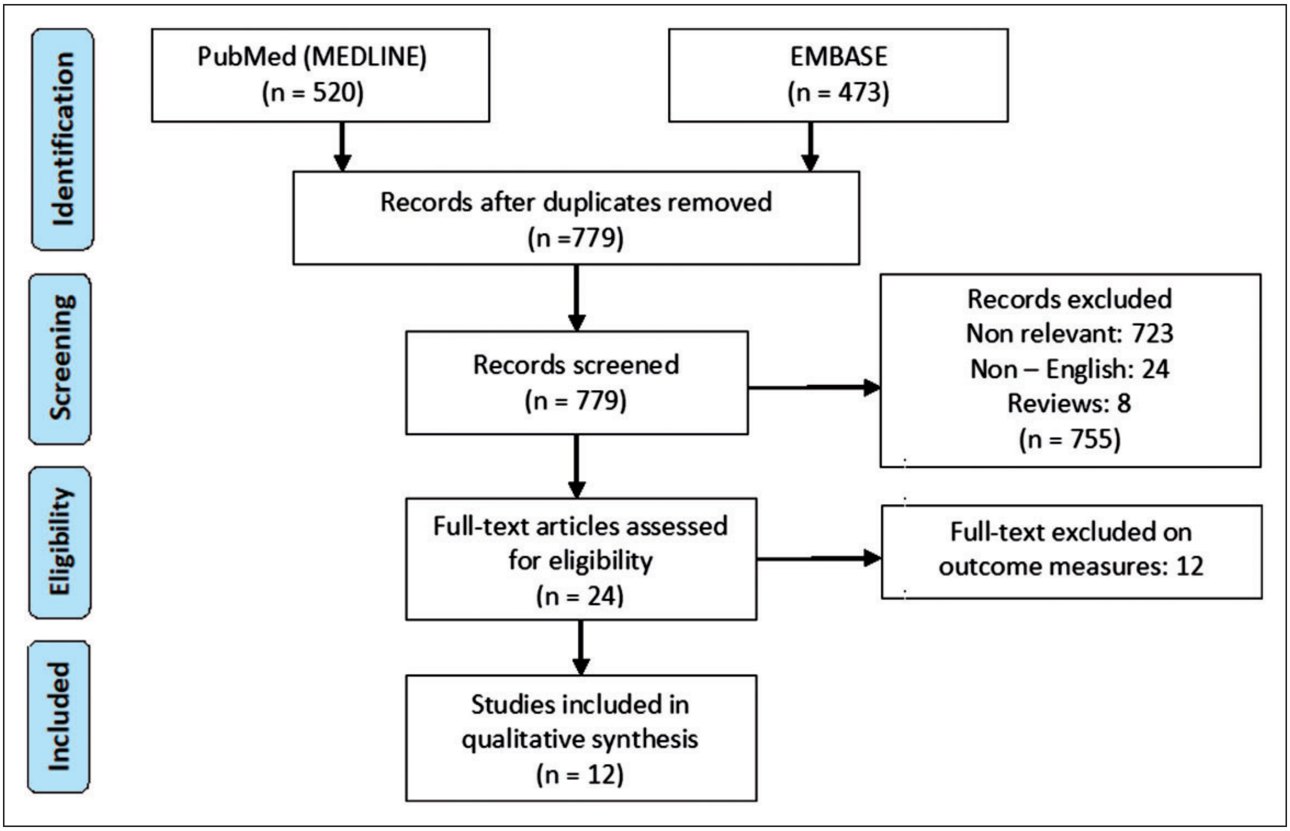

Figure 1. PRISMA flowchart of the screening process in PubMed (MEDLINE) and EMBASE.

the median nerve, articular fibres of the AIN, perforating fibres of the deep branch of the ulnar nerve, articular fibres of the dorsal branch of the ulnar nerve and the articular branch of the posterior antebrachial cutaneous nerve. Variations of Wilhelm's technique are targeting a number of the aforementioned nerves. The partial denervation techniques can be subdivided in resection of only the PIN (PIN only), the AIN and PIN (AIN & PIN), or the aforementioned combined with resection of, for example, cutaneous branches of the radial and/or median nerve (partial) (Delclaux et al., 2017; Patil and Arenas-Prat, 2016; Storey et al., 2011).

Pre- and postoperative pain scores

Five studies with a total of 240 patients described pre- and postoperative pain using the VAS (Table 2). Using the complete denervation technique, Fuchsberger et al. (2017) reported a median preoperative VAS of 84 with an improvement to 32, 6 weeks postoperatively. After 12 years follow-up the median VAS remained low (40) in 124 of the 135 patients. Riches et al. (2016) only resected the PIN. They scored pain according to the Modified Score for the Assessment and Quantification of Chronic Rheumatoid Affections of the Hands (MSACRAH) (Sautner et al., 2004), where Riches et al. (2016) observed a decrease in pain. Their MSACRAH pain score was based on a scale of 200 points. The remaining three studies used a variant of the partial denervation not limited to only the AIN and PIN. According to the GRADEpro tool, when pooled, all studies yielded a 'Low' level of quality for the outcome postoperative pain based on the overall lack of blinding, randomization and low number of patients.

Grip strength

The search resulted in five studies in which grip strength was described for 186 patients (Table 3). Four studies measured grip strength by using the JAMAR Hand Dynamometer (JAMAR Hand Dynamometer Model 1, Clifton, NJ, USA, or Baseline Fabrication Enterprises Inc., Irvington, NY, USA) (Braga-Silva et al., 2011; Delclaux et al., 2017; Hofmeister et al., 2006; Storey et al., 2011; Weinstein and Berger, 2002). The greatest relative improvement was seen in the cohort reported by Braga-Silva et al. (2011), which underwent complete denervation with an increase in grip strength of 64%. According to the GRADEpro tool, the studies yielded a 'Low' level of quality for the outcome grip strength based on the

Table 1. Overview of selected studies and their levels of evidence according to the CEBM guideline.

Studies	Wrists	Denervation techniques	Indications for denervation	Level of evidence (CEBM)
Sgromolo et al., 2018	10/3	AIN & PIN/ PIN only	Chronic idiopathic wrist pain	IV
Delclaux et al., 2017	33	Partial	SLAC, SNAC, (distal) radial fracture sequelae with advanced RC OA, post-traumatic ulnar carpal impingement	IV
Fuchsberger et al., 2017	135	Complete	Kienböck's, scaphoid pseudarthrosis, primary arthritis, secondary arthritis (radius) fracture	IV
Patil and Arenas-Prat, 2016	21	Partial	SLAC, SNAC, Kienböck's, DRUJ OA, post-traumatic OA of the RC joint, ulnocarpal abutment	IV
Riches et al., 2016	12	PIN only	Rheumatoid arthritis	II
Storey et al., 2011	37	Partial	SLAC, SNAC, Kienböck's, (distal) radial/ulna fracture sequelae, wrist OA, STTJ OA, rheumatoid arthritis, SR arthritis, ulnocarpal abutment, scaphoid nonunion, TFCC injury, carpal instability, ligament laxity, CRPS, congenital deformity, non-specific wrist pain	IV
Braga-Silva et al., 2011	49	Complete	SNAC, Kienböck's, primary degenerative OA	IV
Hofmeister et al., 2006	48	AIN & PIN	Dynamic wrist instability	IV
Schweizer et al., 2006	70	Complete	SLAC, Kienböck's, primary osteoarthritis, scaphoid non-union, distal radius fracture, fibrocartilage complex disorders, neurogenic, lupus	IV
Weinstein and Berger, 2002	19	AIN & PIN	SLAC, STTJ arthritis, rheumatoid arthropathy, scaphoid nonunion, post-traumatic RC degenerative joint disease, SL dissociation, SL instability, dorsal wrist pain	IV
Ishida et al., 1993	4/13	Partial/ complete	Kienböck's, (degenerative) arthritis, scaphoid nonunion, distal radius fracture, SL dissociation, sprain or idiopathic	IV
Röstlund et al., 1980	2/7	PIN only/ complete	Scaphoid nonunion, Kienböck's	IV

CEBM: Centre for Evidence-Based Medicine; AIN: anterior interosseous nerve; PIN: posterior interosseous nerve; SLAC: scapholunate advanced collapse; SNAC: scaphoid nonunion advanced collapse; RC: radiocarpal; OA: osteoarthritis; Kienböck's: Kienböck's disease; DRUJ: distal radio-ulnar joint; STTJ: scaphotrapezotrapezoidal joint; SR: scaphoradial; TTFC: triangular fibrocartilage complex; CRPS: chronic regional pain syndrome; SL: scapholunate; Level II of evidence: prospective cohort, comparative study; Level IV of evidence: retrospective case series, no control group.

Table 2. Overview of studies publishing pre- and postoperative pain scores according to the VAS.

Studies	Denervation techniques	Wrists	Mean follow-up (months)	Preoperative VAS	Postoperative VAS	Relative VAS improvement
Sgromolo et al., 2018	AIN & PIN/ PIN only	10/3	13	4 (2–6)[a]	2.2 (0–5)[a]	45%
Delclaux et al., 2017	Partial	33	41	7.1 (4–10)[a]	1.8 (0–8)[a]	75%
Fuchsberger et al., 2017	Complete	124	146	83[b]	40[b]	52%
Patil and Arenas-Prat, 2016	Partial	21	18	86 (75–100)[a]	30 (10–85)[a]	65%
Riches et al., 2016	PIN only	12	24	167 (SD 41)[c]	14 (SD 19)[c]	92%
Storey et al., 2011	Partial	37	18	In rest: 25 (1–46)[b] Activity: 74 (60–82)[b]	In rest: 16 (1–31)[b] Activity: 30 (14–64)[b]	In rest: 36% Activity: 60%

[a]Mean with range or standard deviation (SD).
[b]Median with/without interquartile range (IQR).
[c]M-SACRAH score, which used a 0–200 score.
VAS: visual analogue scale; AIN: anterior interosseous nerve; PIN: posterior interosseous nerve.

Table 3. Overview of studies reporting grip strength.

Studies	Denervation techniques	Wrists	Mean follow-up (months)	Preoperative grip strength (kg)	Postoperative grip strength (kg)	Relative grip improvement
Delclaux et al., 2017	Partial	33	41	33 (13–50)[a]	35 (26–55)[a]	7%
Storey et al., 2011	Partial	37	18	15 (10–24)[b]	21 (11–29)[b]	53%
Braga-Silva et al., 2011	Complete	49	72	11 (SD 3)[a]	18 (SD 3)[a]	64%
Hofmeister et al., 2006	AIN & PIN	48	28	34 (6–60)[a]	41 (21–65)[a]	18%
Weinstein and Berger, 2002	AIN & PIN	19	30	28	37.5	34%

[a]Mean with range or standard deviation (SD).
[b]Median with interquartile range (IQR).

Table 4. Overview of studies reporting return to work rate.

Studies	Denervation techniques	Wrists	Return to type of work	Return to work rate (former job)
Sgromolo et al., 2018	AIN & PIN/PIN only	10/3	2 former job, 6 lighter job, 5 stopped	15%
Delclaux et al., 2017	Partial	33	31 former job	94%
Schweizer et al., 2006	Complete	70	61 former job, 9 lighter job	87%
Weinstein and Berger, 2002	AIN & PIN	19	n/a	73%
Ishida et al., 1993	Partial/complete	4/13	6 former job, 2 lighter job, 4 stopped, 2 (partial/3 (complete) re-operated	35%
Röstlund et al., 1980	PIN/complete	2/7	6 former job, 2 lighter job, 1 other job	67%

AIN: anterior interosseous nerve; PIN: posterior interosseous nerve; n/a: data not available.

incomplete reports on the methods of measuring grip strength.

Return to work

When reported, the majority of patients could return to their former jobs or perform a physically less demanding job. The partial denervation group had a RTW rate ranging from 15% to 94%, while the complete denervation groups had a RTW rate ranging from 35% to 87% (Table 4). According to the GRADEpro tool, these studies yielded a 'Very Low' level of quality on RTW based on the risk of bias, indirectness and the reported categories of outcome measures used.

Patient satisfaction

Patients were generally positive concerning the outcome after denervation with up to 92% being satisfied (Table 5) (Delclaux et al., 2017; Hofmeister et al., 2006; Ishida et al., 1993; Riches et al., 2016; Röstlund et al., 1980; Storey et al., 2011; Weinstein and Berger, 2002). The cohort of Ishida et al. (1993) stands out as only 24% of their cohort was satisfied with the treatment (Ishida et al., 1993). Another criterion for patient satisfaction was the question about whether the patient would recommend selective denervation to others or would undergo the procedure again. This also yielded positive results (Fuchsberger et al., 2017; Riches et al., 2016; Schweizer et al., 2006; Weinstein and Berger, 2002). The assessment with the GRADEpro tool resulted a 'Very Low' level of quality for the patient satisfaction outcome due to the possible publication bias and reporting bias due to the categories used for assessing patient satisfaction.

Complications and re-operations

Postoperative complication rates, including re-operations (including permanent interventions, e.g. proximal row carpectomy) and persistent or worse pain, varied from 6% to 29% (Delclaux et al., 2017; Hofmeister et al., 2006; Storey et al., 2011; Weinstein and Berger, 2002). In the cohort of Ishida et al. (1993), two out of four partial denervation patients needed additional surgery due to persistent pain, in contrast to the three out of 13 complete denervation patients. Using a partial denervation technique,

Table 5. Overview of studies reporting patient satisfaction and recommendation rates.

Study	Denervation technique	Wrists	Satisfaction rate	Recommendation rate
Delclaux et al., 2017	Partial	33	75% (not specified)	n/a
Fuchsberger et al., 2017	Complete	135	n/a	79%
Riches et al., 2016	PIN only	12	92% very or fairly satisfied	100%
Storey et al., 2011	Partial	37	69% satisfied	n/a
Hofmeister et al., 2006	AIN & PIN	48	25 excellent (52%), 15 good (31%), 4 fair (8%), 4 poor (8%)	n/a
Schweizer et al., 2006	Complete	70	n/a	48 (69%) vs 19 (27%) would repeat, 3 undecided (4 %)
Weinstein and Berger, 2002	AIN &PIN	19	70% very or somewhat satisfied	90%
Ishida et al., 1993	Complete	13	3 extremely (23%), 1 satisfied (8%), 1 slightly (8%), 8 dissatisfied (61%)	n/a
Ishida et al., 1993	Partial	4	1 slightly (25%), 3 dissatisfied (75%)	n/a
Röstlund et al., 1980	PIN only, complete	9	4 very (44%), 4 satisfied (44%), 1 unsatisfied (11%)	n/a

n/a: data not available; AIN: anterior interosseous nerve; PIN: posterior interosseous nerve.

Delclaux et al. (2017) reported persisting dysesthesia in 21% of patients, of which one patient developed a complex regional pain syndrome. Neuromas in 8% of patients and transient hypoesthesia were described anecdotally (Braga-Silva et al., 2011).

Denervation versus other surgical techniques

In 2016 Riches et al. published a prospective series of 94 patients with rheumatoid arthritis (RA) with a mean follow-up time of 3 years (Riches et al., 2016). These patients underwent one of eight surgical procedures (Swanson's arthroplasty, wrist arthrodesis, carpal tunnel decompression, RA nodule excision, synovectomy/tenosynovectomy, tendon repair/release and PIN denervation). The 12 patients who underwent PIN denervation did not differ significantly in terms of pain and functional recovery as compared with the other procedures.

Discussion

All studies showed reduction in reported VAS pain scores postoperatively as a result of denervation. Only two studies reported reduction in pain at rest and pain during activity separately (Delclaux et al., 2017; Storey et al., 2011), and both reported an improvement in both domains. Patients with longer follow-up times after denervation tended to benefit less from denervation (Ferreres et al., 1995; Fuchsberger et al., 2017; Röstlund et al., 1980). Progression of the underlying condition could have caused the pain to increase and/or limit the function of the wrist joint (Dellon, 1985). However, with the limited numbers of studies available, we were unable to conclude whether a complete denervation results in better long-term results compared with partial techniques or vice versa. To objectively assess the impact on the patients' well-being, whether positive or negative, the preferred outcome measure for pain is the VAS. Our search only yielded six studies in English in which the VAS was described on a scale of 0–10 or 0–100 (Table 2). In the remaining six studies, only relative changes in pre- and post-operative VAS were reported. The relative VAS improvement of the isolated PIN (PIN only) denervation by Riches et al. (2016) is higher than the other more extensive partial denervation techniques, however, that score is the result of the MSACRAH, which uses a combined pain score of the VAS during activity and in rest is used in contrast to most of the other studies (Table 2). It is unclear whether this explains the relatively high VAS improvement of Riches et al. (2016). The partial denervation studies show an overall higher trend in improvement compared with the complete denervation study of Fuchsberger et al. (2017).

Grip strength was increased after denervation overall, however a relative decrease has also been reported (Röstlund et al., 1980), but this was not included in Table 2, as only a relative difference was described in that report. Grip strength improved the most after complete denervation (Braga-Silva et al., 2011). A factor is that the mean preoperative grip strength in the cohort of Braga-Silva et al. (2011) is lower compared with the other studies, therefore a similar increase in absolute grip strength resulted in a higher relative improvement in grip strength. Patient satisfaction was generally high after denervation in both the complete and partial denervation groups. The partial denervation group of Storey et al. (2011) and Ishida et al. (1993) showed a trend for more dissatisfied patients. Nevertheless, the majority of patients are still in favour of repeat selective denervation if they had the chance to initially choose again for a surgical treatment (Schweizer et al., 2006). The RTW rate was relatively high, despite the fact that a number (four and six, respectively) of patients in two studies had received financial compensation or were amidst a discharge procedure due to their incapacity to work (Sgromolo et al., 2018; Weinstein and Berger, 2002). Weinstein and Berger (2002) stated that a failure of the denervation was independently associated with workers' compensation claims.

The reported complication rates after denervation suggest that further improvement of the current procedures and standardization of complication reports for selective denervation is needed, because it is still unclear which denervation technique is superior regarding complications. The effectiveness of the complete, PIN only, AIN and PIN and other partial denervation techniques varied in the studies published over the years and can in part be explained by the anatomical variation that complicates the identification of relevant nerve branches (Berger, 1998; Braga-Silva et al., 2011; Buck-Gramcko, 1977; Buck-Gramcko, 1993; Delclaux et al., 2017; Dellon, 1985; Ekerot et al., 1983; Ferreres et al., 1995; Fukumoto et al., 1993; Geldmacher et al., 1972; Grechenig et al., 1998; Hofmeister et al., 2006; Ishida et al., 1993; Patil and Arenas-Prat, 2016; Riches et al., 2016; Röstlund et al., 1980; Schweizer et al., 2006; Storey et al., 2011; Weinstein and Berger, 2002; Wilhelm, 2001).

Improving nerve identification may ensure more selective denervation techniques with similar results to complete denervation (Ekerot et al., 1983) to treat chronic pain while preserving the range of motion (Sgromolo et al., 2018) and leaves the option open for other salvage procedures in case of insufficient pain relief. Despite heterogeneity in the literature and therefore without conclusive evidence of which technique is superior, denervation of the wrist shows a trend towards positive patient outcomes in regard to pain relief, RTW rate and patient satisfaction. Standardization of measuring and reporting outcomes (e.g. using standardized scoring systems for pain and grip strength) should be introduced in order to conclude which surgical technique is best for treating chronic pain. Further exploration of methods to overcome disappointing results due to anatomical variation and misidentification of the relevant sensory nerves could lead to more effective denervation procedures.

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