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Radiofrequency denervation for chronic low back pain (Review)

Maas ET, Ostelo RWJG, Niemisto L, Jousimaa J, Hurri H, Malmivaara A, van Tulder MW

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[Intervention Review]

Radiofrequency denervation for chronic low back pain

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ABSTRACT

Background

Radiofrequency (RF) denervation, an invasive treatment for chronic low back pain (CLBP), is used most often for pain suspected to arise from facet joints, sacroiliac (SI) joints or discs. Many (uncontrolled) studies have shown substantial variation in its use between countries and continued uncertainty regarding its effectiveness.

Objectives

The objective of this review is to assess the effectiveness of RF denervation procedures for the treatment of patients with CLBP. The current review is an update of the review conducted in 2003.

Search methods

We searched the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, EMBASE, three other databases, two clinical trials registries and the reference lists of included studies from inception to May 2014 for randomised controlled trials (RCTs) fulfilling the inclusion criteria. We updated this search in June 2015, but we have not yet incorporated these results.

Selection criteria

We included RCTs of RF denervation for patients with CLBP who had a positive response to a diagnostic block or discography. We applied no language or date restrictions.

Data collection and analysis

Pairs of review authors independently selected RCTs, extracted data and assessed risk of bias (RoB) and clinical relevance using standardised forms. We performed meta-analyses with clinically homogeneous studies and assessed the quality of evidence for each outcome using the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) approach.

Main results

In total, we included 23 RCTs (N = 1309), 13 of which (56%) had low RoB. We included both men and women with a mean age of 50.6 years. We assessed the overall quality of the evidence as very low to moderate. Twelve studies examined suspected facet joint pain, five studies disc pain, two studies SI joint pain, two studies radicular CLBP, one study suspected radiating low back pain and one study CLBP with or without suspected radiation. Overall, moderate evidence suggests that facet joint RF denervation has a greater effect on pain compared

with placebo over the short term (mean difference (MD) -1.47, 95% confidence interval (CI) -2.28 to -0.67). Low-quality evidence indicates that facet joint RF denervation is more effective than placebo for function over the short term (MD -5.53, 95% CI -8.66 to -2.40) and over the long term (MD -3.70, 95% CI -6.94 to -0.47). Evidence of very low to low quality shows that facet joint RF denervation is more effective for pain than steroid injections over the short (MD -2.23, 95% CI -2.38 to -2.08), intermediate (MD -2.13, 95% CI -3.45 to -0.81), and long term (MD -2.65, 95% CI -3.43 to -1.88). RF denervation used for disc pain produces conflicting results, with no effects for RF denervation compared with placebo over the short and intermediate term, and small effects for RF denervation over the long term for pain relief (MD -1.63, 95% CI -2.58 to -0.68) and improved function (MD -6.75, 95% CI -13.42 to -0.09). Lack of evidence of short-term effectiveness undermines the clinical plausibility of intermediate-term or long-term effectiveness. When RF denervation is used for SI joint pain, low-quality evidence reveals no differences from placebo in effects on pain (MD -2.12, 95% CI -5.45 to 1.21) and function (MD -14.06, 95% CI -30.42 to 2.30) over the short term, and one study shows a small effect on both pain and function over the intermediate term. RF denervation is an invasive procedure that can cause a variety of complications. The quality and size of original studies were inadequate to permit assessment of how often complications occur.

Authors' conclusions

The review authors found no high-quality evidence suggesting that RF denervation provides pain relief for patients with CLBP. Similarly, we identified no convincing evidence to show that this treatment improves function. Overall, the current evidence for RF denervation for CLBP is very low to moderate in quality; high-quality evidence is lacking. High-quality RCTs with larger patient samples are needed, as are data on long-term effects.

PLAIN LANGUAGE SUMMARY

Radiofrequency denervation for chronic low back pain

Background Low back pain is a widespread problem that has major social and economic consequences. In all, 85% to 90% of low back pain cases are classified as 'non-specific'. Most patients with low back pain are treated successfully in primary care, but approximately 10% to 15% develop chronic symptoms (lasting longer than three months). Chronic low back pain can come from any part of the back that has a nerve supply capable of transmitting pain signals. These sources include discs, vertebrae, sacroiliac joints, facet joints, muscles, ligaments and other structures. Pain specialists try to identify the source of low back pain by using nerve blocks. They numb individual spinal nerves with anaesthetic injections to see if this leads to improvement in back symptoms. With substantial pain relief, they attempt to eliminate pain for a longer time by heating the spinal nerves with radiofrequency waves to ensure that the pain stimulus cannot be passed. This invasive procedure is called radiofrequency denervation. At this time, the effectiveness of this approach has not been proven.

Study characteristics The evidence is current to May 2014. This review includes 23 randomised controlled trials with a total of 1309 participants whose chronic low back pain was evaluated with nerve blocks or other diagnostic tests. Both men and women, with a mean age of 50.6 years, were included. Patients with a positive response to a diagnostic block or to discography were given radiofrequency denervation, a placebo or a comparison treatment.

Key results No high-quality evidence shows that radiofrequency denervation provides pain relief for patients with chronic low back pain. Similarly, no convincing evidence suggests that this treatment improves function. Moderate-quality evidence suggests that radiofrequency denervation might better relieve facet joint pain and improve function over the short term when compared with placebo. Evidence of very low to low quality shows that radiofrequency denervation might relieve facet joint pain as well as steroid injections. For patients with disc pain, only small long-term effects on pain relief and improved function are shown. For patients with SI joint pain, radiofrequency denervation had no effect over the short term and a smaller effect (based on one study) one to six months after treatment when compared with placebo. For low back pain suspected to arise from other sources, the results were inconclusive. Radiofrequency denervation is an invasive procedure that can cause a variety of complications.

Quality of the evidence The studies in this review were not of adequate quality and size to document how often complications occur. Given the poor quality of the evidence, large, high-quality studies are urgently needed to determine whether radiofrequency denervation is safe and effective.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Facet joint: radiofrequency denervation versus placebo

Facet joint: radiofrequency denervation versus placebo

Patient or population: patients with chronic low back pain
Settings: secondary care
Intervention: facet joint radiofrequency denervation
Comparision: placebo

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Placebo	Facet joint radiofrequency denervation				
Pain 1 month post treatment (VAS 0 to 10)[a]	Mean pain score ranged across control groups from **4.3 to 6**	Mean pain score in intervention groups was on average **1.5 lower** (2.3 to 0.7 lower)		160 (3 studies)	⊕⊕⊕⊖ **Moderate** [b]	
Pain 1 to 6 months post treatment (VAS 0 to 10)[a]	Mean pain score ranged across control groups from **4.4 to 4.9**	Mean pain score in intervention groups was on average **0.7 lower** (2.3 lower to 0.8 higher)		182 (3 studies)	⊕⊕⊖⊖ **Low** [b,c]	
Pain > 6 months post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **3.1 to 7.0**	Mean pain score in intervention groups was on average **0.7 lower** (1.5 lower to 0.1 higher)		140 (3 studies)	⊕⊕⊕⊖ **Moderate** [b]	
Function 1 month post treatment (ODI 0 to 100)	Functional status in control group was **30.5**	Mean functioning in intervention groups was on average **5.5 lower** (8.7 to 2.4 lower)		60 (1 study)	⊕⊕⊖⊖ **Low** [b,c]	
Function > 6 months post treatment (ODI 0 to 100)	Functional status in control group was	Mean function in intervention groups was on average **3.7 lower**		60 (1 study)	⊕⊕⊖⊖ **Low** [b,c]	

	28.9	(6.9 to 0.5 lower)			
Complications	Not estimable	Not estimable	Not estimable	0	**No evidence**

CI: Confidence interval; **VAS:** Visual analogue scale.

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Results of the main analyses are presented.
[b]Downgraded when fewer than 400 participants.
[c]I^2 = 82%, P value = 0.0004, CIs hardly overlap, although the deviating study does not show significant results.

Summary of findings 2. Facet joint: radiofrequency denervation versus steroid injections

Facet joint: radiofrequency denervation versus steroid injections

Patient or population: patients with chronic low back pain
Settings: secondary care
Intervention: facet joint radiofrequency denervation
Comparision: steroid injections

Outcomes	**Illustrative comparative risks* (95% CI)**		**Relative effect (95% CI)**	**Number of participants (studies)**	**Quality of the evidence (GRADE)**	**Comments**
	Assumed risk	**Corresponding risk**				
	Steroid injections	**Facet joint radiofrequency denervation**				
Pain 1 month post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **4.4 to 5.4**	Mean pain score in intervention groups was on average **2.2 lower** (2.4 to 2.1 lower)		180 (2 studies)	⊕⊕⊖⊖ **Low** [a,b]	
Pain 6 months post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **4.4 to 6.5**	Mean pain score in intervention groups was on average **2.1 lower** (3.5 to 0.8 lower)		232 (3 studies)	⊕⊖⊖⊖ **Very low** [a,b,c]	

Pain 12 months post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **4.9 to 7.0**	Mean pain score in intervention groups was on average **2.7 lower** (3.4 to 1.9 lower)		180 (2 studies)	⊕⊖⊖⊖ **Very low** [a,b,c]

CI: Confidence interval; **VAS:** Visual Analogue Scale

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Fewer than 6 out of 12 items low risk of bias.
[b]Fewer than 400 participants included.
[c]I^2 higher than 50%.

Summary of findings 3. Discs: radiofrequency denervation versus placebo

Discs: radiofrequency denervation versus placebo

Patient or population: patients with chronic low back pain
Settings: secondary care
Intervention: discs: radiofrequency denervation
Comparision: placebo

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Placebo	Radiofrequency denervation				
Pain 1 month post treatment (VAS 0 to 10)	Pain score in control group was **5.7**	Pain score in intervention groups was **0.4 lower** (1.5 lower to 0.7 higher)		56 (1 study)	⊕⊕⊖⊖ **Low** [a,b]	
Pain 1 to 6 months post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **4.4 to 5.9**	Mean pain score in intervention groups was on average **0.3 higher** (2.3 lower to 2.8 higher)		84 (2 studies)	⊕⊕⊖⊖ **Low** [b,c]	

Pain > 6 months post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **5.3 to 6.6**	Mean pain score in intervention groups was on average **0.8 lower** (1.2 to 0.3 lower)		75 (2 studies)	⊕⊕⊕⊖ **Moderate** [b]
Function 1 month post treatment (ODI 0 to 100)	Functional status in control group was **39.9**	Mean function in intervention groups was on average **1.0 higher** (6.9 lower to 8.9 higher)		57 (1 study)	⊕⊕⊖⊖ **Low** [a,b]
Function 1 to 6 months post treatment (ODI 0 to 100)	Mean functional status ranged across control groups from **36.7 to 40.4**	Mean functioning in intervention groups was on average **0.9 higher** (6.4 lower to 8.1 higher)		85 (2 studies)	⊕⊕⊕⊖ **Moderate** [b]
Function > 6 months post treatment (ODI 0 to 100)	Mean functional status ranged across control groups from **28.2 to 41.2**	Mean functioning in intervention groups was on average **6.8 lower** (13.4 to 0.1 lower)		76 (2 studies)	⊕⊕⊕⊖ **Moderate** [b]

CI: Confidence interval; **VAS:** Visual analogue scale.

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Single study, in any case inconsistent.
[b]Fewer than 400 participants included.
[c]I^2 > 50%.

Summary of findings 4. SI joint: radiofrequency denervation versus placebo

SI joint: radiofrequency denervation versus placebo
Patient or population: patients with chronic low back pain **Settings:** secondary care **Intervention:** SI radiofrequency denervation **Comparision:** placebo

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Placebo	SI joint radiofrequency denervation				
Pain 1 month post treatment (VAS 0 to 10)	Mean pain score ranged across control groups from **3.9 to 6.3**	Mean pain score in intervention groups was on average **2.1 lower** (5.5 lower to 1.2 higher)		79 (2 studies)	⊕⊝⊝⊝ **Very low** [a,b,c]	
Pain 1 to 6 months post treatment (VAS 0 to 10)	Pain score in control group was **5.0**	Mean pain score in intervention groups was on average **1.3 lower** (2.1 to 0.5 lower)		51 (1 study)	⊕⊕⊝⊝ **Low** [b,d]	
Function 1 month post treatment (ODI 0 to 100)	Mean pain score ranged across control groups from **31.0 to 43.6**	Mean pain score in intervention groups was on average **14.1 lower** (30.4 lower to 2.3 higher)		75 (2 studies)	⊕⊝⊝⊝ **Very low** [a,b,c]	
Function 1 to 6 months post treatment (ODI 0 to 100)	Pain score in control group was **37.0**	Mean pain score in intervention groups was on average **11.0 lower** (17.9 to 4.1 lower)		49 (1 study)	⊕⊕⊝⊝ **Low** [b,d]	

CI: Confidence interval; **VAS:** Visual analogue scale.

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Fewer than 6 out of 12 items low risk of bias.
[b]Fewer than 400 participants included.
[c]$I^2 > 50\%$.
[d]Single study, in any case inconsistent.

BACKGROUND

Description of the condition

A major proportion of the adult population has low back pain at some stage of life. Although most patients are treated successfully with conservative treatment or without treatment, a substantial group of patients develop chronic pain symptoms (lasting longer than three months) (Lambeek 2010). Patients with chronic low back pain (CLBP) account for most reported healthcare and socioeconomic costs (Lambeek 2010). Among low back pain diagnoses, about 85% are defined as non-specific low back pain, that is, low back pain not attributable to a recognisable, known specific pathology or anatomical structure (e.g. infection, tumour, osteoporosis, fracture) (Koes 2006; Krismer 2007; Waddel 2005). Suspected sources of back pain include lumbar facet (zygapophyseal) joints, sacroiliac (SI) joints and degenerated intervertebral discs (Bogduk 2005; Cohen 2007; Schwarzer 1994; Schwarzer 1995b).

No gold standard is known for diagnosing facet joint, SI joint or disc pain. Such pain cannot be diagnosed clinically (Manchikanti 2000a) or radiologically (Schwarzer 1995a). Little evidence is available for using diagnostic blocks, which locally anaesthetise medial branch nerves that innervate the painful joint (Boswell 2003; Chou 2007; Dreyfuss 1997; Laslett 2003). Despite lack of validity and the chance of false-positive test results, these diagnostic blocks are used frequently in diagnosing facet joint pain, SI joint pain or disc pain, and in predicting the success of radiofrequency (RF) denervation procedures. However, it should be noted that "nerve blocks" are unvalidated methods of diagnosing the source or sources of CLBP (Chou 2009).

Description of the intervention

Radiofrequency denervation is one of the treatment options for patients with CLBP. In RF denervation, an RF generator produces an alternating current (frequency, 250 to 500 kHz) through an electrode, thereby inducing ionic movements in the tissue directly surrounding the active tip. This leads to molecular friction and heating of the tissue within a limited distance of the electrode (Kline 1996). Since Shealy published his article on RF denervation of the lumbar facet joint in 1976, RF denervation procedures have been modified and now are used frequently for low back pain (Cohen 2007; Dasselaar 1994; Dreyfuss 1997; Dreyfuss 2000; Shealy 1976; Sluijter 1998; Manchikanti 2000b). For example, they are used in the management of SI joint pain and disc pain (Barendse 2001; Ferrante 2001; Rathmell 2001).

How the intervention might work

Radiofrequency denervation is a technique that attempts to modulate neural transmission of nociceptive stimuli to reduce spinal pain. It aims to de-activate the nerves suspected of contributing to pain by applying an electrical current to coagulate the sensory nerves and prevent conduction of nociceptive impulses (Cosman 2005; Kline 1996). Radiofrequency lesioning is used to produce a partial lesion in the nerves supplying the painful structure.

Why it is important to do this review

The current review will be an update of the review conducted in 2003 (Niemisto 2003; Niemisto 2003a). The original review studied the effects of RF denervation procedures in chronic low back and neck pain. Only four trials evaluating RF denervation procedures in CLBP were selected (one studying discogenic low back pain and three studying facet joint pain). The review produced conflicting evidence on the effectiveness of RF denervation for facet joint pain. Limited evidence suggested that intra discal RF denervation may not be effective in relieving discogenic low back pain. Convincing evidence was lacking. The current review was split into separate reviews for chronic neck pain and chronic low back pain, and the literature search was updated until May 2014. This review focusses on CLBP.

OBJECTIVES

The objective of this review is to assess the effectiveness of RF denervation procedures for the treatment of patients with CLBP. The current review is an update of the review conducted in 2003.

METHODS

Criteria for considering studies for this review

Types of studies

We included only randomised controlled trials (RCTs). We imposed no language or date restrictions.

Types of participants

We included patients with CLBP (longer than three months) who had a positive response to diagnostic block or discography. We excluded patients with acute trauma, fracture, malignancy and inflammatory disease.

Types of interventions

Trials had to examine the effects of RF denervation compared with other treatments or placebo. We applied no limits on the temperature used, and we included both continuous and pulsed RF. We included and reported on additional treatments.

Types of outcome measures

Primary outcomes

Primary outcomes considered were pain, functional status (disorder-specific and generic), global improvement, health-related quality of life and complications.

Secondary outcomes

Secondary outcomes consisted of ability to work and satisfaction with treatment. We evaluated these outcomes at short- (less than one month), intermediate- (one to six months) and long-term (longer than six months) follow-up.

Search methods for identification of studies

Electronic searches

The search strategy was based on current recommendations of the Cochrane Back and Neck (CBN) Review Group (Furlan 2009) and built on the literature search of the original review (Niemisto 2003).

We searched the following databases from inception to 2014 May 29 and 30.

- Cochrane Central Register of Controlled Trials (CENTRAL).

- MEDLINE (Ovid SP, 1946 to May Week 3 2014).
- MEDLINE In-Process & Other Non-Indexed Citiations (Ovid SP, 2014 May 29).
- EMBASE (Ovid SP, 1947 to Week 21 2014).
- Cumulative Index to Nursing and Allied Health Literature (CINAHL) (EBSCO, from 1981 to 2014 May 30).
- PsycINFO (Ovid SP, 1806 to May Week 4 2014).
- ClinicalTrials.gov.
- World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP).

For this update, searches were run annually since 2010. Complete search strategies for the eight databases are outlined in Appendix 1; Appendix 2; Appendix 3; Appendix 4; Appendix 5; Appendix 6; Appendix 7; and Appendix 8. We performed a further search in June 2015 and added one trial report (Hashemi 2014) to 'Studies awaiting classification' and determined that three additional studies (Albareeq 2015; Meckhail 2013; Mekhail 2015) are ongoing. Results of 'Studies awaiting classification' and 'Ongoing studies' will be incorporated into the review at the next update.

Searching other resources

We checked the references of identified relevant articles and reviews. Furthermore, we consulted experts in the field of RF denervation treatment to identify potentially relevant studies that might have been missed.

Data collection and analysis

Methods used for this systematic review are based on current recommendations of CBN (Furlan 2009) and the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Selection of studies

Pairs of review authors independently selected the trials. They reviewed included studies from the original review and titles, keywords and abstracts of identified references initially screened by the trials search co-ordinator of CBN, to determine whether the study potentially met the inclusion criteria regarding design, participants and interventions. We retrieved full-text articles on studies that appeared to be relevant and on studies that provided insufficient information to allow a decision. The same pairs of review authors assessed pairwise full-text articles revealed by this literature search and trials that were included in the original review to make a final decision on which articles should be included in this review. We discussed disagreements, and if consensus could not be reached, we consulted a third review author.

Data extraction and management

Pairs of review authors independently extracted the data, using a standardised form that had been developed by CBN. We extracted the following data: characteristics of study design, population, intervention, control, duration of follow-up, outcomes and results. We used a consensus method to resolve disagreements, consulting with a third review author if disagreements persisted.

Assessment of risk of bias in included studies

We assessed risk of bias (RoB) of RCTs using the 12 criteria recommended by CBN (Furlan 2009; Higgins 2011) and defined in Appendix 9. In pairs of two, three review authors (MvT, RO, EM) independently assessed RoB. We used a consensus method to resolve disagreements and consulted the third review author if disagreements persisted.

We scored the criteria as 'high risk, 'low risk' or 'unclear risk'. Low RoB was defined as a trial meeting at least six criteria and having no fatal flaws.

Measures of treatment effect

We defined outcome measures from individual trials through meta-analysis when clinically and methodologically homogeneous. We sent comparisons to an international panel of eight anaesthesiologists, who rated the clinical homogeneity of study populations and interventions within each comparison. The review team assessed homogeneity in comparison treatments, outcomes, measurement instruments and timing of outcomes. An I^2 value greater than 70% might show considerable heterogeneity between studies. We used fixed effects with an I^2 value less than 25%, which indicates statistical homogeneity.

We calculated mean differences (MDs) for pain and functional status. We converted all visual analogue scale (VAS) or numerical rating scale (NRS) scores to scales ranging from zero to 10, when necessary. We expressed precision with 95% confidence intervals (95% CIs). If standard deviations (SDs) were not reported, we calculated these using reported values of the CI. If the CI was not available, we used SDs of baseline scores, or estimations of SDs based on other studies with the same population, treatment and score.

Unit of analysis issues

In the study comparing two interventions with a single control group (Tekin 2007), the number of participants in the control group was divided by two to avoid double counting of participants.

Data synthesis

If a meta-analysis was not possible, we described results from clinically comparable trials in the text.

We assessed the overall quality of evidence for each primary outcome by using an adapted GRADE (Grades of Recommendation, Assessment, Development and Evaluation) approach (Guyatt 2011), as recommended by CBN (Furlan 2009). The quality of evidence on a specific outcome is based on the following domains and is downgraded by one level for each of the factors encountered.

- Limitations in design (> 25% of participants from studies with high RoB).
- Inconsistency of results (severe heterogeneity (I^2 > 50%) or inconsistent findings among studies).
- Indirectness in targeted populations, interventions or outcomes that differ from those in which we are interested.
- Imprecision of results across all studies that measure that particular outcome (total number of participants < 400 for each outcome).
- Publication bias.

We considered comparisons including one RCT with fewer than 400 participants as inconsistent and imprecise and as yielding 'low-quality evidence', which we could further downgrade to 'very low-

quality evidence' if we found limitations in design (i.e. high RoB), indirectness or other considerations.

We applied the following grading of evidence (Guyatt 2011).

- **High quality:** Further research is very unlikely to change the quality of evidence that is based on consistent findings from at least two RCTs with low RoB and is generalisable to the population in question. Data are sufficient and include narrow CIs. No reporting biases are known or suspected.
- **Moderate quality:** Further research is likely to have an important impact on confidence in the estimate of effect and may change the estimate; one domain is not met.
- **Low quality:** Further research is very likely to have an important impact on confidence in the estimate of effect and is likely to change it; two domains are not met.
- **Very low quality:** Great uncertainty surrounds the estimate; three domains are not met.

Assessment of clinical relevance

Assessment of clinical relevance included whether characteristics of participants, interventions and treatment settings were described precisely enough to be comparable with those in practice. Further, we assessed whether clinically relevant outcomes were measured, if their effects were clinically important and if treatment benefits were worth the potential harms (Furlan 2009; Malmivaara 2006; Appendix 10).

Subgroup analysis and investigation of heterogeneity

Subgroups were based on patient selection. We analysed separately participants with pain suspected to originate from the facet joints, SI joints or discs, and those with another type of CLBP. Furthermore, comparisons were based on types of interventions and comparisons, outcomes and timing of outcomes.

We assessed heterogeneity using the Chi^2 test, I^2 and visual inspection of forest plots. If Chi^2 was not statistically significant, if I^2 was below 50% and if confidence intervals were overlapping, we considered the data statistically homogeneous.

Sensitivity analysis

We performed sensitivity analyses if uncertainty remained concerning the clinically homogeneity of studies compared.

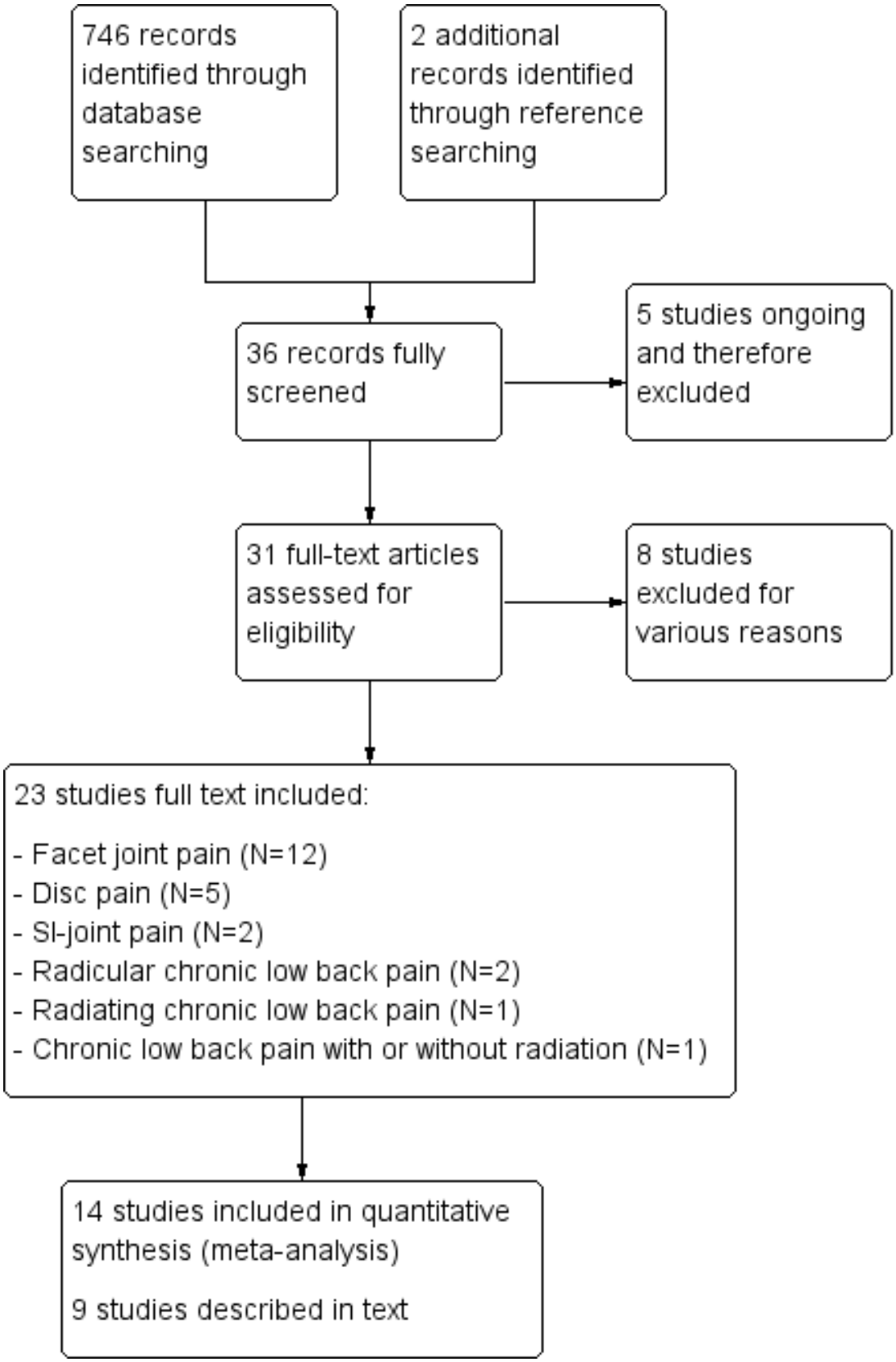
RESULTS

Description of studies

Results of the search

Database searching yielded 746 individual studies. We included two studies after reference searching and full screening of a total of 36 studies. Five studies were still ongoing and were excluded (Dolin 2010; Maas 2012; Norwegian University 2012; Sarwar 2012; SMART 2012). We assessed the remaining 31 studies by reviewing full-text articles. We excluded eight studies for various reasons, resulting in a total of 23 included studies (Figure 1). Following the updated search in June 2015, we added one trial report (Hashemi 2014) to Studies awaiting classification and determined that three additional studies (Albareeq 2015; Meckhail 2013; Mekhail 2015) are ongoing. We summarised characteristics of these studies under Characteristics of studies awaiting classification and Characteristics of ongoing studies.

Figure 1. Study flow diagram.



Included studies

The 23 included studies consisted of 1309 participants, and the sample size of each study ranged from 20 to 120 participants. Baseline characteristics of all participants were similar with regard to age, sex and duration of pain for all except two studies, in which these were not described precisely (Gallagher 1994) or were different (Lin Mu-Lien 2010). Studies included both men and women with a mean age of 50.6 years. Twelve studies examined suspected facet joint pain, five studies disc pain, two studies SI joint pain, two studies radicular CLBP, one study radiating low back pain and one study CLBP with or without radiation. We summarised study characteristics of all included studies under Characteristics of included studies.

Facet joint pain

We included 12 RCTs on suspected chronic facet joint pain (Civelek 2012; Duger 2012; Gallagher 1994; Kroll 2008; Lakemeier 2013; Leclaire 2001; Moon 2013; Nath 2008; Sanders 1999; Tekin 2007; Van Kleef 1999; Van Wijk 2005). These studies included participants with CLBP longer than three months to longer than 12 months. All participants reacted positively to local anaesthetic injections; criteria ranged from a description of 'good or equivocal response to local anaesthetic injection into and around the appropriate painful joints' to 'at least 80% of pain relief of at least one component of their pain after three separate diagnostic blocks with a local anaesthetic solution'.

For RF denervation, one study used the original Shealy technique (Gallagher 1994). The other studies used modified versions, but all researchers induced an RF lesion at 80°C to 85°C for 60 to 90 seconds.

In five studies, placebo was used for control and electrodes were used in the RF lesion group, but no RF lesion was induced (Gallagher 1994; Leclaire 2001; Nath 2008; Van Kleef 1999; Van Wijk 2005). The study by Kroll et al compared continuous RF (CRF) denervation (80°C, 75 seconds) versus pulsed RF denervation (PRF) (42°C, 120 seconds) (Kroll 2008). The study by Tekin et al compared CRF (80°C, 90 seconds) versus PRF denervation (42°C, 240 seconds) using a sham group (Tekin 2007). Two studies compared different methods of RF denervation; the study of Sanders et al compared intra-articular versus extra-articular lumbar facet joint denervation, and the study of Moon et al compared the RF facet denervation distal approach versus the tunnel vision approach (Moon 2013; Sanders 1999). Three studies used steroid injections in the control group (Civelek 2012; Duger 2012; Lakemeier 2013).

Discogenic low back pain

We included five RCTs (Barendse 2001; Ercelen 2003; Kapural 2013; Kvarstein 2009; Oh 2004) on suspected discogenic CLBP, which included participants with duration of low back pain between six months and longer than two years. These trials included only participants with positive response to either analgesic (Barendse 2001; Oh 2004) or provocative discography (Ercelen 2003; Kapural 2013; Kvarstein 2009).

The intervention consisted of percutaneous intra discal RF thermocoagulation (PIRFT) in four studies (Barendse 2001; Ercelen 2003; Kapural 2013; Kvarstein 2009). One study evaluated RF denervation of the ramus communicans nerve (this denervation is performed outside the intervertebral disc) in participants who failed to respond to intra discal electrothermic therapy (IDET) (Oh 2004).

Four studies were placebo-controlled (Barendse 2001; Kapural 2013; Kvarstein 2009; Oh 2004). One study compared high-intensity PIRFT versus low-intensity PIRFT (Ercelen 2003).

Sacroiliac joint pain

We included two RCTs (Cohen 2008; Patel 2012) studying suspected SI joint pain. Both studies included participants with axial low back or buttock pain lasting six months or longer. One study used pain relief of 75% or greater after a single diagnostic SI joint injection as confirmation of SI joint pain (Cohen 2008). The other study performed a dual lateral branch block, in which participants had to have 75% pain relief (Patel 2012).

In the study of Cohen et al, the intervention consisted of RF denervation of 90-second 80°C RF of L4–L5 primary dorsal rami and S1–S3 lateral branch RF using cooling probe technology (Cohen 2008). The other study applied RF energy for 150 seconds at 60°C on L5, then delivered RF energy for 150 seconds at 60°C on S1, S2 and S3 (Patel 2012). Both studies were placebo controlled.

Spinal dorsal root ganglion (DRG) - lumbosacral radicular pain

We included three RCTs (Geurts 2003; Shanthanna 2014; Simopoulos 2008) performing RF denervation of the dorsal root ganglion (DRG) for suspected lumbosacral radicular pain. Two studies included participants with lumbosacral radicular pain for longer than six months with 75% pain reduction after three separate diagnostic blocks (Geurts 2003), or complete relief of radicular symptoms following low-volume segmental nerve block (Simopoulos 2008). The other study included participants with a history of chronic lumbar radicular pain for at least four months with clinical features and computed tomography/magnetic resonance imaging findings of lumbosacral radicular pain (Shanthanna 2014).

Two studies used RF denervation as treatment (Geurts 2003; Shanthanna 2014), and one study used pulsed RF denervation as treatment (Simopoulos 2008). Two studies compared treatment versus placebo (Geurts 2003; Shanthanna 2014), and the other study used PRF plus CRF denervation for comparison (Simopoulos 2008).

Low back pain with or without radiation

We included one RCT (Lin Mu-Lien 2010) on CLBP for longer than six months with or without radiation. This study compared PRF denervation on DRG versus electro-acupuncture therapy, and versus conservative treatment with medication.

Excluded studies

For this update, we fully screened 36 studies. Five studies were ongoing and were excluded (Dolin 2010; Maas 2012; Norwegian University 2012; Sarwar 2012; SMART 2012). Eight studies were retrieved in full text and were eventually excluded (Buijs 2004; Cohen 2010; Dobrogowski 2005; Fukui 2012; Gautam 2011; Gross 2010; Proschek 2010; Reverberi 2005). Reasons for exclusion included no randomised controlled trial as study design and no direct measurement of the effectiveness of RF denervation. In the Characteristics of excluded studies section, we provide additional details of the excluded studies.

Risk of bias in included studies

Figure 2 shows results of the RoB assessment. Thirteen studies (56%) had low RoB.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

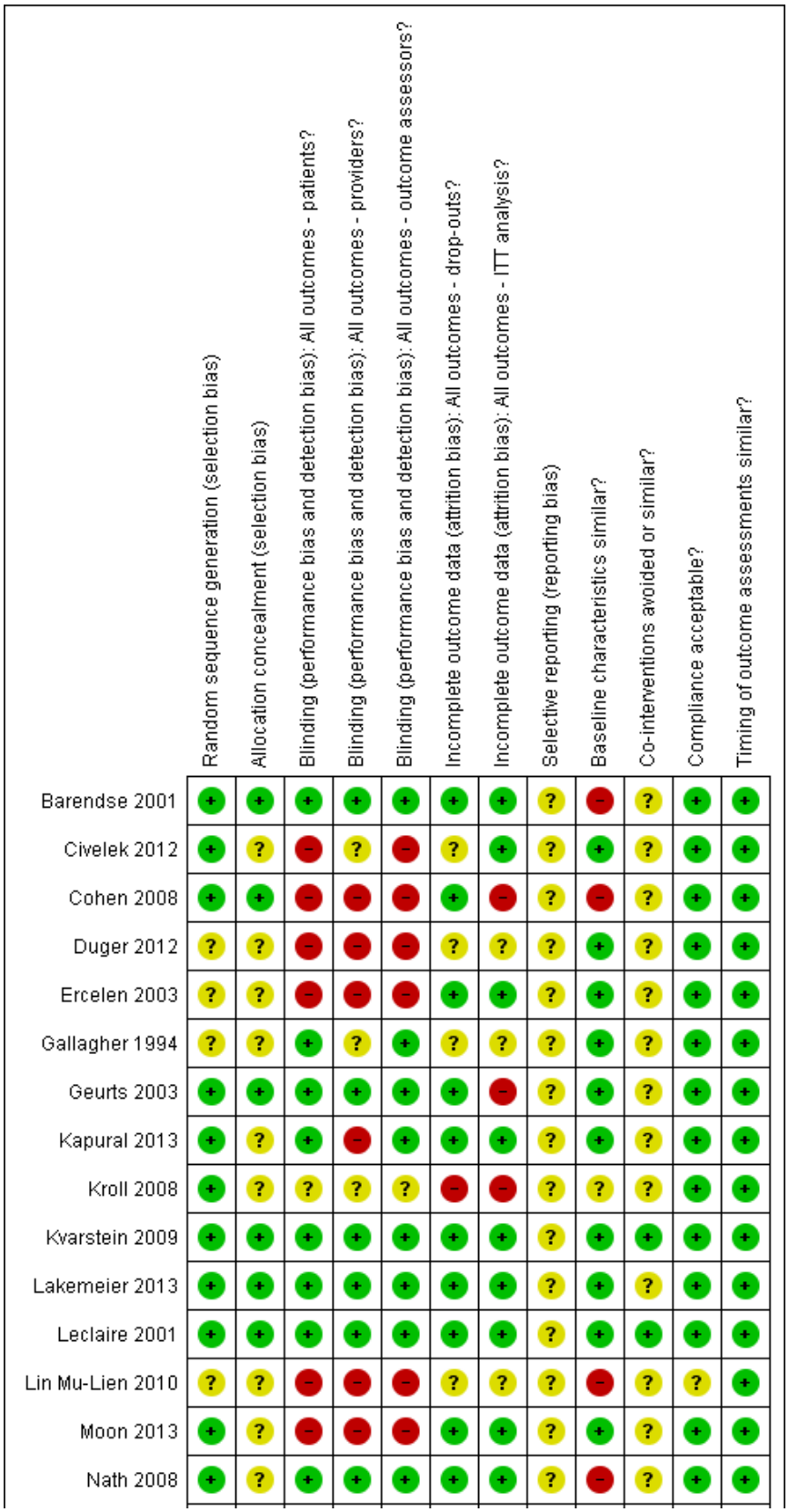
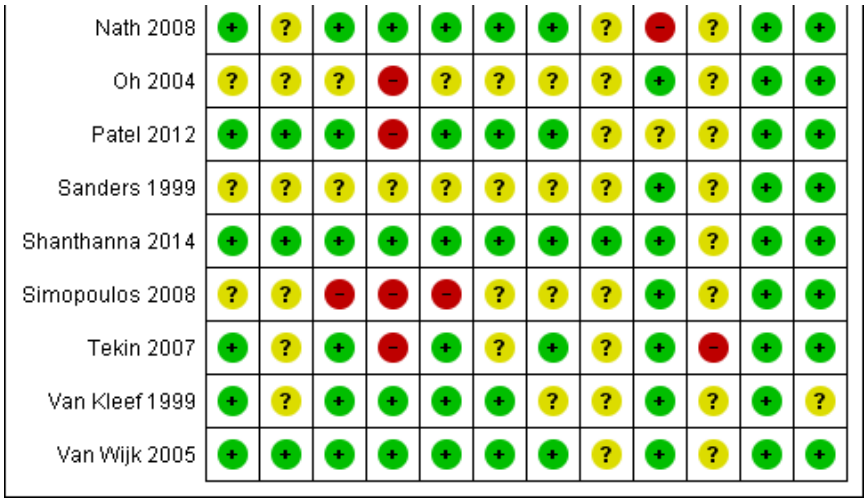


Figure 2. (Continued)



Allocation

Nine studies (40%) described an adequate randomisation procedure in combination with adequate concealment of treatment allocation. Method of randomisation remained unclear in seven studies (30%). Treatment allocation remained unclear in 14 studies (61%).

Blinding

Care providers, participants and outcome assessors were blinded in nine studies (47%).

Incomplete outcome data

Fourteen studies (61%) had acceptable dropout rates. Dropout rates were unclear in eight studies, and in one study the dropout rate was high. Three studies did not perform intention-to-treat analysis.

Selective reporting

Whether selective reporting occurred remained unclear in all but one study. All studies included core outcomes (pain and function), and we identified no protocols for all but one (Shanthanna 2014) study.

Other potential sources of bias

Groups were similar at baseline in 17 studies (74%) regarding demographic factors and most important prognostic factors. The description of possible co-interventions was unclear in 20 studies, co-interventions were avoided in two studies and co-interventions could have introduced bias in one study. Two studies did not adequately describe compliance, showing unclear risk of bias. Timing of outcome assessments was similar between studies.

Effects of interventions

See: **Summary of findings for the main comparison** Facet joint: radiofrequency denervation versus placebo; **Summary of findings 2** Facet joint: radiofrequency denervation versus steroid injections; **Summary of findings 3** Discs: radiofrequency denervation versus placebo; **Summary of findings 4** SI joint: radiofrequency denervation versus placebo

Feasibility of statistical pooling

We considered statistical pooling only if subgroups of studies were clinically homogeneous, and if study authors provided sufficient information on study characteristics, outcome measures and study results. Review of included study characteristics revealed that four treatment subgroups were sufficiently clinically homogeneous to permit statistical pooling, as shown in the summary of findings tables: Summary of findings for the main comparison - Facet joint: RF denervation versus placebo; Summary of findings 2 - Facet joint: RF denervation versus steroid injections; Summary of findings 3 - Disc: RF denervation versus placebo; and Summary of findings 4 - SI joint: RF denervation versus placebo.

Comparisons considering facet joint pain

Facet joint: RF denervation versus placebo

For short-term outcomes (< one month), three RCTs measured pain on a visual analogue scale (VAS) (Gallagher 1994; Leclaire 2001; Tekin 2007). We considered the studies in this comparison as statistically homogeneous (MD -1.47, 95% CI -2.28 to -0.67) (Analysis 1.1). Moderate-quality evidence (three RCTs; N = 160; imprecision) suggests that facet joint RF denervation is more effective than placebo for pain relief over the short term.

For intermediate-term outcomes (one to six months), three RCTs measured pain on a VAS (Leclaire 2001; Van Kleef 1999; Van Wijk 2005). One study reported outcomes in a different direction from the others. However, because of clinical homogeneity, we performed pooling, with pooled MD of -0.71 (95% CI -2.25 to 0.84) (Analysis 1.2). Low-quality evidence (three RCTs; N = 182; inconsistency; imprecision) suggests that facet joint RF denervation is no more effective than placebo for pain relief over the intermediate term.

For long-term outcomes (> six months), three RCTs measured pain on a VAS (Gallagher 1994; Nath 2008; Tekin 2007) and showed statistical homogeneity. The pooled MD was -0.70 (95% CI -1.48 to 0.08) (Analysis 1.3). Moderate-quality evidence (three RCTs; N = 130; imprecision) suggests that facet joint RF denervation is no more effective than placebo for pain relief over the long term.

When we removed the comparison of pulsed RF denervation versus placebo in the study of Tekin from the analysis (as recommended by one of the clinicians on the advisory team), the pooled MD for pain intensity was -1.51 (95% CI -2.79 to -0.23) over the short term (Analysis 1.1; sensitivity analysis) and -1.06 (95% CI -2.23 to 0.11) over the long term (Analysis 1.3; sensitivity analysis). Removal of this study component from the comparisons slightly altered the pooled MD; the long-term effect became somewhat larger but less precise (moderate quality of evidence).

One RCT with two intervention groups measured functional status on the Oswestry Disability Index (ODI) (zero to 100) over the short term (Tekin 2007). Low-quality evidence (one RCT; N = 60; inconsistency, imprecision) suggests that facet joint RF denervation is more effective than placebo for functional status over the short term (MD -5.53, 95% CI -8.66 to -2.40) (Analysis 2.1).

None of the included studies measured functional status over the intermediate term.

For long-term outcomes (> six months), one RCT with two intervention groups measured functional status on the ODI (zero to 100) (Tekin 2007). Low-quality evidence (one RCT; N = 60; inconsistency, imprecision) suggests that facet joint RF denervation is more effective than placebo for functional status over the long term (MD -3.70, 95% CI -6.94 to -0.47) (Analysis 2.2).

One RCT that compared two intervention groups (PRF and CRF) versus placebo measured participant satisfaction on a four-point scale (Tekin 2007). Low-quality evidence (one RCT; N = 60; inconsistency, imprecision) suggests that both interventions are more effective than placebo in achieving participant satisfaction. Timing of measurement and MDs between groups were not stated.

Facet joint: continuous RF denervation versus pulsed RF denervation

One RCT compared continuous facet RF denervation versus pulsed RF denervation (Kroll 2008). Investigators reported no significant results for pain three months after treatment. Very low-quality evidence (one RCT; N = 26; serious RoB; inconsistency, imprecision) suggests that continuous RF denervation is no more effective than pulsed RF denervation (MD 0.07, 95% CI -1.82 to 1.96) (Analysis 3.1).

Facet joint: percutaneous intra-articular denervation versus percutaneous extra-articular denervation

One RCT compared facet percutaneous intra-articular RF denervation versus percutaneous extra-articular RF denervation (Sanders 1999). Very low-quality evidence (one RCT; N = 34; serious RoB; inconsistency, imprecision) suggests that intra-articular RF denervation is more effective than extra-articular RF denervation for pain relief three months after the intervention (MD -2.20, 95% CI -3.69 to -0.71) (Analysis 4.1).

Facet joint: RF denervation: distal approach versus tunnel vision approach

One RCT compared the distal approach versus the tunnel vision approach to performing facet joint RF denervation (Moon 2013). Researchers observed no significant results for pain one month (MD -0.20, 95% CI -1.21 to 0.81) and longer than six months after treatment (MD 0.00, 95% CI -1.08 to 1.08). Very low-quality evidence (one RCT; N = 68; serious RoB; inconsistency, imprecision) suggests that the distal approach is no more effective than the tunnel vision approach (Analysis 5.1; Analysis 5.2).

For functional status, no significant results were found one month (MD 2.20, 95% CI -2.28 to 6.68) and longer than six months after treatment (MD 2.90, 95% CI -1.71 to 7.51). Very low-quality evidence (one RCT; N = 68; serious RoB; inconsistency, imprecision) suggests that the distal approach is no more effective than the tunnel vision approach (Analysis 6.1; Analysis 6.2).

Facet joint: RF denervation versus steroid injections

For short-term outcomes (< one month) when RF denervation was compared with steroid injections, two RCTs measured pain on a VAS (Civelek 2012; Duger 2012) and reported statistical homogeneity. When these studies were pooled, the MD was -2.23 (95% CI -2.38 to -2.08) (Analysis 7.1). Low-quality evidence (two RCTs; N = 180; serious RoB; imprecision) suggests that facet joint RF denervation is more effective than steroid injections for pain relief over the short term.

For intermediate-term outcomes (one to six months), three RCTs measured pain on a VAS (Civelek 2012; Duger 2012; Lakemeier 2013). On the basis of Chi^2, I^2 and confidence intervals, the studies were deemed statistically heterogeneous, in large part because of the small SDs, which were difficult to extract from the study of Civelek (Civelek 2012). Confidence intervals were hardly overlapping, but because of clinical homogeneity, and because all effects were noted to be in the same direction, we decided to pool the results of these studies. The MD was -2.13 (95% CI -3.45 to -0.81) (Analysis 7.2). Very low-quality evidence (three RCTs; N = 132; serious RoB; imprecision, inconsistency) suggests that facet joint RF denervation is more effective than steroid injection for pain relief over the intermediate term.

For long-term outcomes (> six months), two RCTs measured pain on a VAS (Civelek 2012; Duger 2012). For the same reason as in Analysis 7.2, statistical pooling was performed unless limitations in this approach were noted. The MD was -2.65 (95% CI -3.45 to -1.88) (Analysis 7.3). Very low-quality evidence (three RCTs; N = 180; serious RoB; imprecision, inconsistency) suggests that facet joint RF denervation is more effective than steroid injection for pain relief over the intermediate term.

One RCT compared RF denervation versus steroid injections and measured function (Lakemeier 2013). Investigators reported no significant results for function six months after treatment (MD -5.00, 95% CI -15.19 to 5.19). Very low-quality evidence (one RCT; N = 52; serious RoB; inconsistency, imprecision) suggests that RF denervation is no more effective than steroid injections over the long term (Analysis 8.1).

One RCT compared RF denervation versus steroid injections and measured participant satisfaction (Duger 2012). Low-quality evidence (one RCT; N = 80; serious RoB; inconsistency, imprecision) suggests that facet joint RF denervation is more effective than steroid injection for participant satisfaction over the short, intermediate and long term (Analysis 9.1; Analysis 9.2; Analysis 9.3).

Comparisons considering discogenic low back pain

120-Second disc RF denervation versus 360-second RF denervation

One study compared 360-second RF denervation versus 120-second RF denervation (Ercelen 2003). Researchers found no

significant differences in pain and function between groups at any follow-up assessment. Very low-quality evidence (one RCT; N = 37; serious RoB; imprecision) suggests that 360-second RF denervation is no more effective for pain and function than 120-second RF denervation over the short, intermediate and long term (Analysis 10.1; Analysis 10.2; Analysis 10.3; Analysis 11.1; Analysis 11.2).

Disc: RF denervation versus lidocaine

One study compared the effects of RF denervation versus lidocaine in participants with disc pain. Investigators reported no significant results for pain four months after the procedure (Oh 2004). Very low-quality evidence (one RCT; N = 49; serious RoB; inconsistency, imprecision) suggests that RF denervation is more effective than lidocaine four months post treatment (Analysis 12.1).

Disc: RF denervation versus placebo

One study (Kapural 2013) compared RF denervation versus placebo and reported short-term outcomes. Low-quality evidence (one RCT; N = 56; inconsistency, imprecision) suggests that RF denervation is no more effective than placebo for pain and function over the short term (Analysis 13.1; Analysis 14.1).

Two studies compared RF denervation versus placebo and reported outcome measures for pain and function. Researchers reported no significant results for pain and function one to six months after the intervention (Barendse 2001; Kapural 2013). Low-quality evidence (two RCTs; N = 84; imprecision, inconsistency) suggests that RF denervation is no more effective than placebo for pain (MD 0.27, 95% CI -2.25 to 2.79) and function over the intermediate term (MD 0.86, 95% CI -6.37 to 8.10) (Analysis 13.2; Analysis 14.2).

Over the long term, two studies (Kapural 2013; Kvarstein 2009) showed small significant results for pain and function six and 12 months after treatment. Moderate-quality evidence (two RCTs; N = 75; imprecision) suggests that RF denervation is more effective than placebo for pain (MD -1.63, 95% CI -2.58 to -0.68) and function over the long term (MD -6.75, 95% CI -13.42 to -0.09) (Analysis 13.3; Analysis 14.3).

Comparison considering SI joint pain

SI joint: RF denervation versus placebo

Two low-quality studies (N = 79; serious RoB; imprecision, inconsistency) compared RF denervation versus placebo (Cohen 2008; Patel 2012) over the short term. Very low-quality evidence suggests that RF denervation is no more effective than placebo for pain (MD -2.12, 95% CI -5.45 to 1.21) and function (MD -14.06, 95% CI -30.42 to 2.30) one month post treatment (Analysis 15.1; Analysis 16.1).

One low-quality study (Patel 2012) (one RCT; N = 51; inconsistency, imprecision) showed a smaller effect of RF denervation compared with placebo for pain and function one to six months after the intervention (Analysis 15.2; Analysis 16.2).

Comparisons considering the dorsal root ganglion

Radiating low back pain: pulsed RF denervation versus pulsed RF denervation and continuous RF denervation

In one study (N = 76; serious RoB; inconsistency, imprecision), very low-quality evidence suggests that PRF denervation versus PRF and CRF has no effect three months after treatment on pain relief, functional improvement or health-related quality of life (Simopoulos 2008); and that PRF is not more or less effective for pain relief than PRF and CRF denervation over the short term (two months). Low-quality evidence suggests that RF denervation causes no serious complications (Analysis 17.1).

Dorsal root ganglion: RF denervation versus placebo

One study compared RF denervation versus placebo (Geurts 2003). Investigators reported no significant results for pain three months after the procedure. Low-quality evidence (one RCT; N = 80; imprecision) suggests that RF denervation is no more effective than placebo three months post treatment. Researchers presented no other results for VAS leg, daily physical activities scores, numerical analgesics rating scale scores, global subjective efficacy ratings and Short Form (SF)-36 scores. Adverse events and complications did not differ between treatments, and no serious complications or side effects occurred in either group (Analysis 18.1).

Dorsal root ganglion: pulsed RF denervation versus placebo

One study provided low-quality evidence showing that pulsed RF denervation is no more effective than placebo in the dorsal root ganglion over the short term. Long-term data or data considering functional status could not be extracted, but the study reports no statistically significant differences in pain and function between PRF and placebo until three months after the intervention (Shanthanna 2014) (Analysis 19.1).

Low back pain with or without radiation

In one study, very low-quality evidence (one RCT; N = 100; serious RoB; inconsistency, imprecision) suggests that PRF denervation on dorsal root ganglion compared with either electro-acupuncture or sham offers better short-term effects for pain relief and health-related quality of life but not for functional improvement among individuals suffering from CLBP (Lin Mu-Lien 2010).

We have summarised additional details in the Characteristics of included studies table.

Clinical relevance of included studies

Table 1 presents clinical relevance scores for each study. Most studies described the study population (91%) and the interventions and settings (87%) well enough for comparison with clinical practice. Seventeen studies (74%) measured clinically relevant outcomes (pain and function). When assessing the clinically important size of the effect, researchers considered 30% reduction on VAS/NRS for pain or 8% to 12% improvement in function on the ODI over the short term as clinically important. Only seven studies (30%) showed clinically relevant effects on one of these outcomes (Cohen 2008; Duger 2012; Gallagher 1994; Oh 2004; Tekin 2007; Van Kleef 1999; Van Wijk 2005). All included studies had small sample sizes, and most poorly described side effects or other complications. Therefore, whether treatment benefits were worth the potential harms remains unclear in all studies.

DISCUSSION

Summary of main results

The objective of this systematic review was to assess the effectiveness of radiofrequency (RF) denervation procedures for treatment of chronic low back pain (CLBP) on the basis of information provided by randomised controlled trials (RCTs). We included 23 RCTs, 13 (56%) of which were considered to have low

risk of bias (RoB), even though all had deficiencies, as discussed below. Reviewed studies provided evidence of low to moderate quality suggesting that RF denervation of the facet joint could offer greater pain relief (visual analogue scale (VAS)) (short term) and small improvement in function (Oswestry Disability Index (ODI)) (short and long term) when compared with placebo and steroid injections. For suspected discogenic lumbar pain, evidence of low to very low quality suggests that RF denervation has no effect beyond placebo over the short term, and evidence of moderate quality suggests that RF denervation when compared with placebo has a smaller effect on pain (Numerical Rating Scale (NRS)) and function (ODI) over the long term. For suspected sacroiliac (SI) joint pain, low-quality evidence shows small effects over the intermediate term and no effects over the short term. For other sources of pain, evidence of low to very low quality shows no effects of RF denervation.

Overall completeness and applicability of evidence

The overall number of participants in all 23 studies - 1309 - makes the number of participants included in each individual trial small. This methodological shortcoming contributes to the overall low quality of the evidence. From a clinical perspective, because of the specialised invasiveness of the technique and exposure to x-ray, the small number of participants was understandable. However, it should be pointed out that these interventions were tested in highly selected groups that had undergone diagnostic blocks, and the results must therefore be interpreted with care. Furthermore, no reliable data can be found on the diagnostic accuracy or clinical utility of diagnostic facet joint, SI joint or selective nerve root blocks (Chou 2007).

Outcome measures

Five studies did not fulfil the two main clinically relevant outcome measures (Civelek 2012; Duger 2012; Geurts 2003; Oh 2004; Simopoulos 2008): pain and disorder-specific disability. The studies of Gallagher (Gallagher 1994), Duger (Duger 2012) and Simopoulos (Simopoulos 2008) used pain as the only outcome measure. In this review, we did not consider “ability to work” as an imperative criterion, as it is not always relevant among individuals with CLBP. Only one study assessed treatment-related costs (Van Wijk 2005).

Follow-up

Follow-up time for intention-to-treat analysis varied from one month to one year. However, only one study included follow-up measurement one year after the start of treatment. In six studies, the blinding code was broken in cases of treatment failure, and an escape treatment was offered (Cohen 2008; Geurts 2003; Kvarstein 2009; Leclaire 2001; Patel 2012; Van Wijk 2005). Longer follow-up periods are needed - not only to prove efficacy in RF denervation, but also to track eventual long-term adverse effects.

Adverse effects

No adverse effects were reported in 10 studies (Barendse 2001; Duger 2012; Ercelen 2003; Gallagher 1994; Lakemeier 2013; Leclaire 2001; Lin Mu-Lien 2010; Sanders 1999; Shanthanna 2014; Simopoulos 2008). Two studies (Nath 2008; Patel 2012) reported subsiding pain associated with the procedure. The study of Oh (Oh 2004) reported complaints of mild lower limb weakness that dissipated completely. Cohen (Cohen 2008) reported transient non-painful paraesthesias that resolved without therapy. Symptoms were more common and lasted longer in the RF denervation group. However, no permanent complications were reported. Two studies found no statistically significant differences between groups (Geurts 2003; Van Wijk 2005). In one study, two actively treated and three sham-treated participants experienced increased pain (Kvarstein 2009). For ethical reasons, inclusion of new participants was therefore discontinued. Three studies reported complications (change in pain characteristics, exacerbation of pain, small superficial burns after RF denervation) that did not last longer than one month (Civelek 2012; Kapural 2013; Moon 2013). Furthermore, most RCTs were small and were not designed to evaluate adverse events, so no clear conclusion can be drawn regarding risks of RF denervation.

Quality of the evidence

Thirteen studies (56%) had an overall low RoB. The RoB items ‘compliance’ and ‘similar timing of outcome assessment’ were scored best with both 22 studies that complied to these items. However, compliance was in most of the studies irrelevant because it was a single session intervention. Selective reporting and the avoidance or similarity of co-interventions was scored worst, with respectively one and two studies which complied to this item. Selective reporting was scored unclear if no study protocol was published. Most studies included core outcomes (pain and function), but protocols could not be identified in all but one study (Shanthanna 2014). In most studies it was not reported clearly if co-interventions were avoided or similar. Especially these RoB items need improvement in future studies. The RoB item 'patient blinding' was scored 'Yes' if the intervention and control groups are indistinguishable for the patients or if the success of blinding was tested among the patients and it was successful (Furlan 2009). However, blinding the RF denervation procedure is very difficult and debatable. For future reviews it can be discussed if this item should be scored 'yes' if blinding was described as indistinguishable for patients but was not tested.

Potential biases in the review process

The primary limitation of this review - lack of studies with low RoB - is encountered in many systematic reviews. Methodologically well-conducted studies with an appropriate sample size undertaken to examine the effectiveness of RF denervation remain scarce. Also, many included studies had no published protocol and, to our knowledge, had not been registered in any of the trial registries. Another limitation is the possibility of publication bias, which we attempted to minimise by conducting an extensive database search. This search is up-to-date until May 2014; the fact that one study is not incorporated may be a source of potential bias. The influence of publication bias on the results was impossible to assess because a small number of studies contributed to each pooled estimate.

Agreements and disagreements with other studies or reviews

Since the original review was published in 2003 (Niemisto 2003), 19 new studies about RF denervation for CLBP have been reported. The original review showed conflicting evidence for the effectiveness of facet joint RF denervation. This evidence remains conflicting; however, we found moderate-quality evidence for effects favouring RF denervation over placebo for pain (short term), and low-quality evidence supports RF denervation for functional

improvement (over the short, intermediate and long term). In 2003, Niemisto et al (Niemisto 2003) reported limited evidence that intradiscal RF denervation may not be effective for discogenic pain. This review supports these results over the short and intermediate term, but moderate-quality evidence shows small positive results over the long term. The current review found greater variation among control groups, most of which did not show significant differences. Only low-quality evidence was found to favour the effects of RF denervation over steroid injections for pain.

In 2010, Henschke et al published a systematic review on injection therapy and denervation procedures for CLBP (Henschke 2010). They concluded that only low-quality to very low-quality evidence could support the use of injection and denervation procedures over placebo and other treatments. The only possible beneficial treatment effect reported by these review authors was facet joint RF denervation. The current review supports this conclusion. Henschke et al showed the same limited results for injection therapy, as did the systematic review of Staal et al (Staal 2008), which concluded that evidence was insufficient to support use of injection therapy for subacute and chronic low back pain. This finding was consistent with our results (although based on low-quality evidence) suggesting that RF denervation is more effective than steroid injections for facet joint pain.

Poetscher et al (Poetscher 2014) concluded that facet joint RF denervation was more effective than placebo for pain control and functional improvement and was possibly more effective than steroid injections for pain control. These results are supported by evidence of low to moderate quality and show similarities with our results. All previously published reviews state that adverse effects were not sufficiently reported.

AUTHORS' CONCLUSIONS

Implications for practice

In general, all conclusions concerning the effects of continuous radiofrequency (CRF) or pulsed radiofrequency (PRF) denervation on CLBP are based on evidence of very low, low or moderate quality. Given this overall quality of evidence, it is recommended that practitioners should be careful when making the decision to use RF denervation in routine clinical practice until rigorous, high-quality studies on effectiveness and cost-effectiveness have been performed. As the original studies were not of adequate quality and size to permit assessment of how often complications of RF denervation occur, RF denervation for suspected facet joint pain may have smaller effects in reducing pain (short term) and improving function (short term and long term) in comparison with placebo, but valid evidence on harms is lacking. For suspected discogenic pain, evidence of low to moderate quality shows no short-term and intermediate-term effects. This undermines the clinical plausibility of moderate evidence for small effects favouring RF denervation over the long term. For suspected SI joint pain, low-quality evidence suggests that RF denervation may not provide short-term effects on pain and functional improvement, and may confer small effects over the long term. For other CLBP, the evidence is low in quality and is too sparse to allow any conclusions. Studies listed under Studies awaiting classification and Ongoing studies may alter the conclusions of the review, once assessed.

Implications for research

Additional high-quality registered RCTs with larger patient samples, careful pre-selection of patients with diagnostic blocks, longer follow-ups and meaningful standardised outcomes are needed, as are trials on indications for which RF denervation is now used without scientific evidence of efficacy.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Barendse 2001

Methods	RCT
Participants	University Hospital Maastricht, The Netherlands (N = 28) **Inclusion criteria** • Chronic non-specific low back pain for longer than 1 year • History of unsuccessful conservative treatment • 30 to 65 years of age

Barendse 2001 *(Continued)*

	• 50% temporary pain relief 30 minutes after an analgesic discography **Exclusion criteria** • Spinal stenosis, spondylolisthesis, multi-level burnt-out disc lesions, coagulation disturbances, pregnancy and initial "high" visual analogue score < 5.0 • Diabetes mellitus • Patients with > 1 pain syndrome • - Patients with multi-level discogenic pain
Interventions	**Experiment group** • RF lesion group was treated with a 90-second 70°C lesion in the centre of the intervertebral disc (N = 13) **Control group** • In the sham group, electrodes were introduced as in (E), but without use of RF current (N = 15)
Outcomes	• No significant changes between groups for all primary and secondary outcomes after 8 weeks of treatment • Pain intensity: change in VAS score mean: -0.61 (E), -1.14 (C) • Disorder-specific functional status: change score in ODI: -2.62 (E), -4.93 (C) • Quality of life: change score in Coop/Wonca: -1.85 (E), -0.21 (C)
Notes	Dropouts: number unclear

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Double-blind, randomised study
Allocation concealment (selection bias)	Low risk	Participants randomly assigned to 2 treatment groups by computer programme through a disinterested third party
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Anaesthesia adequate during the procedure. Participant could not determine whether he or she had received RF or sham treatment
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Treating physicians left the operating room
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Data obtained by an investigator blinded to allocation of participants
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	One participant lost to follow-up evaluation
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Intention-to treat analysis performed

Barendse 2001 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	High risk	Table 1. Differences in months of pain and VAS scores
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Measured at baseline and at 3, 6 and 12 months

Civelek 2012

Methods	RCT
Participants	Setting unknown, Turkey (N = 100) **Inclusion criteria** • Chronic and debilitating LBP leading to diagnosis of lumbar facet syndrome • Not responding to conservative treatment for up to 6 weeks, including various analgesics and physical therapy and additional pain relief after FJI for participants with FJRF • Symptoms of facet syndrome include local tenderness over 1 or more FJs, back pain aggravated by hyperextension and rotation, morning stiffness or pain increasing in the morning and hip and buttock pain of a non-radicular distribution **Exclusion criteria** • Radicular pain, neurogenic claudication and neurological deficits • Acute or uncontrolled medical illness • Known history of adverse reactions to local anaesthetics • Pregnancy or lactation
Interventions	**Experiment group** • RF denervation at 80°C for 120 seconds **Control group** • Facet joint injection with medial branch block of posterior primary ramus with 1 cc of methylprednisolone acetate (40 mg) (diluted with 1 cc SF) combined with 2 cc bupivacaine hydrochloride (diluted with 2 cc SF)
Outcomes	• Pain intensity: change in VAS score at 1 month: -6 (E), -5.1 (C). Significant difference between E and C • Pain intensity: change in VAS score at 6 months: -5.7 (E), -4.1 (C). Significant difference between E and C • Pain intensity: change in VAS score at 12 months: -2.6 (E), -4.9 (C). Significant difference between E and C
Notes	Dropouts: incomplete information on participant flow and follow-up

Risk of bias

Bias	Authors' judgement	Support for judgement

Civelek 2012 *(Continued)*

Random sequence generation (selection bias)	Low risk	Random assignment to 2 groups performed by random number generation, with balance after every 10 participants
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	No stimulation in injection group before treatment; impossible to blind participants
Blinding (performance bias and detection bias) All outcomes - providers?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Incomplete information on participant flow and follow-up
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Data from all participants incorporated into the analysis
Selective reporting (reporting bias)	Unclear risk	Remained unclear from text
Baseline characteristics similar?	Low risk	Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant; intervention performed only once
Timing of outcome assessments similar?	Low risk	Meaured pre-procedure, post procedure and at 1, 6 and 12 months post procedure

Cohen 2008

Methods	RCT
Participants	Johns Hopkins Medical Institutions, Maryland & Walter Reed Army Medical Center, Washington, DC, USA (N = 28) **Inclusion criteria** • Older than 18 years • Axial low back or buttock pain ≥ 6 months • Tenderness overlying SI joint(s) • Failure to respond to conservative therapy • Long-term (2 months) pain relief with SI joint corticosteroid injections

Cohen 2008 *(Continued)*

	• Pain relief ≥ 75% as calculated from a 6-hour post-block pain diary after a single diagnostic SI joint injection **Exclusion criteria** • Focal neurological signs or symptoms • Radiological evidence of symptomatic herniated disc • Spondyloarthropathy • Untreated coagulopathy • Unstable medical or psychiatric illness that might preclude an optimal treatment response
Interventions	**Experiment group** • Cooled RF denervation group received L4–L5 primary dorsal rami and S1–S3 lateral branch RF denervation (80°C, 90 seconds) using cooling probe technology after local anaesthetic block (N = 14) **Control group** • Control group received local anaesthetic block followed by placebo denervation, in which 0.5 mL lidocaine 2% was administered with no current (N = 14) • Participants who did not respond to placebo injections crossed over and were treated with RF denervation using conventional technology
Outcomes	Significant changes between groups for pain intensity (VAS) 1 and 3 months after treatment, and for function (ODI) 1 month after treatment • Pain intensity: change in VAS score at 1 month: -3.7 (E), -0.2 (C) • Pain intensity: change in VAS score at 3 months: -3.7 (E), -0.5 (C) • Function: change in ODI score at 1 month: -16.2 (E), -4.3 (C) • Function: change in ODI score at 3 months: -13.1 (E), -23.9 (C)
Notes	Dropouts: none

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random assignment in blocks of 4 via pre sealed envelopes
Allocation concealment (selection bias)	Low risk	Presealed envelopes
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	Blinding evaluated shortly after conclusion of the procedure, when effects of local anaesthetic were still active
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Participants treated with placebo after 1 month
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participant-reported outcome measures. Participants who did not show adequate symptomatic improvement were unblinded at follow-up. For those who reported significant relief 1 month after the procedure, unblinding was done 3 months after treatment
Incomplete outcome data (attrition bias)	Low risk	No dropouts; only 3 placebo participants refused to cross over

Cohen 2008 *(Continued)*

All outcomes - drop-outs?		
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	High risk	Cross-over procedure
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	High risk	Meaningful differences in morphine use and function
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Similar until 3-month follow-up

Duger 2012

Methods	RCT; random assignment to 3 groups
Participants	Department of Anesthesiology, Cumhuriyet University School of Medicine, Sivas, Turkey (N = 120) **Inclusion criteria** • Single-sided low back pain arising from facet joint • Between 18 and 60 years of age • Complaints longer than 6 months • Limited functions and daily life • Presented with at least 2 of the 4 troubling symptoms of facet syndrome, including back pain aggravated by hyperextension and rotation, morning stiffness or pain increasing in the morning, local tenderness over 1 or more facet joints and hip and buttock pain of a non-radicular distribution **Exclusion criteria** • Patients not accepting the procedure • Patients not giving informed consent • Coagulation defect • Major depression and uncontrolled psychiatric disorder • Pregnancy or lactation • Respiratory or cardiac problems in prone position • Opioid treatment during previous month • Undergoing surgical procedure at the same site • Infection at the procedure site • Disc-related radicular symptoms
Interventions	**RF denervation group** • In group R (RF denervation), localisation of radiofrequency electrode in the facet joint causing pain was determined by sensorial stimulus and C-armed scope device. Pulse RF thermocoagulation was applied for 6 minutes at 40°C with RF lesion generator

Duger 2012 *(Continued)*

	Injection group • In group B (block), after C-arm scope-guided determination of injection point, 1.5 mL of 20 mg methylprednisolone acetate mixed with 5 mg bupivacaine was injected into the facet joint **RF denervation and injection groups** • In Group RB (RF denervation and block) patients, localization of electrode in the facet joint causing pain was determined by sensorial stimulus and scope device. Pulsed RF thermocoagulation was applied for 6 minutes at 40°C and a 1.5 ml mixture of 20 mg methylprednisolone acetate and 5 mg bupivacaine was injected to the facet joint at the same localization
Outcomes	• Pain intensity: change in VAS score at 1 month: -4.4 (R), -1.74 (B), -4.2 (RB). Significant difference between R and B; and between RB and B • Pain intensity: change in VAS score at 6 months: -4.2 (R), -0.6 (B), -4.3 (RB). Significant difference between R and Bl and between RB and B • Pain intensity: change in VAS score at 12 months: -3.3 (R), -0.1 (B), -3.4 (RB). Significant difference between R and Bl and between RB and B
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Remained unclear from text
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	No stimulation in injection group before treatment. Therefore, decision was made that it was impossible to blind participants
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	All procedures performed by the same physician
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Incomplete information on participant flow and follow-up
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables

Duger 2012 *(Continued)*

Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: intervention if performed only once
Timing of outcome assessments similar?	Low risk	Table 2. Baseline, day 1, day 2, week 1, week 2, month 1, month 6 and month 12 measures

Ercelen 2003

Methods	RTC
Participants	VKV American Hospital, Pain Management Department, Istanbul, Turkey (N = 39) **Inclusion criteria** • Chronic low-back pain • Receiving some kind of conservative treatment ≥ 2 years • Persistent pain • Quality of life severely affected • No nerve compression found • Concordant pain reproduced at 1 or 2 suspicious levels with no pain or discordant pain with adjacent disc stimulation **Exclusion criteria** • Spinal stenosis, instability, spondylolisthesis, diabetes mellitus, tumour infiltration, coagulation disorders, clinical radiculopathy, other neurological abnormalities or systemic inflammatory diseases
Interventions	**Group A** was treated with a 120-second 80°C lesion of the intervertebral disc after injection of a mixture of 1 to 2 mL of dye and local anaesthetic (N = 20) **Group B** was treated with a 360-second 80°C lesion of the intervertebral disc after injection of a mixture of 1 to 2 mL of dye and local anaesthetic (N = 19)
Outcomes	No significant changes between groups in pain and function • Pain intensity: change in VAS score at 1 month: -3.4 (A), -2.9 (B) • Pain intensity: change in VAS score at 6 months: -1.3 (A), -1.4 (B) • Function: change in ODI score at 1 month: -16.1 (A), -17.8 (B) • Function: change in ODI score at 6 months: -3.6 (A), -4.3 (B)
Notes	Dropouts: 2 (5%)

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Participants randomly assigned to 2 treatment groups by computer
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias)	High risk	Participants not blinded

Ercelen 2003 *(Continued)*

All outcomes - patients?		
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Providers not blinded
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participants not blinded and all outcomes participant reported
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Two participants (5%) dropped out
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Attrition bias unlikely because of design ?
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Outcomes measured directly after procedure and at 1 week, 2 weeks, 1 month, 2 months, 3 months and 6 months after procedure

Gallagher 1994

Methods	RCT

Participants	Departments of Pain Relief, Rheumatology and Orthopaedics, Guy's Hospital, London, UK (N = 41)
	Inclusion criteria
	• Back pain > 3 months
	• Age 25 to 55 years
	• and ≥ 4 of the following:
	  ○ Tenderness on palpation
	  ○ More pain on extension than on flexion
	  ○ Pain on rotation of the spine
	  ○ Referred pain (above the knee)
	  ○ Pain exacerbated by exercise and relieved by rest
	  ○ Pain exacerbated by sitting or standing
	  ○ Pain not exacerbated by coughing or sneezing
	  ○ Radiological evidence of facet joint degeneration or predisposing factors
	  ○ Pain relief over 12 hours after local anaesthetic
	Exclusion criteria

Gallagher 1994 *(Continued)*

- Previous back operations
- Neurological signs of nerve root compression in lower limbs
- Patients with major mental illness or severe personality disorder
- Pending compensation claims
- General ill health

Interventions	**Experiment group**
	• After area was anaesthetised (nerves above and below and the painful nerve) with lignocaine 2% 0.5 mL, RF lesion was made at 80°C for 90S of medial branch of posterior primary ramus of lumbar segmental nerves
	  ○ Group A (N = 18): good response to diagnostic block + denervation
	  ○ Group B (N = 6): equivocal response to diagnostic block + denervation
	Control group
	• Nerves to joints were identified by stimulation, local anaesthetic was injected in the usual way, but no heat lesion was made
	  • Group C (N = 12): good response to diagnostic block + placebo
	  • Group D (N = 5): equivocal response to diagnostic block + placebo

Outcomes	Significant differences in mean pain scores (VAS 0 to 100) between groups A and C at 1 month and at 6 months • Pain intensity: change in VAS score at 1 month: -17 (A), -13 (B), -13 (C), -12 (D) • Pain intensity: change in VAS score at 6 months: -7 (A), -5 (B), -3 (C), -17 (D)
Notes	Dropouts: number unclear

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Remained unclear from text
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Placebo procedure indistinguishable from intervention
Blinding (performance bias and detection bias) All outcomes - providers?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participant reported outcome measures by blinded participants
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias)	Unclear risk	Remained unclear from text

Gallagher 1994 *(Continued)*

All outcomes - ITT analysis?		
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	No differences between groups in terms of age or duration of pain
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Participants assessed before any treatment, before denervation, at 1 month and at 6 months

Geurts 2003

Methods	RCT
Participants	University Medical Centre, Utrecht, RIjnstate Hospital, Arnhem, Juliana Hospital, Apeldoorn, Twenteborg Hospital, Almelo (N = 83) **Inclusion criteria** • 18 years of age and older • Predominance of leg pain over low back pain as measured by VAS • Lumbosacral pain lasting > 6 months • ≥ 75% relief of leg pain from 20 minutes after injection to ≥ 1 hour, and if blocks of adjacent nerves did not provide relief **Exclusion criteria** • Previous RF treatment • Presence of disorders needing low back surgery • Pregnancy • Coagulation disorders • Malignant disease • Language barrier • Mental handicap • Allergy to radiopaque contrast or local anaesthetics • Presence of neuropathic sensory or motor deficit • Non-segmental pattern of irradiation leg pain
Interventions	**Experiment group** • RF lesioning of dorsal root ganglion at 67°C for 90S (N = 45) **Control group** • Electrodes and thermocouple probes positioned similarly but without RF current (N = 38)
Outcomes	No significant changes between groups in pain intensity, global subjective efficacy or any SF-36 scale • Pain intensity: change in VAS score at 3 months: -0.6 (E), -1.1 (C)

Geurts 2003 *(Continued)*

	• Global improvement: > 50% pain relief on GSER for back pain: 21% (E), 17% (C)
Notes	Dropouts: 3 (4%)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants randomly allocated by 4 batches of sealed envelopes
Allocation concealment (selection bias)	Low risk	Envelope drawn at random by an independent investigator
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants masked to allocation
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Treating doctor masked to allocation
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Clinical outcomes calculated by independent masked doctor
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Dropouts: 3
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	High risk	Analyses for secondary outcomes (including pain intensity, physical activity, use of analgesics and quality of life) per protocol
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Similar during 3 months of follow-up

Kapural 2013

Methods	RCT
Participants	Department of Pain Management at Cleveland Clinic, Cleveland, Ohio, USA

Kapural 2013 *(Continued)*

	Center for Clinical Research at Carolina's Pain Institute, Winston-Salem, North Carolina, USA **Inclusion criteria** • ≥ 18 years of age • History of chronic low back pain unresponsive to non-operative care (including physical therapy and anti-inflammatory medication) > 6 months • No surgical intervention within previous 3 months • Back pain greater than leg pain, which is commonly exacerbated by sitting • Pain reproduced on provocative discography (completed within 12 months before enrolment) in degenerated disc • Suspected pain generator disc but no control discs • Disc height ≥ 50% of adjacent control disc • Evidence of single-level degenerative disc disease or 2-level disease with no evidence of additional degenerative changes in other disc spaces on magnetic resonance imaging (MRI) (completed within 12 months of enrolment) **Exclusion criteria** • Prior lumbar surgery of any kind; nucleus pulposus herniation, disc bulges > 5 mm, presence of free disc fragments or > 2 discs degenerated on MRI • Evidence of structural abnormality at symptomatic level, such as spondylolisthesis • Evidence of compressive radiculopathy with predominant leg pain • Presence of concordant cervical or thoracic pain • Symptoms or signs of lumbar canal stenosis • Chronic severe conditions such as rheumatoid arthritis and fibromyalgia • Immunosuppression (e.g. AIDS, cancer, diabetes, other surgery within past 3 months) • History of coagulopathy or unexplained bleeding • Progressive neurological deficits • Traumatic spinal fracture • Pending workers' compensation claims • Litigation or disability income remuneration • Psychological issues by exam or history • Beck Depression Inventory > 20 • Pregnancy • Systemic infection or localised infection at anticipated entry needle site • Allergies to contrast media or to any medication to be used in the procedure • History of opioid abuse • Smoking • Body mass index (BMI) > 30 kg/m^2 • Participant unwilling to consent to the study • Participation in another investigation within 30 days of signing informed consent
Interventions	**Experiment group** • In 13 participants, RF energy was delivered at 45°C in bipolar configuration for 15 minutes; in 16 participants, RF energy was delivered at 50°C in bipolar configuration for 15 minutes followed by monopolar lesioning around each electrode at 60°C for 2:30 minutes (N = 32) **Control group** • Sham procedures mimicked active treatment procedures, except that introducers and electrodes were positioned just outside the disc, and no RF energy was delivered through electrodes. Thus, sham participants were provided tactile, auditory and visual experiences similar to those given to treatment participants, without receiving active RF treatment (N = 32)
Outcomes	• Pain intensity: change in NRS scores at 1 month: -1.79 (E), -1.47 (C). Not significant

Kapural 2013 *(Continued)*

- Pain intensity: change in NRS scores at 3 months: -2.19 (E), -1.20 (C). Not significant
- Pain intensity: change in NRS scores at 6 months: -2.19 (E), -0.64 (C). Significant
- General health: change in SF-36 scores at 1 month: 2.99 (E), 0.58 (C). Not significant
- General health: change in SF-36 scores at 3 months: 10.14 (E), 1.97 (C). Not significant
- General health: change in SF-36 scores at 6 months: 15.00 (E), 2.63 (C). Significant
- Function: change in ODI scores at 1 month: 0.48 (E), -1.09. Not significant
- Function: change in ODI scores at 3 months: -2.94 (E), -0.50. Not significant
- Function: change in ODI scores at 6 months: -7.43 (E), 0.53. Significant

Notes	Dropouts: 3 (5%) Exclusions before treatment: 5 Breach of eligibility criteria: 1 Participants chose not to receive active treatment: 3

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated codes maintained in sequentially numbered opaque envelopes
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Equipment in fluoroscopy suite arranged such that the participant was visually isolated from RF generator
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Randomisation code revealed to treating physician and nurse operating the generator, who was in control of RF delivery to participant
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Instruments completed by blinded participants in both groups at baseline, on the day of the procedure before treatment was given, and at 1 month, 3 months and 6 months post procedure
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	2 dropouts from 29 participants in experiment group
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	All participants incorporated into the analysis
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text

Kapural 2013 *(Continued)*

Compliance acceptable?	Low risk	Irrelevant: single intervention
Timing of outcome assessments similar?	Low risk	1, 3 and 6 months post procedure

Kroll 2008

Methods	RCT
Participants	Henry Ford Hospital IRB, Detroit, Michigan, USA (N = 26) **Inclusion criteria** • 18 years of age and older • ASA physical status I, II and III • Unilateral or bilateral lumbar back pain for longer than 1 month • No radiating symptoms below the knee • > 50% pain reduction based on mean VAS after 2 separate diagnostic medial branch blocks with 1.0 mL of 0.5% bupivacaine **Exclusion criteria** • History of previous back surgery • Presence of neurological deficits • Claudication • Active psychiatric disorder • Bleeding disorder • Involved in current litigation • Ongoing workers' compensation claims • Disc herniation and spinal stenosis (ruled out radiographically)
Interventions	**Continuous RF group** • Continuous RF thermocoagulation lesioning performed at 80°C for 75S (N = 13) **Pulsed RF group** • Pulsed RF lesioning at 42°C with pulse duration of 20 ms and pulse rate of 2 Hz for 120S (N = 13)
Outcomes	No significant differences between groups at 3 months after treatment for pain (zero to 100) and function • Pain intensity: change in VAS score at 3 months: -24.3 (CRF) and -11.3 (PRF) • Function: change in ODI score at 3 months: -10.3 (CRF), -2.7 (PRF)
Notes	Dropouts: 24 (48%)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation via random numbers generator

Kroll 2008 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Unclear risk	Unclear whether difference between CRF and PRF could be noticed by participants
Blinding (performance bias and detection bias) All outcomes - providers?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	High risk	Dropouts: 24 (48%)
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	High risk	No ITT analysis. Only 26 of 50 participants completed follow-up evaluation; their data were analysed
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Unclear risk	Baseline characteristics recorded for only 26 of 50 participants who completed follow-up evaluation
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Three months after treatment, VAS and Oswestry scores were measured

Kvarstein 2009

Methods	RCT
Participants	Pain Clinic, The Interventional Centre at Oslo University Hospital, Rikshopitalet (N = 20) **Inclusion criteria** • 20 to 65 years of age • Unremitting low back pain for longer than 6 months • Pain intensity ≥ 5 of maximum 10 (NRS) and low back pain > leg pain • Exacerbated by sitting and relieved by lying • No neurological deficits and negative straight raised leg test • No previous surgical interventions • Failure to improve with conservative treatment • Signs of disc degeneration (MRI scan) or posterior annular tear (CT scan)

Kvarstein 2009 *(Continued)*

- Disc height reduction < 30% and disc protrusion < 4 mm
- Positive 1-level pain provocation discography after 3-level pressure-controlled provocation discography

Exclusion criteria

- Acute infection
- History of drug abuse
- Psychological or cognitive disturbances or somatic disorder that could affect outcome
- Previous lumbar spine surgery
- Abnormal neurological examination
- Radicular pain by history or examination
- Structural spinal deformity or vertebral canal stenosis
- Intervertebral disc herniation equivalent to or > 4 mm or sequestered intervertebral disc herniation
- Pregnancy
- Allergy to contrast media or to drugs to be used in the procedure

Interventions	**Experiment group** • Incremental heating, starting at 50°C, increasing by 5°C every second minute and ending with a 4-mm interval at 65°C (N = 10) **Control group** • Similar intervention, but annulus was not exposed to RF heating (N = 10)
Outcomes	No significant changes in pain and function between groups after 6 months and 12 months • Average pain intensity: change in NRS score at 6 months: -0.9 (E), -0.2 (C) • Average pain intensity: change in NRS score at 12 months: -1.4 (E), -0.6 (C) • Function: change in ODI score at 6 months: -6.4 (E), -2.2 (C) • Function: change in ODI score at 12 months: -11.6 (E), -0.4 (C)
Notes	No dropouts

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Gender-stratified blocks of 8 by use of random numbers
Allocation concealment (selection bias)	Low risk	Block size and randomisation codes not revealed until all measurements had been entered into database after 12-month observation
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants blinded by shutting off sound from the RF generator; blinding tested at 12-month follow-up
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Operator not present during RF treatment procedure
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participants reported outcome measures and independent assessor not present during RF treatment procedure

Kvarstein 2009 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	No dropouts
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Primary endpoint, pain intensity, subjected to both intention-to-treat and per-protocol analyses
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. All primary outcomes presented are similar for baseline
Co-interventions avoided or similar?	Low risk	Two participants did not respond to all questionnaires; no additional co-interventions
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Baseline, 6 months and 12 months

Lakemeier 2013

Methods	RCT
Participants	Department of Orthopedics, University Hospital Goettingen, Goettingen, Germany (N = 56) **Inclusion criteria** • Lumbar facet joint-related low back pain for ≥ 24 months • 18 years of age and older • Ability to understand study protocol, to provide voluntary written informed consent and to participate in outcome measurements • Benefit in pain reduction ≥ 50% after test injection of local anaesthetics into L3/L4–L5/S1 LFJs • MRI-proven LFJ osteoarthritis and hypertrophy in L3/L4–L5/S1 segments **Exclusion criteria** • Lack of positive response to L3/L4–L5/S1 test infiltration • History of osteoporosis or malignancy • Allergy to local anaesthetic • Pregnancy or lactation • Lumbar spinal stenosis or spinal instability • Vertebral fracture • Symptomatic radiculopathy • Uncontrolled psychiatric disorder • Uncontrolled medical illness • Condition that could interfere with interpretation of outcome assessments • History of adverse reactions to corticosteroids
Interventions	**Experiment group** • RF was performed according to International Spine Intervention Society practice standards

Lakemeier 2013 *(Continued)*

	• RF probe then was reinserted into cannula and lesion at 80°C for 90 seconds using an RF generator (N = 29) **Control group** • Intra-articular injection of steroids was performed • Same setting was used for LFJ infiltrations and RF denervation • RF probe was then reinserted into cannula and denervation process (80°C for 90 seconds) was begun, but electrodes were not connected to pain generator device (N = 27)
Outcomes	• Pain intensity: change in VAS scores at 6 months: -1.6 (E), -1.9 (C). Not significant • Pain intensity: change in RMQ scores at 6 months: -4.2 (E) -3.7 (C). Not significant • Pain intensity: change in ODI scores at 6 months: -5.7 (E), -12.8 (C). Not significant
Notes	Dropouts: 4 (7%)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Concealed randomisation performed through independent institution after participants gave informed consent. Assignments performed using computer-generated random allocation sequence with permuted blocks, 4 and 6 in size
Allocation concealment (selection bias)	Low risk	Concealed randomisation performed through independent institution after participants gave informed consent. Assignments performed using computer-generated random allocation sequence with permuted blocks, 4 and 6 in size
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants unblinded after 6-month follow-up examination, or if requested before that time
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	In both groups, all procedures performed by the same experienced spine surgeon. Only unblinded treatment personnel in this study were primary spine surgeon and study nurse assistant. Neither primary spine surgeon nor study nurse assistant were involved in further treatment of participants
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participants unblinded after 6-month follow-up examination, or if requested before that time
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	4 dropouts among 56 participants
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Citate: For all analyses, intention-to-treat principles were used
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables

Lakemeier 2013 *(Continued)*

Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single intervention
Timing of outcome assessments similar?	Low risk	All outcomes measured at baseline and at 6 months

Leclaire 2001

Methods	RCT
Participants	Center Hospitalier de l'Universite de Montreal, Hopital Notre-Dame (N = 70) **Inclusion criteria** • 18 to 65 years of age • Significant relief of low back pain for ≥ 24 hours during week after intra-articular facet injections under fluoroscopy using Omnipaque **Exclusion criteria** • Allergy to local anaesthetic • Blood coagulation disorder • Cardiac pacemaker • Sciatic pain with neurological deficit • Low back pain not related to mechanical disorder • Low back surgery • Concomitant medical illness likely to compromise ability to participate
Interventions	**Experiment group** • RF facet joint denervation at minimum of 2 levels to medial branch of distal portion of spinal posterior rami nerve at 80°C for 90 seconds (N = 36) **Control group** • Same procedure as in experiment group, except that temperature of electrode tip was not raised but was maintained at 37°C (N = 34)
Outcomes	Significant differences were found in RMQ between groups 12 weeks after treatment. No significant differences in VAS (0 to 100) and ODI scores were found • Pain intensity: change in VAS score at 4 weeks: -3.6 (E), -0.6 (C) • Pain intensity: change in VAS score at 12 weeks: -0.5 (E), -7.2 (C) • Function: change in ODI score at 4 weeks: -2.7 (E), -2.1 (C) • Function: change in ODI score at 12 weeks: -4.7 (E), -2.7 (C)
Notes	Dropouts: 4 (6%)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation performed in blocks of 4 by opaque prenumbered envelopes

Leclaire 2001 *(Continued)*

Allocation concealment (selection bias)	Low risk	Envelopes containing participant assignments given to physician who performed the technique
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants kept blind to treatment group
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Participants kept blind to treatment group
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Dropouts: 4 (6%)
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Primary analysis based on intention-to-treat principle
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	No meaningful differences at baseline
Co-interventions avoided or similar?	Low risk	Analysis of co-interventions showed no significant differences between the 2 groups
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Baseline, 4 weeks and 12 weeks

Lin Mu-Lien 2010

Methods	RCT (unclear description of randomisation)
Participants	National Taiwan University, Taipei City, Taiwan (N = 100) **Inclusion criteria** • Chronic low back pain ≥ 6 months • With or without radiation pain **Exclusion criteria** • Congenital deformities, tumours of infection
Interventions	**Pulsed RF group** • Pulsed RF therapy on dorsal root ganglion for 120S (N = 29)

Lin Mu-Lien 2010 *(Continued)*

	Electro-acupuncture group • Electro-acupuncture therapy with low pulse frequency 15 Hz for duration of 30 minutes 3 times a week, continuing for 4 weeks (N = 36) **Control group** • Conservation treatment with medication and no stimulation (N = 36)
Outcomes	• Pain intensity: change in VAS score at 4 weeks: -2.56 (PRF), -0.85 (EA), -0.01 (C) • Function: change in ODI score at 4 weeks: -1.4 PRF, -3.0 (EA), -0.02 (C) • Results unclearly described
Notes	Dropouts: unknown

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	No mention of randomisation methods
Allocation concealment (selection bias)	Unclear risk	No mention of allocation concealment
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	Treatment methods and frequency of treatment procedures different
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Treatment methods and frequency of treatment procedures different
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participants not blinded and participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	High risk	Baseline characteristics differed statistically for both ODI and VAS scores
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Unclear risk	No data on dropouts, short 1-month follow-up

Lin Mu-Lien 2010 *(Continued)*

Timing of outcome assessments similar?	Low risk	Status measured 1 month after follow-up

Moon 2013

Methods	RCT
Participants	Department of Anesthesiology and Pain Medicine, Seoul National University Hospital, Seoul National University College of Medicine, Seoul, Republic of Korea (N = 81) **Inclusion criteria** • >18 years of age • Predominantly axial low back pain for ≥ 3 months • Paraspinal tenderness overlying L2 to L4 lumbar facet joints • Failure to respond to conservative therapy such as physical therapy or pharmacotherapy • Concordant pain relief > 50% after comparative local anaesthetic block with 0.5 mL lidocaine 1% (≥ 1 hour) and levo-bupivacaine hydrochloride (Chirocaine®, Abbott Korea, Seoul, South Korea) 0.5% (≥ 3 hours) at L1 to L4 medial branches **Exclusion criteria** • Any focal neurological signs or symptoms • Radiological evidence of symptomatic herniated disc • Severe spinal stenosis or structural lumbar spinal deformity • Positive response to previous spinal interventions such as sacroiliac joint block or epidural steroid injection • Discogenic pain verified by discography • Lumbar spine fusion • Untreated coagulopathy • Concomitant medical or psychiatric condition likely to undermine diagnostic workup or assessment of treatment response
Interventions	**Experiment group (distal approach)** • Fluoroscopic distal approach was used for L1 to L4 medial branches in distal approach group (N = 41) **Control group (tunnel vision approach)** • LMBRFD was performed under fluoroscopic guidance in an oblique 'tunnelled' view, as described by Bogduk (Bogduk 2005) (N = 41)
Outcomes	• Pain intensity: change in NRS score at 1 month: -2.4 (distal approach), -1.9 (tunnel vision approach). Not significant • Pain intensity: change in NRS score at 6 months: -1.9 (distal approach), -2.0 (tunnel vision approach). Not significant • Function: change in ODI score at 1 month: -7.3 (distal approach), -5.8 (tunnel vision approach). Not significant • Function: change in ODI score at 6 months: -6.8 (distal approach), -6.0 (tunnel vision approach). Not significant
Notes	Dropouts: 11 (13%)
Risk of bias	

Moon 2013 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants randomly allocated using envelope method
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	Citation from discussion: '*Our investigation could be critiqued for the absence of a control group, lack of blinding and crossover design*'
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Citation from discussion: '*Our investigation could be critiqued for the absence of a control group, lack of blinding and crossover design*'
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Citation from discussion: '*Our investigation could be critiqued for the absence of a control group, lack of blinding and crossover design*'
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	68 of 82 participants with complete follow-up
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Figure 1. All participants analysed by group
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 2. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single intervention
Timing of outcome assessments similar?	Low risk	NRS and ODI measured at 1 month and 6 months after intervention

Nath 2008

Methods	RCT
Participants	Smartkliniken, Umea, Sweden. Department of Hand Surgery, Orebro University Hospital, Orebro, Sweden (N = 40) **Inclusion criteria** • Adult participants • Continuous low back pain ≥ 2 years • No response to previous treatment

Nath 2008 *(Continued)*

	• ≥ 80% relief of pain following controlled medial branch blocks **Exclusion criteria** • Pregnancy • Coagulopathy • Malignancy • Infection • Mental handicap • Psychiatric disorder • Motor deficit or any other indication for surgical treatment • Live too far away to be able to participate
Interventions	**Experiment group** • RF denervation of lumbar facet joint for 60S at 85°C (N = 20) **Control group** • Identical to experiment group, except no current was used and electrode tip remained at body temperature (N = 20)
Outcomes	Significant changes in generalised pain 6 months after treatment. No significant changes in back pain • Back pain: change in VAS score at 6 months: -2.1 (E), 0.7 (C) • Generalised pain: change in VAS score at 6 months: 1.93 (E), 0.37 (C)
Notes	Dropouts: none

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated randomisation schedules used
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants blinded to their assignment throughout study period
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	RF machine placed behind operator, who was unaware of current level of another operator
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	All outcome measurements performed by same orthopedic surgeon at another institution
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	No dropouts
Incomplete outcome data (attrition bias)	Low risk	Participants analysed by group; no dropouts

Nath 2008 *(Continued)*

All outcomes - ITT analysis?		
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	High risk	Participants in RF treatment group had significantly more generalised pain, low back pain and referred pain to the leg when compared with placebo group. All hip movements were worse in the RF treatment group
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	All participants re-examined after 6 months

Oh 2004

Methods	RCT
Participants	Clinical Pain Research Center, Sumsang Fine Hospital, Seoul, Korea (N = 49) **Inclusion criteria** • Chronic discogenic low back pain > 1 year • History of failed conservative treatment for several months • No significant improvement in pain during 9 months after IDET • > 50% pain relief after diagnostic block of ramus communicans nerve **Exclusion criteria** • Positive response on diagnostic block of medial branch of primary dorsal rami of segmental nerves of L3, L4 and L5 • Verbal decline • Failure to provide written informed consent • Spinal stenosis • Spinal instability • Multi-level disc lesions • Previous spinal surgery • History of excessive bleeding or coagulopathy • Obvious psychological problems
Interventions	**Experiment group** • RF lesioning of ramus communicans nerve for affected disc at 65°C for 60 seconds (N = 26) **Control group** • Injection of 2 mL of preservative-free 1% lidocaine without RF lesioning (N = 23)
Outcomes	Pain intensity: change in VAS score at 4 months: -3.3 (E), -0.7 (C)
Notes	Dropouts: unclear

Oh 2004 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Remained unclear from text
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Control group received lidocaine injection instead of RF thermocoagulation. Impossible to blind
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	All outcome data evaluated 4 months after procedure
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	All outcome data measured at baseline and after 4 months

Patel 2012

Methods	RCT
Participants	Advanced Pain Management, Green Bay, Wisconsin, USA (N = 51) **Inclusion criteria** • Predominantly axial pain below L5 vertebrae • Axial pain lasting longer than 6 months

Patel 2012 *(Continued)*

- Three-day average NRS between 4 and 8
- Older than 18 years of age
- Failure to achieve adequate improvement with comprehensive non-operative treatments, including but not limited to activity alteration, non-steroidal anti-inflammatory drugs, physical and/or manual therapy and fluoroscopically guided injections of steroids into SIJ or sacroiliac ligaments
- Other possible sources of low back pain reasonably excluded (by means of physical exam, medical history and magnetic resonance imaging/computed tomography/X-ray as required), including but not limited to bone fracture, hip joint, symptomatic spondylolisthesis, tumour and other regional soft tissue structures

Exclusion criteria

- Beck Depression Inventory score > 20
- Irreversible psychological barriers to recovery
- Spinal pathology that may impede recovery, such as spondylolisthesis at L5/S1, or scoliosis; symptomatic moderate or severe foraminal or central canal stenosis
- Systemic infection or localised infection at anticipated introducer entry site
- Concomitant cervical or thoracic pain > 2/10 on an NRS scale
- Uncontrolled or acute illness
- Chronic severe conditions such as rheumatoid/inflammatory arthritis
- Pregnancy
- Active radicular pain
- Immunosuppression (e.g. AIDS, cancer, diabetes, surgery < 3 months before); workers' compensation, injury litigation or disability remuneration
- Allergy to injectate or medications used during procedure
- High narcotics usage (> 30 mg morphine daily or equivalent)
- Active smokers (termination ≥ 6 months with no smoking during follow-up period acceptable with caution)
- Participant unwillingness to consent to the study

Interventions	**Experiment group** • L5 dorsal ramus RF energy applied for 150 seconds at set temperature of 60°C using pain management RF generator • After coagulation of L5 dorsal ramus, sacral lateral branches of S1, S2 and S3 were targeted. RF energy was delivered for 150 seconds at set temperature of 60°C (N = 34) **Control group** • Same procedure as in experimental group, except that RF energy was not delivered. Probe placements, procedure duration, equipment sounds and visual indications for participants were identical in both groups (N = 17)
Outcomes	Pain intensity: change in NRS score at 1 month: -2.7 (E), -1.7 (C). Not significant Pain intensity: change in NRS score at 3 months: -2.4 (E), -0.8 (C). Significant Function: change in ODI score at 1 month: -12 (E), -4 (C). Significant Function: change in ODI score at 3 months: -11 (E), 2 (C). Significant
Notes	Dropouts: 9 (17.6%)

Risk of bias

Bias	Authors' judgement	Support for judgement

Patel 2012 *(Continued)*

Random sequence generation (selection bias)	Low risk	Participants randomly assigned on a 2:1 basis to treatment group or sham group using presealed envelopes
Allocation concealment (selection bias)	Low risk	Presealed envelopes given by a nurse not involved in the study
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participant remained visually isolated from equipment and was exposed to typical equipment noises regardless of treatment group
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Physician blinding not possible
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Both assessors and participants blinded to randomisation at 1-month and 3-month follow-up time points
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Dropouts: 9 out of 51
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Figure 1. All patients included in analysis
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Unclear risk	Remained unclear from text
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	All outcomes after 1, 3 and 6 months (cross-over after 3 months)

Sanders 1999

Methods	RCT
Participants	Spaarne Hospital, Haarlem, The Netherlands (N = 34) **Inclusion criteria** • Low back pain > 6 months • Pain exacerbated by extension of lumbar spine, prolonged standing or sitting • Deep pressure pain over lumbar facet joints and absence of neurological abnormalities • No improvement from physical therapy • Pain intensity on VAS > 4

Sanders 1999 *(Continued)*

	Exclusion criteria • Radicular pain (neurological signs of nerve root compression) • Previous back operation(s) • Younger than 18 years • Bleeding disorders • Presence of prominent functional or non-physiological signs
Interventions	**Experimental group** • Percutaneous intra-articular facet denervation. Technique of PIFD is analogue to diagnostic procedure: 20-gauge disposable needle of 100 mm length with 5 mm active tip was guided into the centre of the articular cavity of the facet joint. Lateral fluoroscopy ensured proper location of the needle tip, avoiding the vicinity of the intervertebral foramen. Electrical stimulation was performed using a 50 Hz current. Localisation was considered to be correct if a sensory response was found at a threshold < 1 V. After injection of 1 mL lidocaine 2%, 3 RF lesions (60 s, 22 V) were made in the articular cavity and central, rostral and caudal of facet joint (N = 17) **Control group** • Participants in group B received percutaneous extra-articular facet denervation according to the method described by Mehta and Sluijter (N = 17)
Outcomes	Pain intensity: change in VAS score at 3 months: -4.7 (intra-articular), -2.1 (extra-articular). Significant
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Remained unclear from text
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - providers?	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Remained unclear from text
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text

Sanders 1999 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Tables 1, 2 and 3. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single intervention
Timing of outcome assessments similar?	Low risk	Before and 3 months after procured participants were evaluated

Shanthanna 2014

Methods	RCT
Participants	St Joseph's Healthcare Hamilton, Ontario, Canada (N = 31) **Inclusion criteria** • 18 years or older • History of chronic lumbar radicular pain ≥ 4 months • Average pain score of 5 on VAS of 0 to 10 • Failure of conservative therapy (e.g. physiotherapy, medication trial) **Exclusion criteria** • Patient refusal to participate • Any contraindication to neuraxial injections • History of predominant back pain over leg pain • Significant anatomical deformity (congenital or acquired), making it difficult to access the foramen as evidenced by computed tomography/magnetic resonance imaging • Severe psychiatric illness • Presence of cancer accounting for back pain • Inability to communicate in English • Allergy to local anaesthetics or contrast medium • History of motor findings in affected leg
Interventions	**Experiment group** • Study group participants had PRF treatment at 42°C for 120 seconds to dorsal root ganglion (N = 16) **Control group** • Participants in control group had low-intensity (0.2 V) sensory stimulation (50 Hz) with no active treatment for the same duration (N = 15)
Outcomes	PRF group achieved 32% (5 out of 16 participants) more than 50% decrease in VAS score (0 to 10) compared with 25% more (3 out of 15 participants) in placebo group
Notes	Dropouts: 2 (6%)
Risk of bias	

Shanthanna 2014 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Allocation was given to the assistant in a sealed opaque envelope to be handed over to the nurse operating the RF machine
Allocation concealment (selection bias)	Low risk	Enrolled participants were randomly assigned on the day of the study intervention at a central location by a single research person, who was not involved in any other part of the study
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants in control group had low-intensity sensory stimulation, with no active treatment for the same duration. This was done to ensure participant blinding
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Allocation was given to the assistant in a sealed opaque envelope to be handed over to the nurse operating the RF machine All other operating room personnel, including the physician performing the intervention and the participant, were blinded to randomisation and treatment
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Assessor (blinded to randomisation code) met with all participants in recovery
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Dropouts: 2 of 31 participants
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	As the study was analysed using the intention-to-treat principle, missing outcomes were imputed using 'multiple imputation'
Selective reporting (reporting bias)	Low risk	Protocol showed same outcomes
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single intervention
Timing of outcome assessments similar?	Low risk	1 month and 3 months of follow-up

Simopoulos 2008

Methods	RCT
Participants	Beth Israel Deaconess Medical Center, Arnold Pain Management Center, Brookline, Massachusetts, USA (N = 76) **Inclusion criteria** • > 6-month history of segmental pain of lumbar or sacral origin radiating from the back into the foot

Simopoulos 2008 *(Continued)*

- > 18 years of age
- Unsatisfactory pain control with oral pharmacotherapy and physical therapy
- Absence of chronic or progressive motor deficit or sensory deficit
- No indication for percutaneous or open surgical intervention
- Magnetic resonance imaging evidence of nerve root involvement
- Response to epidurally administered depo-steroid ≤ 1 month
- Complete relief of radicular symptoms following low-volume segmental nerve block
- Informed consent

Exclusion criteria

- Evidence of significant neurological deficit
- Hypersensitivity to injected materials: local anaesthetics, contras, depo-corticosteroids
- Coagulopathy
- Significant psychopathology
- Pending workmans' compensation claims
- Pregnancy
- Language barrier

Interventions	**Experiment group 1** • Pulsed radiofrequency lesion at 42°C for 120 seconds (N = 37) **Experiment group 2** • Identical pulsed radiofrequency lesion protocol; upon completion of pulsed radiofrequency lesion, participants received continuous radiofrequency lesion to maximum tolerated temperature that created a burning sensation from the low back to the foot. Temperature averaged at 54°C for 60 seconds (N = 39)
Outcomes	No significant difference in VAS change between the 2 groups • Pain intensity: change in VAS score at 2 months: -4.3 (PRF), -4.8 (PRF + CRF)
Notes	Dropouts: not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants randomly assigned to 1 of 2 groups
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	High risk	Participants not blinded; treatment 60 or 120 seconds
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Treatment 60 or 120 seconds
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	High risk	Participant reported outcome measures

Simopoulos 2008 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	Dropouts: not reported
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	No meaningful differences at baseline
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Follow-up until 1 year after procedure

Tekin 2007

Methods	RCT
Participants	Celal Bayar University, Manisa, Turkey (N = 60) **Inclusion criteria** • > 17 years of age • Continuous low back pain with or without radiating into upper leg, with focal tenderness over facet joints, pain on hyperextension, no finding of obvious neurological defect, no indication for low back surgery, no radicular syndrome, unresponsiveness to traditional conservative treatments; all > 6 months • > 50% pain relief on VAS to diagnostic medial branch block **Exclusion criteria** • Prior RF treatment • Coagulation disturbances • Allergy to radiopaque contrast media or local anaesthetics • Malignancy • Mental handicap • Psychiatric condition precluding adequate communication • Language problems • Pregnancy
Interventions	**Experiment group 1, CRF** • Continuous radiofrequency lesions to medial branch at 80°C for 90 seconds at level L1 to L3 or L3 to L5 (N = 20) **Experiment group 2, PRF**

Tekin 2007 *(Continued)*

	• Two Hertz PRF waves were applied for 4 minutes (45V) at 42°C (N = 20) **Control group** • Electrodes and thermocouple probes were positioned similarly without switching on RF current; only bupivacaine 0.5% 0.3 mL was injected (N = 20)

Outcomes	• Significant changes in VAS (0 to 10) and ODI scores between PRF and CRF groups compared with control group post procedure and between CRF and control groups after 6 months. At 1 year, VAS scores in CRF groups were lower than those in PRF and control groups. ODI scores were lower for both RF groups at 1 year than for control group
	• Participant satisfaction was lower in the control group than in the other groups, and was highest in the CRF group
	  • Pain intensity: change in VAS score post procedure: -3.8 (PRF), -4.2 (CRF), -2.5 (C)
	  • Pain intensity: change in VAS score at 6 months: -3.7 (PRF), -4.2 (CRF), -3.7 (C)
	  • Pain intensity: change in VAS score at 12 months: -3.1 (PRF), -4.1 (CRF), -2.9 (C)
	  • Function: change in ODI score post procedure: -15 (PRF), -13.6 (CRF), -9.6 (C)
	  • Function: change in ODI score at 6 months: -14.1 (PRF), -14.1 (CRF), -11.2 (C)
	  • Function: ODI score at 12 months: -10.9 (PRF), -11.2 (CRF), -6.5 (C)

Notes	Dropouts: unclear

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Subsequent randomisation into 3 groups performed by random number generation, with balance after every 8 participants
Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants not able to state which treatment they were receiving
Blinding (performance bias and detection bias) All outcomes - providers?	High risk	Providers not blinded
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participant reported outcomes measured and the latest outcome data evaluated by an independent observer
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Unclear risk	It is expected to be unlikely that all participants completed follow-up
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	Participants analysed by group; no dropouts
Selective reporting (reporting bias)	Unclear risk	No protocol available

Tekin 2007 *(Continued)*

Baseline characteristics similar?	Low risk	No meaningful differences at baseline
Co-interventions avoided or similar?	High risk	Number of participants using analgesics higher in control group than in PRF group
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Follow-up immediately after procedure, at 6 months and at 1 year

Van Kleef 1999

Methods	RCT
Participants	Pain Management and Research Centre, University Hospital Maastricht, The Netherlands (N = 31) **Inclusion criteria** • 20 to 60 years of age • Chronic non-specific low-back pain > 12 months • Initial mean VAS score > 4 or VAS high score > 7 • No satisfactory pain relief from conservative therapy • Absence of neurological deficits identified by routine neurological examination • > 50% pain relief after diagnostic dorsal ramus nerve block with local anaesthetic solution **Exclusion criteria** • Previous back surgery • Known specific cause of low back pain • Diabetes mellitus • > 1 pain syndrome
Interventions	**Experiment group** • 60-Second RF lesion at 80°C for medial branch of posterior primary ramus of segmental nerves L3-L5 on 1 side or on both sides (N = 15) **Control group** • Identical procedure as in the experiment group but without RF current (N = 16)
Outcomes	Significant differences in mean VAS score and ODI at 8 weeks • Pain intensity: mean change in VAS score at 8 weeks: -2.37 (E), -0.43 (C) • Function: change in ODI score: -11.07 (E), -1.69 (C)
Notes	Dropouts: 1 (3%)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation with the help of a computer programme in blocks of 2

Van Kleef 1999 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	Remained unclear from text
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	Participants not aware of the type of treatment received
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	Treating physician left the operating room after inserting electrodes and injecting local anaesthetic solution
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	Only 1 randomly assigned participant was excluded from analyses
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Unclear risk	Remained unclear from text
Selective reporting (reporting bias)	Unclear risk	No protocol available
Baseline characteristics similar?	Low risk	Table 1. Groups comparable on relevant demographic and clinical variables
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Unclear risk	Remained unclear from text

Van Wijk 2005

Methods	RCT
Participants	University Medical Center, Utrecht; Rijnstate Hospital, Arnhem, Juliana Hospital, Apeldoorn, Twenteborgh Hospital, Almelo; The Netherlands (N = 81) **Inclusion criteria** • > 17 years of age • Continuous low back pain with or without radiating pain into upper leg for longer than 6 months with focal tenderness of facet joints • No radicular syndrome • No indication for low back surgery • > 50% pain reduction on standard VAS applied 30 minutes after diagnostic block of lumbar facet joints **Exclusion criteria**

Van Wijk 2005 *(Continued)*

- Prior RF treatment
- Coagulation disturbances
- Allergy to radiopaque contrast or local anaesthetics
- Malignancy
- Mental handicap or psychiatric condition precluding adequate communication
- Language problems
- Pregnancy

Interventions	**Experiment group** • 60-Second RF lesion at 80°C of dorsal ramus medial branches of relevant facet joints (N = 40) **Control group** • Identical procedure as in experiment group, without switching on RF current (N = 41)
Outcomes	No significant differences in combined outcome measures, and between changes in VAS back, changes in daily physical activities and use of analgesics. Significant difference in GPE favoured RF treatment 3 months after treatment Pain intensity: change in VAS back score at 3 months: -2.1 (E), -1.6 (C)
Notes	No dropouts

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation performed independently and in a separate setting
Allocation concealment (selection bias)	Low risk	Envelope drawn at random from appropriate set of envelopes and opened by an independent physician, who instructed RF generator setup by a technician
Blinding (performance bias and detection bias) All outcomes - patients?	Low risk	RF generator display turned away from operating table, participant and treating physician could not be informed on the nature of the procedure
Blinding (performance bias and detection bias) All outcomes - providers?	Low risk	RF generator display turned away from operating table, participant and treating physician could not be informed on the nature of the procedure
Blinding (performance bias and detection bias) All outcomes - outcome assessors?	Low risk	Participant reported outcome measures
Incomplete outcome data (attrition bias) All outcomes - drop-outs?	Low risk	After randomisation and before 3-month follow-up, no dropouts occurred
Incomplete outcome data (attrition bias) All outcomes - ITT analysis?	Low risk	No description of ITT analysis but no indication of cross-overs
Selective reporting (reporting bias)	Unclear risk	No protocol available

Van Wijk 2005 *(Continued)*

Baseline characteristics similar?	Low risk	Participant characteristics and baseline values showed adequate matching between groups
Co-interventions avoided or similar?	Unclear risk	Remained unclear from text
Compliance acceptable?	Low risk	Irrelevant: single-session intervention
Timing of outcome assessments similar?	Low risk	Outcomes measured at 0, 3, 6, 9 and 12 months

Abbrevations: AIDS= acquired immunodeficiency syndrome; ASA= American Society of Anesthesiologists; C= control; CRF= continuous radiofrequency; CT= computed tomography; E= experiment; GPE= global perceived effect; GSER= global subjective efficacy rating; ITT= intention to treat; LFJ= lumbar facet joints; LBMRFD= lumbar medial branch radiofrequency denervation; MRI= magnetic resonance imaging; NRS= numerical rating scale; ODI= Oswestry disability index; PRF= pulsed radiofrequency; RCT= randomised controlled trial; RF= radiofrequency; RFA= radiofrequency ablation; RMQ= Roland Morris Questionnaire; SF-36= Short Form 36; VAS= visual analogue scale

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Buijs 2004	Compares temperature-controlled vs voltage-controlled mode - not effectiveness of RF denervation
Cohen 2010	Compares diagnostic block treatment paradigms - not effectiveness of RF denervation
Dobrogowski 2005	No control group for RF neurotomy procedure
Fukui 2012	No RCT
Gautam 2011	RF used as additional therapy
Gross 2010	No full-text article of the study
Proschek 2010	No RCT, no control group
Reverberi 2005	No RCT

Abbrevations: RCT= randomised controlled trial; RF= radiofrequency;

Characteristics of studies awaiting assessment *[ordered by study ID]*

Hashemi 2014

Methods	Randomised controlled trial
Participants	**Inclusion criteria** • Spondylolisthesis grade I in MRI at 1 single level • Chronic low back pain > 6 months • Supravertebral facet tenderness • Pain in hyperextension • Minimum NRS score of 4 • Positive diagnostic medial branch block test

Hashemi 2014 *(Continued)*

	Exclusion criteria • Radicular pain • Neurological deficit • Indication for surgery • Stenosis of spinal canal • Spondylolysis • Positive straight leg raising test • Suppressed reflex • Known psychiatric disease • Spinal deformity • Neoplastic or infectious disease
Interventions	Group 1: pulsed RF using a 22 G cannula SMK C10 with method described by van Kleef et al applied for a duration of 120 s with 45 V with silent time 480 ms Group 2: steroid injections (1 mL (40 mg) triamcinolone) and 0.5 mL bupivacaine 0.5%
Outcomes	Primary outcome: decrease in NRS score > 50% and pain relief defined as up to 6 months Secondary outcome: improvement in functional status (ODI)
Notes	

Characteristics of ongoing studies *[ordered by study ID]*

Albareeq 2015

Trial name or title	Radiofrequency in sacroiliac arthropathy; bipolar RF 6 points vs monopolar RF at 6 and 3 points (RFSIBIMONO6)
Methods	Prospective, single-centre, double-blind, controlled randomised trial
Participants	**Inclusion criteria** • Moderate to severe low back pain > 6 months with positive Patrick's and Yeoman's tests and tenderness over SI joint • Pain not responding to usual medical treatment • > 50% pain relief after diagnostic injection with local anaesthetic Exclusion criteria • Patient refusal to do the procedure or to share in the study • Focal neurological signs • Significant anticoagulation, e.g. clopidogrel (low-dose aspirin excluded) • Pregnancy, breast feeding or planning on becoming pregnant during trial • Infection at intended injection site
Interventions	• Group 1: Six RF needles will be put between SIJ and lateral aspects of ipsilateral dorsal sacral foramina. After sensory and motor stimulation, bipolar lesion RF at 80°C for 90 seconds will be applied between successive pairs of needles • Group 2: RF needle will be inserted at 6 levels in the area between SI joint and lateral aspects of ipsilateral dorsal sacral foramina. After sensory and motor stimulation, monopolar lesion RF at 80°C will be applied for 90 seconds

Albareeq 2015 *(Continued)*

	• Group 3: RF needle will be inserted at 6 levels in the upper, middle and lower parts of the area between the SIJ and lateral aspects of ipsilateral dorsal sacral foramina. After sensory and motor stimulation, monopolar lesion RF will be applied at 80°C for 90 seconds
Outcomes	Visual analogue pain scale after 2 weeks, 1 month, 3 months and 6 months
Starting date	September 2014
Contact information	ClinicalTrials.gov identifier: NCT02382289
Notes	

Dolin 2010

Trial name or title	Double-blind, randomised, controlled, cross-over trial of RF annuloplasty for treatment of low back pain
Methods	Double-blind, randomised, controlled, cross-over trial
Participants	**Inclusion criteria** • 16 to 70 years of age at first assessment • Moderate/severe discogenic pain • Oswestry Disability Index 20% + • Failed 6 months of conservative treatment • No previous disc surgery at symptomatic levels; body mass index (BMI) average or overweight range • Loss of disc height not > 50% of normal level on MRI or X-ray • Maximum 2-level pathology on MRI scan confirmed by discography
Interventions	Experimental group: RF annuloplasty Placebo group: same protocol but no lesioning performed - RF generator on test mode
Outcomes	Not provided at time of registration
Starting date	March 2002
Contact information	Dr Simon Dolin, Pain Service, St Richards Hospital, Spitalfield Lane, Chichester, PO19 4SE, United Kingdom
Notes	

Maas 2012

Trial name or title	Minimal interventional procedures for chronic mechanical low back pain patients
Methods	Three randomised, controlled trials with an economic evaluation
Participants	**Inclusion criteria** • Chronic mechanical low back pain • 18 to 70 years of age

Maas 2012 *(Continued)*

	• No improvement in conservative treatment • No severe psychiatric or psychological problems • No pregnancy • No disturbed coagulation • Positive diagnostic block (> 50% pain reduction or positive discography)
Interventions	Experimental group: RF therapy and 3-month physiotherapy programme Control group: 3-month physiotherapy programme
Outcomes	Pain intensity, global perceived effect, functional status, general health, participant satisfaction, pain experience, costs
Starting date	Start inclusion January 2013
Contact information	Dutch Trial Register number: NTR3531
Notes	

Meckhail 2013

Trial name or title	Comparison of decreased pain in transforaminal epidural steroid injections and pulsed radiofrequency in patients with low back pain
Methods	Randomised controlled trial
Participants	Main inclusion criteria: persistent low back pain with or without pain radiating to upper leg; age > 18 years; ASA class I to II; Lasek test ≥ 50 degrees; confirmed involvement of nerve roots; vertebral disc protrusion based on clinical examination, CT scan and MRI findings; symptoms of chronic low back pain > 6 months; absence of neurological defects; absence of epidural injection; absence of radicular syndrome; no response to traditional treatments; positive diagnostic block; hyperextension pain; no history of lumbar surgery; contraindication for lumbar surgery; signing consent to participate in the study Main exclusion criteria: patients previously treated with radiofrequency; coagulation disorders; contrast sensitivity radiopaque or local anaesthetic solution; malignancy; psychiatric problems and poor patient co-operation; speech problems; pregnancy; surgery indication; local skin infection at operative site; spinal deformity; spinal stenosis; discogenic axial pain; degenerative disc herniation; epidural injection of steroids in past 6 months; history of opioid abuse; use of long-acting opioids; radicular pain over a year ago; patients with history of sensitivity to corticosteroids or contrast material; inflammatory spondylopathy; vertebral fracture, tumour or infection of the spine; no signing of consent to participate in the study
Interventions	Experimental group: Participants received pulsed radiofrequency in nerve segment as confirmed by positive diagnostic block Control group: Participants received epidural steroid injection method transforaminal interlaminar under fluoroscopic guidance close to site of pathology
Outcomes	Visual analogue scale, Oswestry Disability Index score, success rate, participant request for analgesia
Starting date	August 2013
Contact information	Iranian Registry of Clinical Trials number: IRCT201411037984N22

Meckhail 2013 *(Continued)*

Notes	

Mekhail 2015

Trial name or title	Effect of temperature used in thermal radiofrequency ablation on outcomes of lumbar facet medial branch denervation procedures: a randomised, double-blinded trial
Methods	Randomised, double-blinded trial
Participants	**Inclusion criteria** • > 18 years of age • Able to give informed consent and to understand and comply with study requirements • Predominantly axial low back pain = 3 months in duration with no radicular pain below the knee that failed with conservative therapy • Chronic back pain attributed to lumbar facet joint arthropathy based on clinical evaluation • No history of previous back surgery at intended treatment levels • Adequate response to diagnostic blocks without use of steroids at same levels as intended block (defined as = 70% pain relief) • RFA of 3 to 4 lumber facet medial branches on 1 side only **Exclusion criteria** • Declined to provide written consent or follow-up • History of adverse reactions to local anaesthetic • Pregnancy • Bleeding disorders or active anticoagulation that cannot be stopped for a few days close to the time of the procedure • Active systemic or local infection • Radicular pain below the knee • Other specific causes of low back pain (e.g. significant spinal canal stenosis, grade 2 or 3 spondylolisthesis) • Secondary gain (i.e. ongoing litigation, workers' compensation or other financial incentives) • Psychopathology including depression, somatisation or poor coping skills • Physical factors including non-sedentary lifestyle (e.g. morbid obesity (BMI > 35 kg/m^2)) • Previous RFA at same level(s) in previous 12 months
Interventions	Experimental group: radiofrequency ablation at 90°C Control group: radiofrequency ablation at 80°C
Outcomes	Change in pain relief after 12 months, number of repeats of procedure over 12 months
Starting date	May 2014
Contact information	ClinicalTrials.gov Identifier: NCT02148003
Notes	

Norwegian University 2012

Trial name or title	The effect of RF treatment on patients with facet joint pain in cervical- and lumbar-columna
Methods	Double-blind, randomised, controlled trial
Participants	Patients 20 to 75 years of age with 1-sided neck pain of at least 1 year's duration
Interventions	Experimental intervention: RF neurotomy of medial branch at 80°C needle temperature for 70 seconds, after diagnostic blocks Sham comparator: RF neurotomy of medial branch at 37°C needle temperature for 70 seconds, after diagnostic blocks
Outcomes	Reduction in self reported pain intensity
Starting date	August 2004
Contact information	ClinicalTrials.gov identifier: NCT00476684
Notes	

Sarwar 2012

Trial name or title	A randomised, placebo-controlled trial of transdiscal RF annuloplasty for treatment of discogenic low-back pain
Methods	Randomised placebo-controlled trial
Participants	18 + years of age, history of chronic low back pain unresponsive to non-operative care (including physical therapy and anti-inflammatory medication) for > 6 months, ≥ 5 on VAS, no surgical interventions within past 3 months, back pain greater than leg pain, which is commonly exacerbated by sitting; pain reproduction present on provocative discography in degenerated disc but not in control discs; disc height ≥ 50% of adjacent control disc; evidence of single-level degenerative disc disease or 2-level disease without evidence of additional degenerative changes in other disc spaces on MRI
Interventions	Active comparator: Two electrodes are placed on both sides of the posterior annulus fibrosus of the intervertebral disc under x-ray guidance. RF current flows within the disc between the 2 electrodes, heating tissue in the disc to desired temperature Sham comparator: same procedures as in Active group except no RF current will be applied
Outcomes	Effectiveness of intradiscal RF annuloplasty at 1 year
Starting date	September 2007
Contact information	ClinicalTrials.gov identifier: NCT00750191
Notes	

SMART 2012

Trial name or title	Prospective, randomised, double-blind, controlled investigation evaluating the intracept intraosseous nerve ablation system for reduction in pain in patients with chronic axial low back pain

SMART 2012 *(Continued)*

Methods	Randomised, double-blind, controlled trial
Participants	25 to 70 years of age, inclusive chronic lower back pain for ≥ 6 months, failure to respond to ≥ 6 months of non-operative conservative management, Oswestry Disability Index (ODI) at time of evaluation ≥ 30 points, baseline visual analog scale (VAS) score ≥ 4 cm on a 10-cm scale, with the following test indicating that the vertebral body is the source of pain: MRI showing Type 1 or Type II Modic changes in at least 1 vertebral endplate, at ≥ 1 level from L3 to S1
Interventions	Experimental intervention: percutaneous transpedicular RF ablation of an intraosseous nerve within the lumbar vertebral body to treat chronic axial low back pain. Sham comparator: percutaneous transpedicular access to lumbar vertebra, no RF ablation delivered
Outcomes	Oswestry Disability Index at 3 months, participant success at 3 months and Oswestry Disability Index at 6 months
Starting date	October 2011
Contact information	ClinicalTrials.gov identifier: NCT01446419
Notes	

Abbrevations: CT= computed tomography; MRI= magnetic resonance imaging; NRS= numerical rating scale; ODI= Oswestry disability index; RF= radiofrequency; RFA= radiofrequency ablation

DATA AND ANALYSES

Comparison 1. Facet joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	3		Mean Difference (IV, Random, 95% CI)	Subtotals only
1.1 Main analysis	3	160	Mean Difference (IV, Random, 95% CI)	-1.47 [-2.28, -0.67]
1.2 Sensitivity analysis	3	140	Mean Difference (IV, Random, 95% CI)	-1.51 [-2.79, -0.23]
2 VAS 1 to 6 months	3	182	Mean Difference (IV, Random, 95% CI)	-0.71 [-2.25, 0.84]
3 VAS > 6 months	3		Mean Difference (IV, Random, 95% CI)	Subtotals only
3.1 Main analysis	3	130	Mean Difference (IV, Random, 95% CI)	-0.70 [-1.48, 0.08]
3.2 Sensitivity analysis	3	110	Mean Difference (IV, Random, 95% CI)	-1.06 [-2.23, 0.11]

Analysis 1.1. Comparison 1 Facet joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.

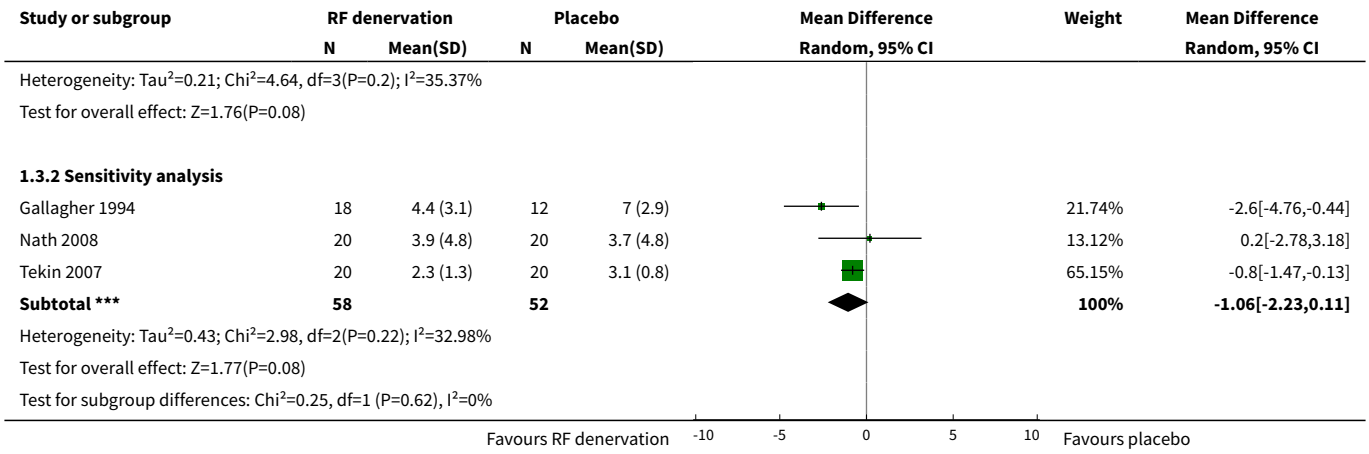
Study or subgroup	RF denervation N	RF denervation Mean(SD)	Placebo N	Placebo Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
1.1.1 Main analysis							
Gallagher 1994	18	3.4 (2.9)	12	6 (3.4)		9.62%	-2.6[-4.94,-0.26]
Leclaire 2001	36	4.8 (2.5)	34	5.2 (2.1)		26.83%	-0.4[-1.48,0.68]
Tekin 2007	20	2.8 (1.5)	10	4.3 (1)		31.35%	-1.5[-2.4,-0.6]
Tekin 2007	20	2.3 (1.4)	10	4.3 (1)		32.21%	-2[-2.87,-1.13]
Subtotal ***	**94**		**66**			**100%**	**-1.47[-2.28,-0.67]**
Heterogeneity: Tau^2=0.33; Chi^2=6.09, df=3(P=0.11); I^2=50.74%							
Test for overall effect: Z=3.58(P=0)							
1.1.2 Sensitivity analysis							
Gallagher 1994	18	3.4 (2.9)	12	6 (3.4)		18.81%	-2.6[-4.94,-0.26]
Leclaire 2001	36	4.8 (2.5)	34	5.2 (2.1)		37.6%	-0.4[-1.48,0.68]
Tekin 2007	20	2.3 (1.4)	20	4.3 (1)		43.59%	-2[-2.75,-1.25]
Subtotal ***	**74**		**66**			**100%**	**-1.51[-2.79,-0.23]**
Heterogeneity: Tau^2=0.83; Chi^2=6.5, df=2(P=0.04); I^2=69.23%							
Test for overall effect: Z=2.32(P=0.02)							
Test for subgroup differences: Chi^2=0, df=1 (P=0.96), I^2=0%							

Analysis 1.2. Comparison 1 Facet joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 2 VAS 1 to 6 months.

Study or subgroup	RF denervation N	RF denervation Mean(SD)	Placebo N	Placebo Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Leclaire 2001	36	5.2 (2.7)	34	4.4 (1.8)		34.81%	0.8[-0.27,1.87]
Van Kleef 1999	15	2.8 (2.4)	16	4.8 (2.5)		27.46%	-1.94[-3.67,-0.21]
Van Wijk 2005	40	3.7 (1.8)	41	4.9 (1.8)		37.73%	-1.2[-1.98,-0.42]
Total ***	**91**		**91**			**100%**	**-0.71[-2.25,0.84]**
Heterogeneity: Tau^2=1.48; Chi^2=11.09, df=2(P=0); I^2=81.97%							
Test for overall effect: Z=0.9(P=0.37)							

Analysis 1.3. Comparison 1 Facet joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 3 VAS > 6 months.

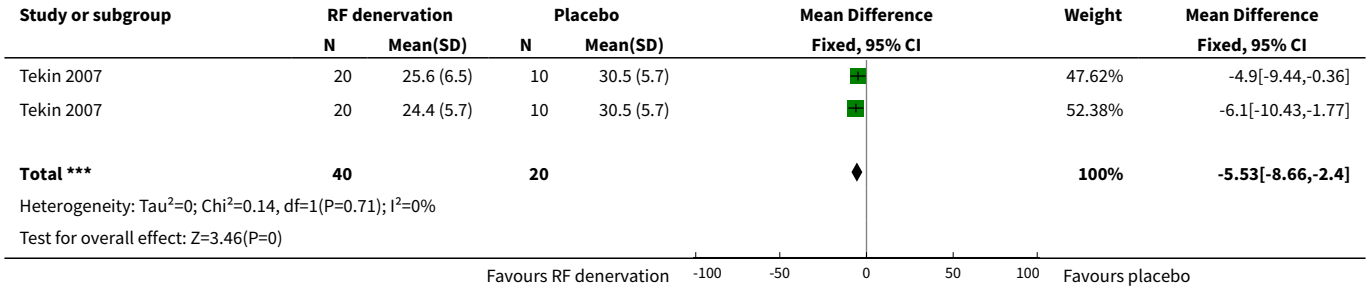
Study or subgroup	RF denervation N	RF denervation Mean(SD)	Placebo N	Placebo Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
1.3.1 Main analysis							
Gallagher 1994	18	4.4 (3.1)	12	7 (2.9)		11.07%	-2.6[-4.76,-0.44]
Nath 2008	20	3.9 (4.8)	20	3.7 (4.8)		6.3%	0.2[-2.78,3.18]
Tekin 2007	20	2.9 (1.6)	10	3.1 (0.8)		38.98%	-0.2[-1.06,0.66]
Tekin 2007	20	2.3 (1.3)	10	3.1 (0.8)		43.65%	-0.8[-1.56,-0.04]
Subtotal ***	**78**		**52**			**100%**	**-0.7[-1.48,0.08]**



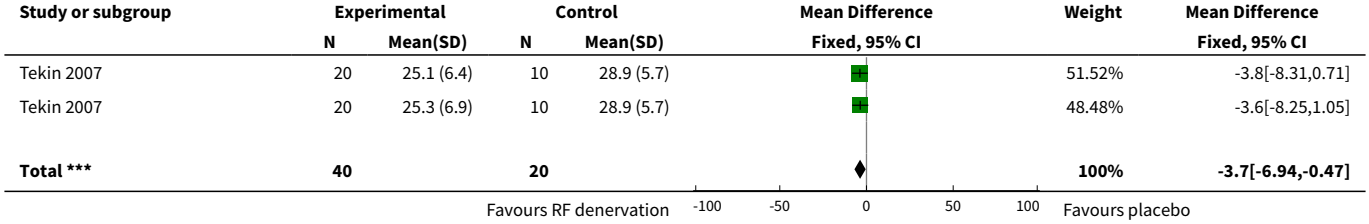
Comparison 2. Facet joint: radiofrequency denervation versus placebo, functional status (ODI)

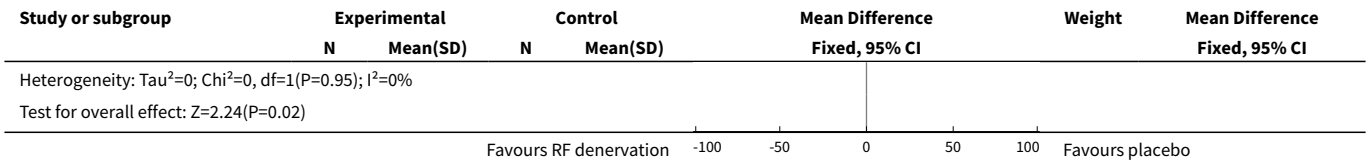
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI 1 month	1	60	Mean Difference (IV, Fixed, 95% CI)	-5.53 [-8.66, -2.40]
2 ODI > 6 months	1	60	Mean Difference (IV, Fixed, 95% CI)	-3.70 [-6.94, -0.47]

Analysis 2.1. Comparison 2 Facet joint: radiofrequency denervation versus placebo, functional status (ODI), Outcome 1 ODI 1 month.



Analysis 2.2. Comparison 2 Facet joint: radiofrequency denervation versus placebo, functional status (ODI), Outcome 2 ODI > 6 months.

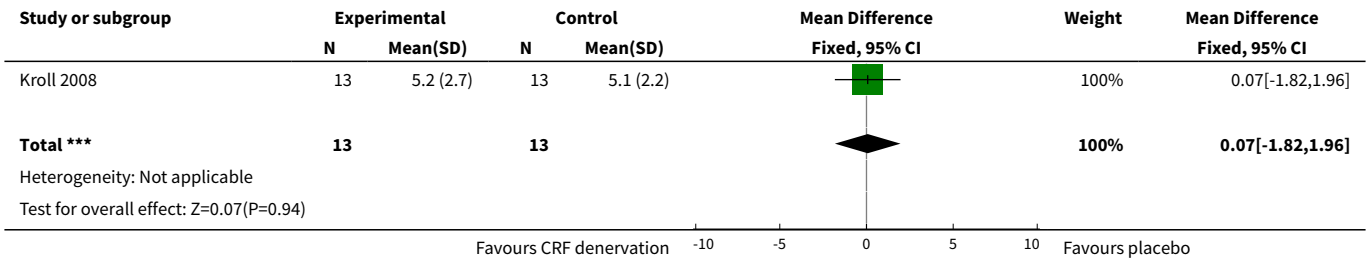




Comparison 3. Facet joint: continuous radiofrequency denervation versus pulsed radiofrequency denervation, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 to 6 months	1	26	Mean Difference (IV, Fixed, 95% CI)	0.07 [-1.82, 1.96]

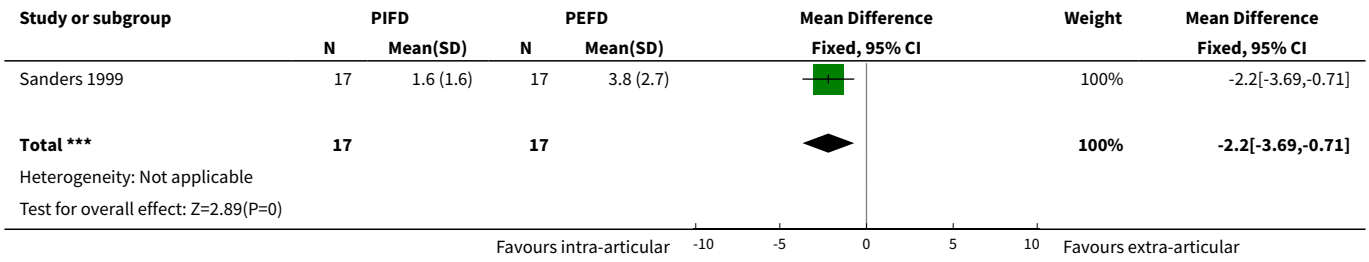
Analysis 3.1. Comparison 3 Facet joint: continuous radiofrequency denervation versus pulsed radiofrequency denervation, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 to 6 months.



Comparison 4. Facet joint: percutaneous intra-articular denervation versus percutaneous extra-articular denervation, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 to 6 months	1	34	Mean Difference (IV, Fixed, 95% CI)	-2.20 [-3.69, -0.71]

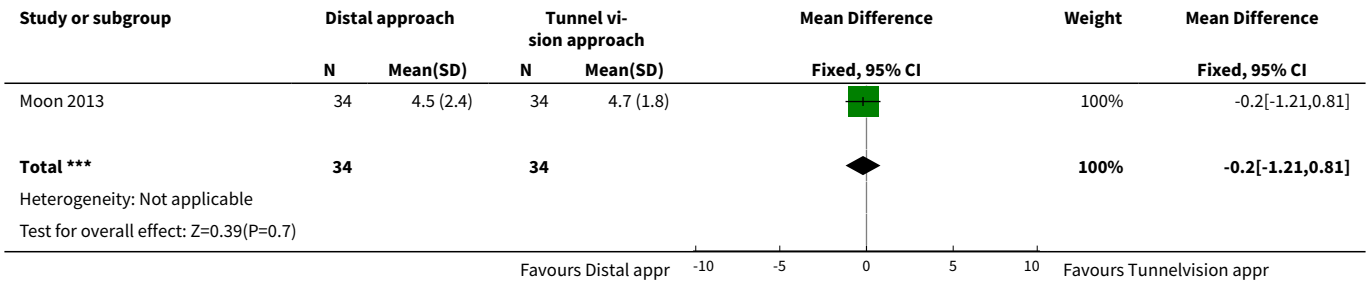
Analysis 4.1. Comparison 4 Facet joint: percutaneous intra-articular denervation versus percutaneous extra-articular denervation, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 to 6 months.



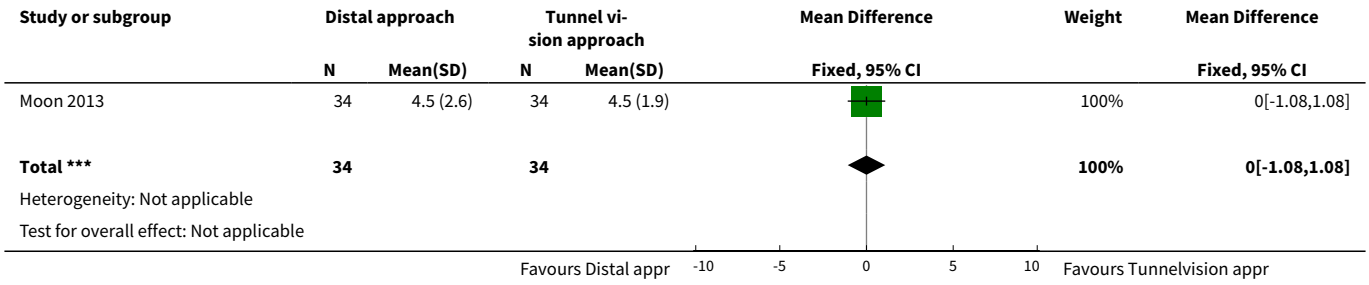
Comparison 5. Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	1	68	Mean Difference (IV, Fixed, 95% CI)	-0.20 [-1.21, 0.81]
2 VAS > 6 months	1	68	Mean Difference (IV, Fixed, 95% CI)	0.0 [-1.08, 1.08]

Analysis 5.1. Comparison 5 Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.



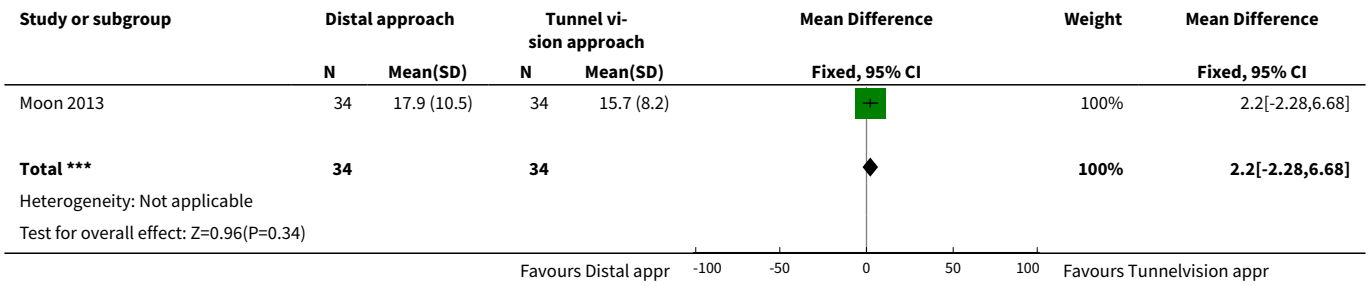
Analysis 5.2. Comparison 5 Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, pain intensity (VAS 0 to 10), Outcome 2 VAS > 6 months.



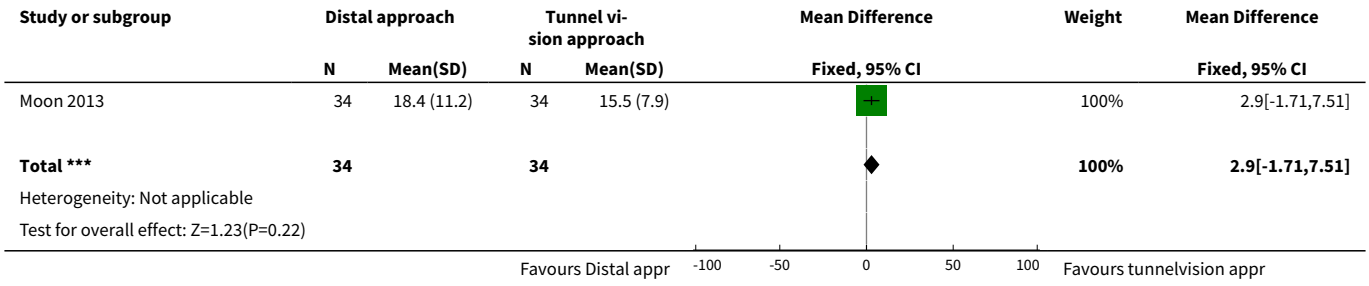
Comparison 6. Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, functional status (ODI)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI 1 month	1	68	Mean Difference (IV, Fixed, 95% CI)	2.20 [-2.28, 6.68]
2 ODI 6 months	1	68	Mean Difference (IV, Fixed, 95% CI)	2.90 [-1.71, 7.51]

Analysis 6.1. Comparison 6 Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, functional status (ODI), Outcome 1 ODI 1 month.



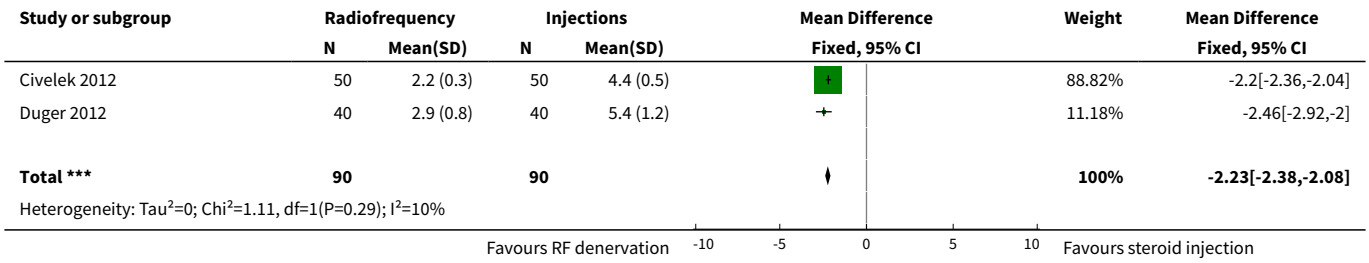
Analysis 6.2. Comparison 6 Facet joint: radiofrequency denervation distal approach versus tunnel vision approach, functional status (ODI), Outcome 2 ODI 6 months.



Comparison 7. Facet joint: radiofrequency denervation versus steroid injections, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	2	180	Mean Difference (IV, Fixed, 95% CI)	-2.23 [-2.38, -2.08]
2 VAS 6 months	3	232	Mean Difference (IV, Random, 95% CI)	-2.13 [-3.45, -0.81]
3 VAS 12 months	2	180	Mean Difference (IV, Random, 95% CI)	-2.65 [-3.43, -1.88]

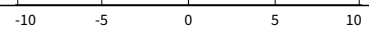
Analysis 7.1. Comparison 7 Facet joint: radiofrequency denervation versus steroid injections, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.



Study or subgroup	Radiofrequency N	Mean(SD)	Injections N	Mean(SD)	Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
Test for overall effect: Z=28.68(P<0.0001)							

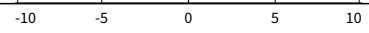
Analysis 7.2. Comparison 7 Facet joint: radiofrequency denervation versus steroid injections, pain intensity (VAS 0 to 10), Outcome 2 VAS 6 months.

Study or subgroup	Radiofrequency N	Mean(SD)	Injections N	Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Civelek 2012	50	2.5 (0.4)	50	4.4 (0.7)		36.53%	-1.9[-2.12,-1.68]
Duger 2012	40	3 (0.7)	40	6.5 (1.2)		35.48%	-3.49[-3.93,-3.05]
Lakemeier 2013	26	4.7 (2.4)	26	5.4 (2.1)		27.98%	-0.7[-1.93,0.53]
Total ***	**116**		**116**			**100%**	**-2.13[-3.45,-0.81]**
Heterogeneity: Tau^2=1.22; Chi^2=46.24, df=2(P<0.0001); I^2=95.68%							
Test for overall effect: Z=3.17(P=0)							



Analysis 7.3. Comparison 7 Facet joint: radiofrequency denervation versus steroid injections, pain intensity (VAS 0 to 10), Outcome 3 VAS 12 months.

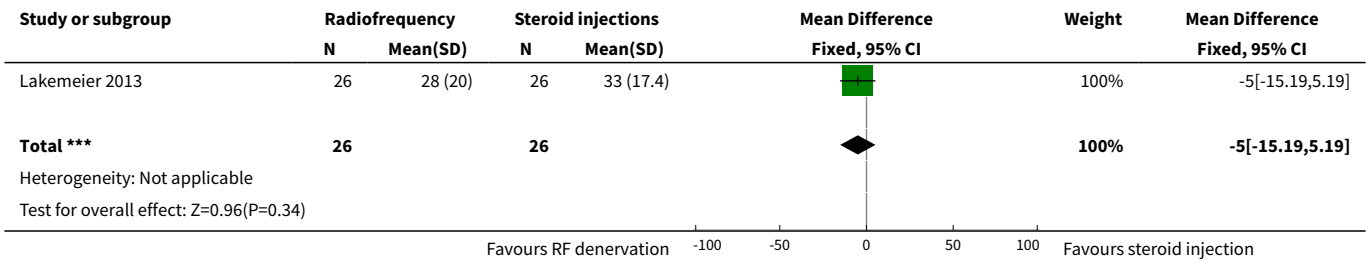
Study or subgroup	Radiofrequency N	Mean(SD)	Injections N	Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Civelek 2012	50	2.6 (0.4)	50	4.9 (0.7)		55.07%	-2.3[-2.52,-2.08]
Duger 2012	40	3.9 (1.3)	40	7 (1.2)		44.93%	-3.09[-3.63,-2.55]
Total ***	**90**		**90**			**100%**	**-2.65[-3.43,-1.88]**
Heterogeneity: Tau^2=0.27; Chi^2=6.99, df=1(P=0.01); I^2=85.7%							
Test for overall effect: Z=6.76(P<0.0001)							



Comparison 8. Facet joint: radiofrequency denervation versus steroid injections, functional status (ODI)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI 6 months	1	52	Mean Difference (IV, Fixed, 95% CI)	-5.0 [-15.19, 5.19]

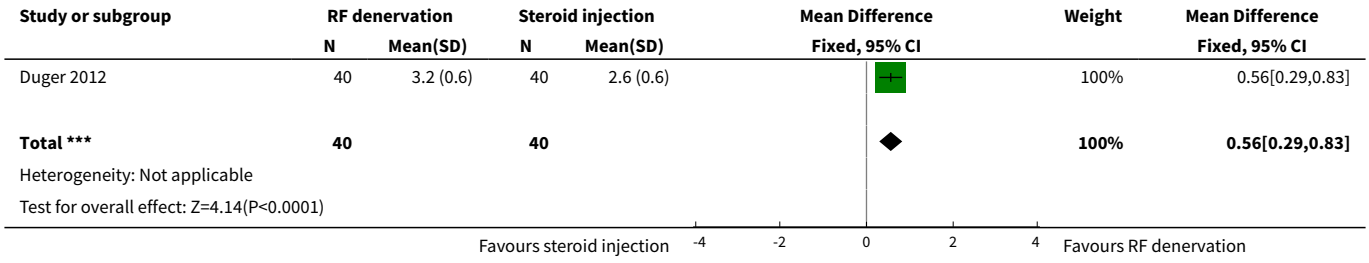
Analysis 8.1. Comparison 8 Facet joint: radiofrequency denervation versus steroid injections, functional status (ODI), Outcome 1 ODI 6 months.



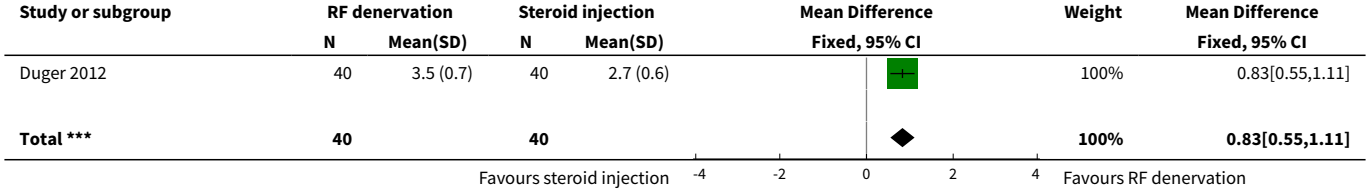
Comparison 9. Facet joint: radiofrequency denervation versus steroid injections, participant satisfaction (scale 1 to 4)

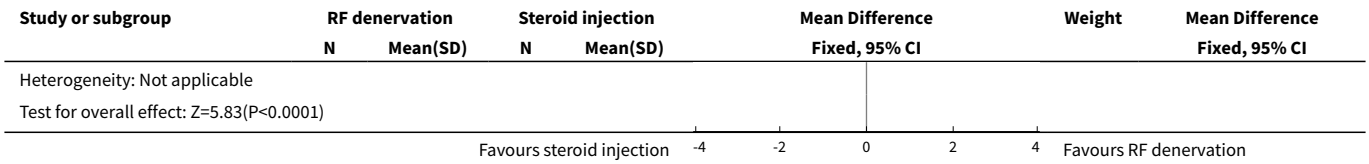
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Participant satisfaction 1 month	1	80	Mean Difference (IV, Fixed, 95% CI)	0.56 [0.29, 0.83]
2 Participant satisfaction 6 months	1	80	Mean Difference (IV, Fixed, 95% CI)	0.83 [0.55, 1.11]
3 Participant satisfaction 12 months	1	80	Mean Difference (IV, Fixed, 95% CI)	0.53 [0.22, 0.84]

Analysis 9.1. Comparison 9 Facet joint: radiofrequency denervation versus steroid injections, participant satisfaction (scale 1 to 4), Outcome 1 Participant satisfaction 1 month.

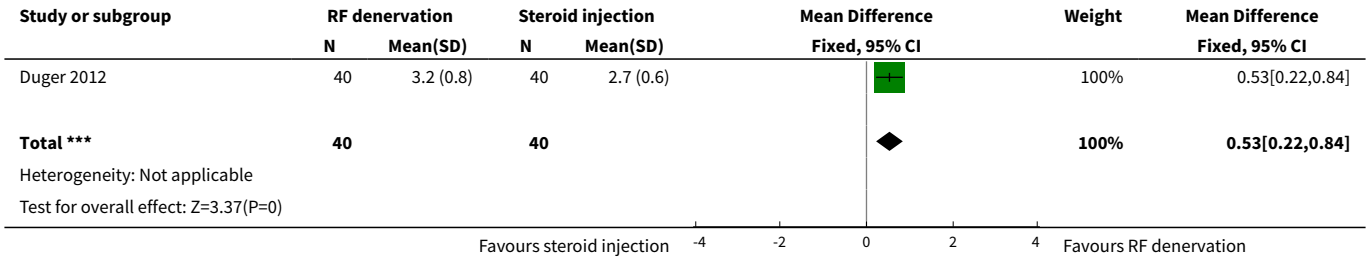


Analysis 9.2. Comparison 9 Facet joint: radiofrequency denervation versus steroid injections, participant satisfaction (scale 1 to 4), Outcome 2 Participant satisfaction 6 months.





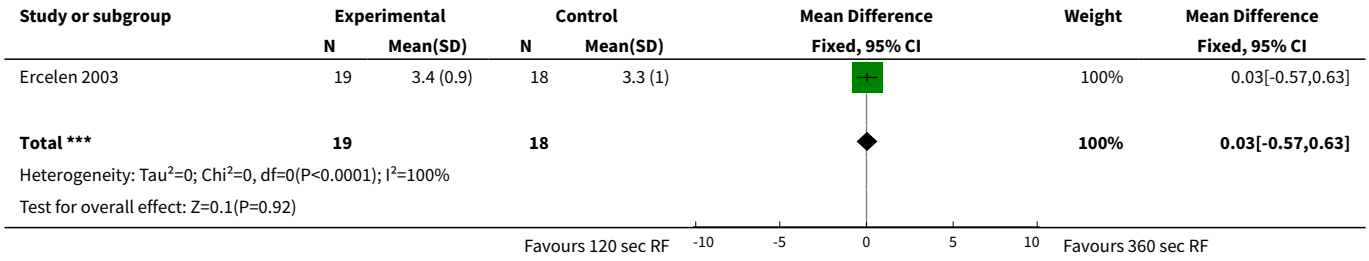
Analysis 9.3. Comparison 9 Facet joint: radiofrequency denervation versus steroid injections, participant satisfaction (scale 1 to 4), Outcome 3 Participant satisfaction 12 months.



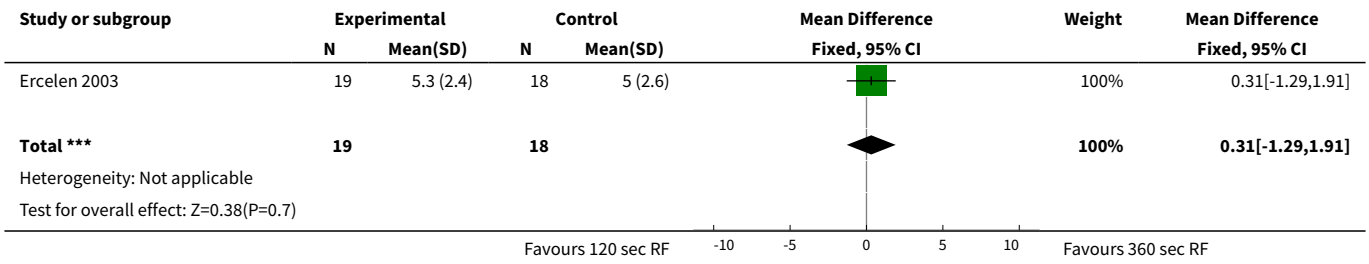
Comparison 10. Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	1	37	Mean Difference (IV, Fixed, 95% CI)	0.03 [-0.57, 0.63]
2 VAS 1 to 6 months	1	37	Mean Difference (IV, Fixed, 95% CI)	0.31 [-1.29, 1.91]
3 VAS 6 months	1	37	Mean Difference (IV, Fixed, 95% CI)	0.59 [-0.88, 2.06]

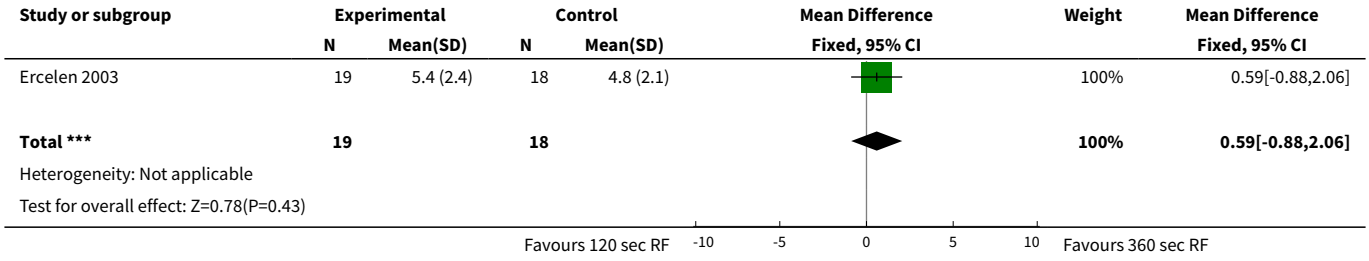
Analysis 10.1. Comparison 10 Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.



Analysis 10.2. Comparison 10 Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, pain intensity (VAS 0 to 10), Outcome 2 VAS 1 to 6 months.



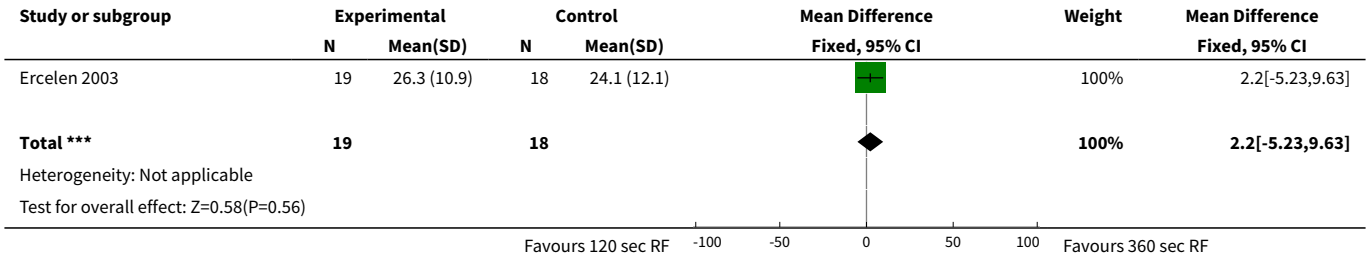
Analysis 10.3. Comparison 10 Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, pain intensity (VAS 0 to 10), Outcome 3 VAS 6 months.



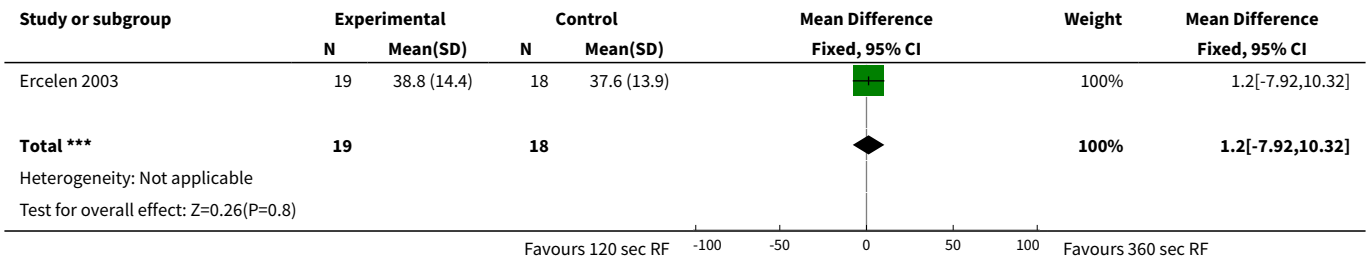
Comparison 11. Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, functional status (ODI)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI < 1 month	1	37	Mean Difference (IV, Fixed, 95% CI)	2.20 [-5.23, 9.63]
2 ODI > 6 months	1	37	Mean Difference (IV, Fixed, 95% CI)	1.20 [-7.92, 10.32]

Analysis 11.1. Comparison 11 Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, functional status (ODI), Outcome 1 ODI < 1 month.



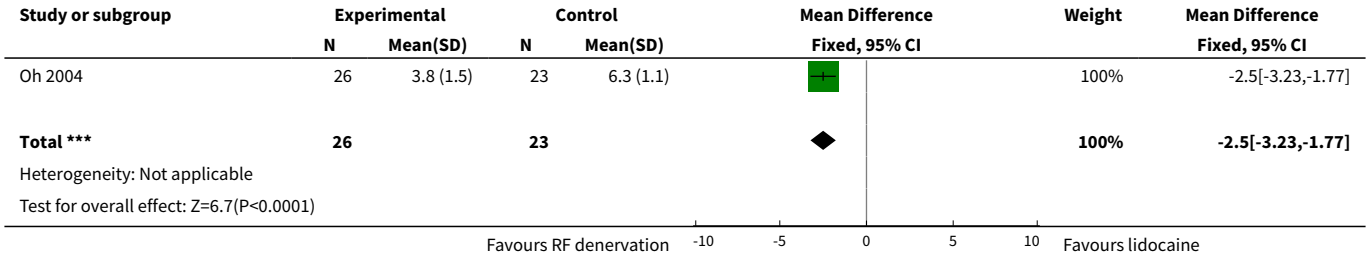
Analysis 11.2. Comparison 11 Discs: 120-second radiofrequency denervation versus 360-second radiofrequency, functional status (ODI), Outcome 2 ODI > 6 months.



Comparison 12. Discs: radiofrequency denervation versus lidocaine, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 to 6 months	1	49	Mean Difference (IV, Fixed, 95% CI)	-2.5 [-3.23, -1.77]

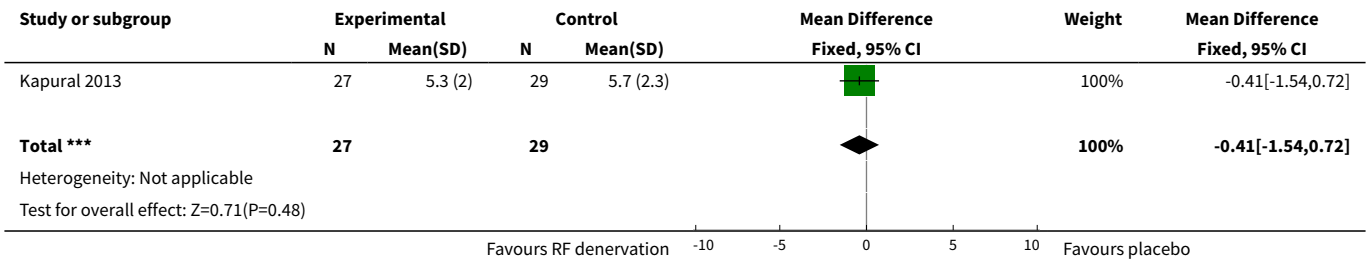
Analysis 12.1. Comparison 12 Discs: radiofrequency denervation versus lidocaine, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 to 6 months.



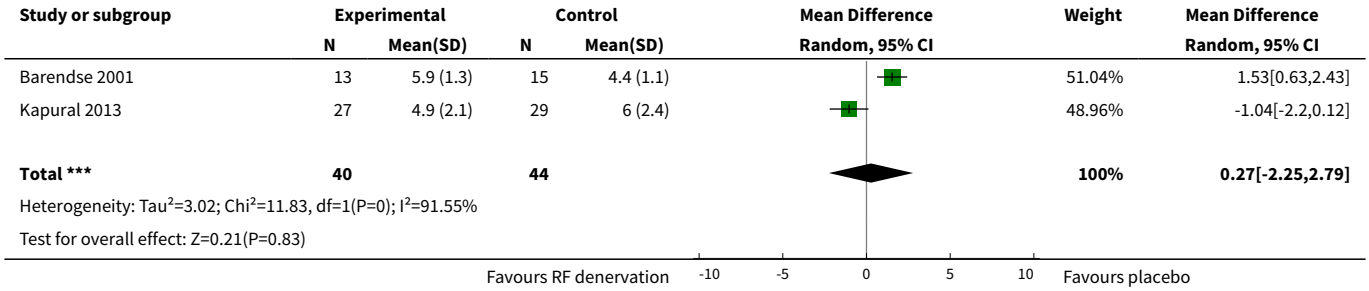
Comparison 13. Discs: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	1	56	Mean Difference (IV, Fixed, 95% CI)	-0.41 [-1.54, 0.72]
2 VAS 1 to 6 months	2	84	Mean Difference (IV, Random, 95% CI)	0.27 [-2.25, 2.79]
3 VAS 6 months	2	75	Mean Difference (IV, Fixed, 95% CI)	-1.63 [-2.58, -0.68]

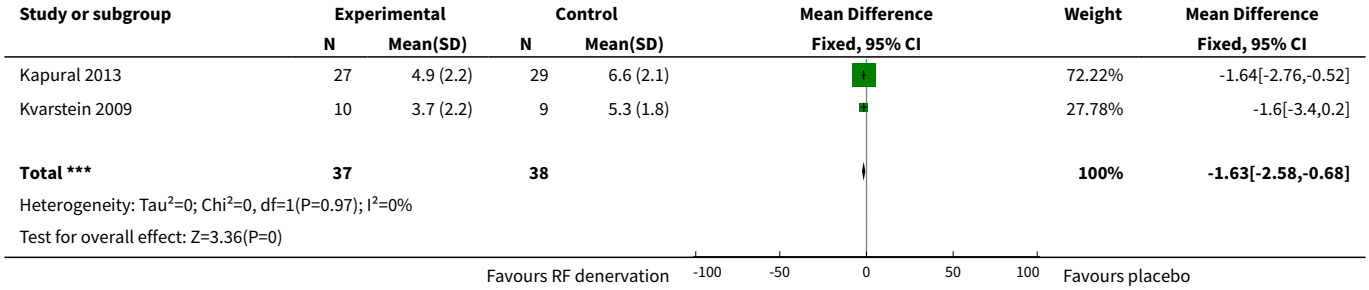
Analysis 13.1. Comparison 13 Discs: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.



Analysis 13.2. Comparison 13 Discs: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 2 VAS 1 to 6 months.



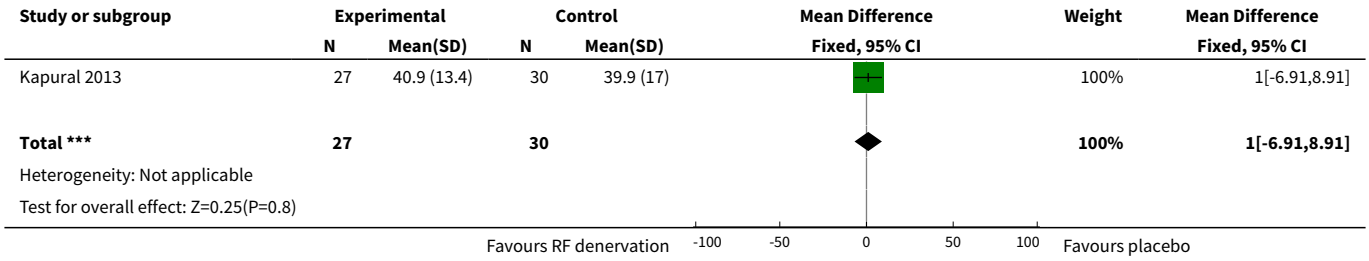
Analysis 13.3. Comparison 13 Discs: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 3 VAS 6 months.



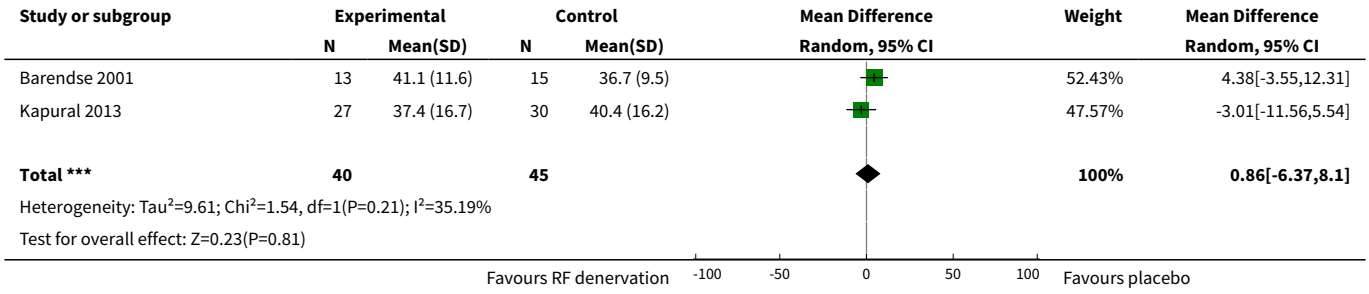
Comparison 14. Discs: radiofrequency denervation versus placebo, functional status (ODI)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI 1 month	1	57	Mean Difference (IV, Fixed, 95% CI)	1.0 [-6.91, 8.91]
2 ODI 1 to 6 months	2	85	Mean Difference (IV, Random, 95% CI)	0.86 [-6.37, 8.10]
3 ODI 6 months	2	76	Mean Difference (IV, Fixed, 95% CI)	-6.75 [-13.42, -0.09]

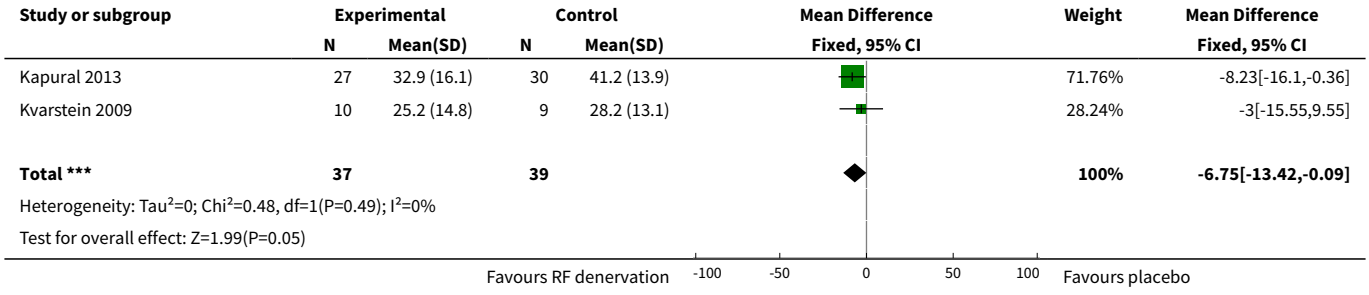
Analysis 14.1. Comparison 14 Discs: radiofrequency denervation versus placebo, functional status (ODI), Outcome 1 ODI 1 month.



Analysis 14.2. Comparison 14 Discs: radiofrequency denervation versus placebo, functional status (ODI), Outcome 2 ODI 1 to 6 months.



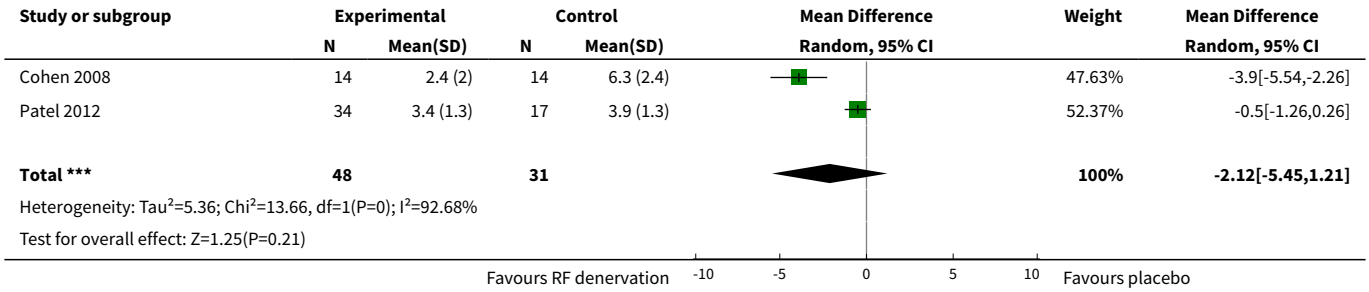
Analysis 14.3. Comparison 14 Discs: radiofrequency denervation versus placebo, functional status (ODI), Outcome 3 ODI 6 months.



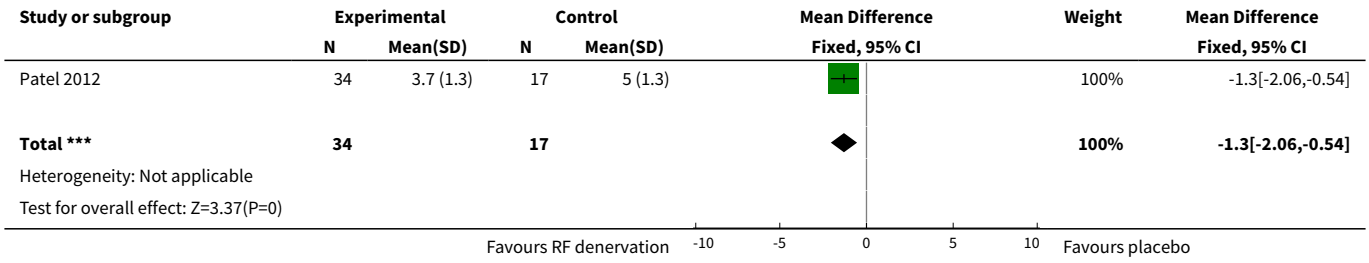
Comparison 15. SI joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	2	79	Mean Difference (IV, Random, 95% CI)	-2.12 [-5.45, 1.21]
2 VAS 1 to 6 months	1	51	Mean Difference (IV, Fixed, 95% CI)	-1.30 [-2.06, -0.54]

Analysis 15.1. Comparison 15 SI joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 month.



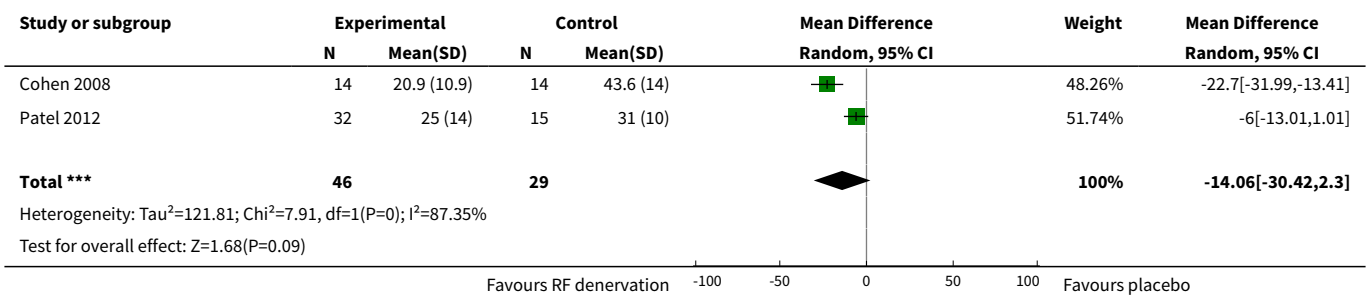
Analysis 15.2. Comparison 15 SI joint: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 2 VAS 1 to 6 months.



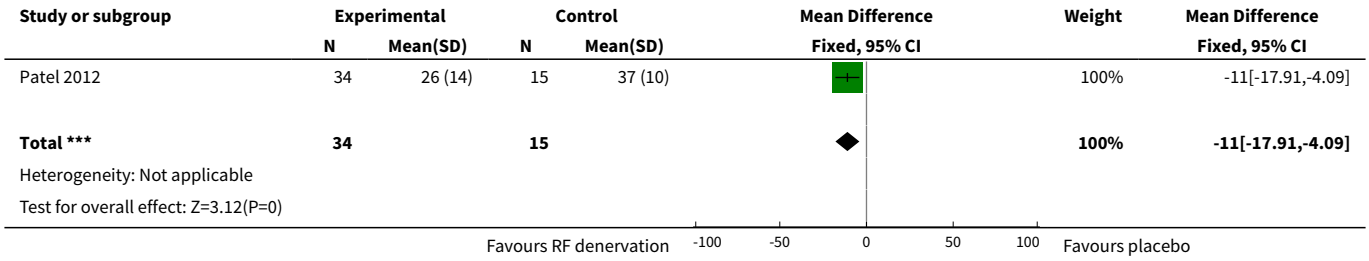
Comparison 16. SI joint: radiofrequency denervation versus placebo, functional status (ODI)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 ODI 1 month	2	75	Mean Difference (IV, Random, 95% CI)	-14.06 [-30.42, 2.30]
2 ODI 1 to 6 months	1	49	Mean Difference (IV, Fixed, 95% CI)	-11.0 [-17.91, -4.09]

Analysis 16.1. Comparison 16 SI joint: radiofrequency denervation versus placebo, functional status (ODI), Outcome 1 ODI 1 month.



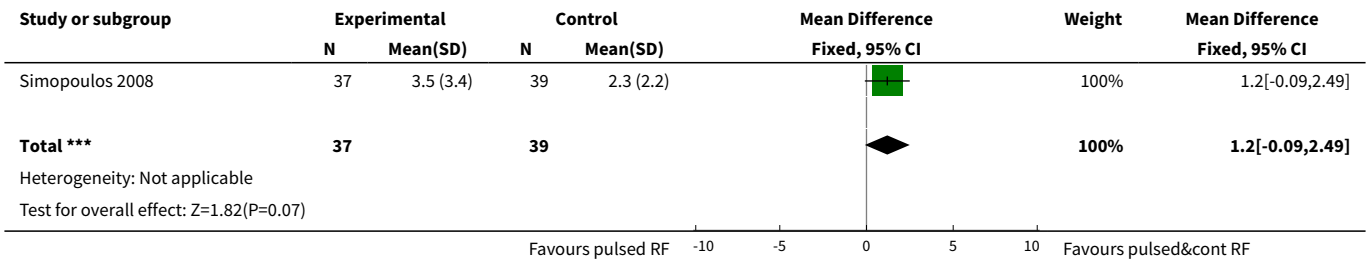
Analysis 16.2. Comparison 16 SI joint: radiofrequency denervation versus placebo, functional status (ODI), Outcome 2 ODI 1 to 6 months.



Comparison 17. Radiating LBP: pulsed radiofrequency denervation versus pulsed radiofrequency denervation and continuous radiofrequency denervation, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 to 6 months	1	76	Mean Difference (IV, Fixed, 95% CI)	1.20 [-0.09, 2.49]

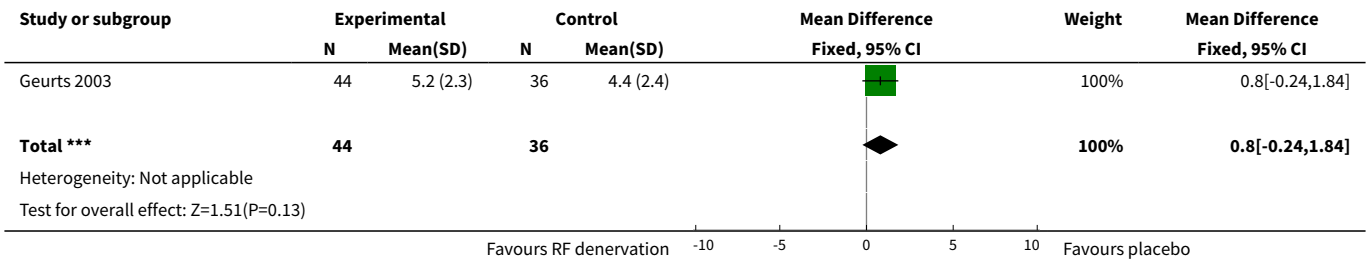
Analysis 17.1. Comparison 17 Radiating LBP: pulsed radiofrequency denervation versus pulsed radiofrequency denervation and continuous radiofrequency denervation, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 to 6 months.



Comparison 18. Dorsal root ganglion: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 to 6 months	1	80	Mean Difference (IV, Fixed, 95% CI)	0.80 [-0.24, 1.84]

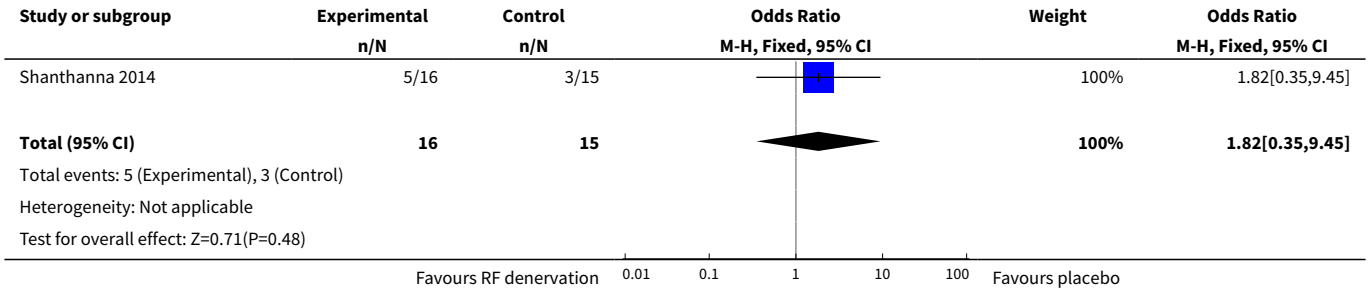
Analysis 18.1. Comparison 18 Dorsal root ganglion: radiofrequency denervation versus placebo, pain intensity (VAS 0 to 10), Outcome 1 VAS 1 to 6 months.



Comparison 19. Dorsal root ganglion: pulsed radiofrequency versus placebo (number of participants with > 50% reduction in VAS 0 to 10)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 VAS 1 month	1	31	Odds Ratio (M-H, Fixed, 95% CI)	1.82 [0.35, 9.45]

Analysis 19.1. Comparison 19 Dorsal root ganglion: pulsed radiofrequency versus placebo (number of participants with > 50% reduction in VAS 0 to 10), Outcome 1 VAS 1 month.



ADDITIONAL TABLES

Table 1. Clinical relevance

	1 Patients	2 Int + setting	3 Outcomes Pain and function	4 Effects Pain or function over the short term	5 Benefits > harms
Facet joint pain					
Gallagher	+	-	-	+	?
Kroll	+	+	+	-	?

Table 1. Clinical relevance *(Continued)*

Leclaire	+	-	+	-	?
Nath	+	+	+	?	?
Tekin	+	+	+	+	?
Van Kleef	+	+	+	+	?
Van Wijk	+	+	+	+	?
Sanders	+	+	+	-	?
Moon	+	+	+	-	?
Civelek	+	+	-	-	?
Duger	+	+	-	+	?
Lakemeier	+	+	+	-	?
Disc pain					
Barendse	+	+	+	-	?
Kapural	+	+	+	-	?
Ercelen	+	+	+	-	?
Kvarstein	+	+	+	-	?
Oh	?	+	-	+	?
SI joint pain					
Cohen	+	+	+	+	?
Patel	+	+	+	-	?
Dorsal root ganglion					
Geurts	+	+	-	-	?
Shantanna	+	+	+	-	?
Radiating LBP					
Simopoulos	+	+	-	-	?

Table 1. Clinical relevance *(Continued)*

LBP with or without radiation					
Mu-Lien Lin	-	?	+	?	?

APPENDICES

Appendix 1. CENTRAL search strategy

Last searched May 29, 2014. Lines 29 and 35 were added.

#1 MeSH descriptor: [Back Pain] explode all trees

#2 dorsalgia

#3 backache

#4 MeSH descriptor: [Low Back Pain] explode all trees

#5 lumbar next pain or coccyx or coccydynia or spondylosis

#6 MeSH descriptor: [Spine] explode all trees

#7 MeSH descriptor: [Spinal Diseases] explode all trees

#8 lumbago OR discitis OR disc near degeneration OR disc near prolapse OR disc near herniation

#9 spinal fusion

#10 facet near joints

#11 MeSH descriptor: [Intervertebral Disk] explode all trees

#12 postlaminectomy

#13 arachnoiditis

#14 failed near back

#15 MeSH descriptor: [Cauda Equina] explode all trees

#16 lumbar near vertebra*

#17 spinal near stenosis

#18 slipped near (disc* or disk*)

#19 degenerat* near (disc* or disk*)

#20 stenosis near (spine or root or spinal)

#21 displace* near (disc* or disk*)

#22 prolap* near (disc* or disk*)

#23 MeSH descriptor: [Sciatic Neuropathy] explode all trees

#24 sciatic*

#25 back disorder*

#26 back near pain

#27 #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26

#28 MeSH descriptor: [Radio Waves] explode all trees

#29 MeSH descriptor: [Pulsed Radiofrequency Treatment] explode all trees

#30 radiofrequency

#31 radio frequency or radio-frequency

#32 MeSH descriptor: [Electrocoagulation] explode all trees

#33 electrocoag*

#34 thermocoag*

#35 neurotom* or neuroly*

#36 #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35

#37 #27 and #36 in Trials

2013 search strategy

#1 MeSH descriptor: [Back Pain] explode all trees

#2 dorsalgia

#3 backache

#4 MeSH descriptor: [Low Back Pain] explode all trees

#5 lumbar next pain OR coccyx OR coccydynia OR sciatica OR spondylosis

#6 MeSH descriptor: [Spine] explode all trees

#7 MeSH descriptor: [Spinal Diseases] explode all trees

#8 lumbago OR discitis OR disc near degeneration OR disc near prolapse OR disc near herniation

#9 spinal fusion

#10 spinal neoplasms

#11 facet near joints

#12 MeSH descriptor: [Intervertebral Disk] explode all trees

#13 postlaminectomy

#14 arachnoiditis

#15 failed near back

#16 MeSH descriptor: [Cauda Equina] explode all trees

#17 lumbar near vertebra*

#18 spinal near stenosis

#19 slipped near (disc* or disk*)

#20 degenerat* near (disc* or disk*)

#21 stenosis near (spine or root or spinal)

#22 displace* near (disc* or disk*)

#23 prolap* near (disc* or disk*)

#24 MeSH descriptor: [Sciatic Neuropathy] explode all trees

#25 sciatic*

#26 back disorder*

#27 back near pain

#28 #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27

#29 MeSH descriptor: [Radio Waves] explode all trees

#30 radiofrequency

#31 radio frequency

#32 MeSH descriptor: [Electrocoagulation] explode all trees

#33 electrocoagul*

#34 thermocoagul$

#35 #29 or #30 or #31 or #32 or #33 or #34

#36 #28 and #35 from 2012 to 2013, in Trials

2010 search strategy

#1 MeSH descriptor Back explode all trees

#2 MeSH descriptor Buttocks, this term only

#3 MeSH descriptor Leg, this term only

#4 MeSH descriptor Back Pain explode tree

#5 MeSH descriptor Back Injuries explode all trees

#6 MeSH descriptor Low Back Pain, this term only

#7 (low next back next pain)

#8 (lbp)

#9 MeSH descriptor Sciatic Neuropathy explode all trees

#10 MeSH descriptor Spine explode all trees

#11 MeSH descriptor Spinal Diseases explode all trees

#12 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11)

#13 MeSH descriptor Radio Waves explode all trees

#14 radiofrequency

#15 radio frequency

#16 MeSH descriptor Electrocoagulation explode all trees

#17 electrocoagul*

#18 thermocoagul$

#19 (#13 OR #14 OR #15 OR #16 OR #17 OR #18)

#20 (#12 AND #19)

#21 (#20), from 2009 to 2010

Appendix 2. MEDLINE search strategy

Last searched May 29, 2014. Lines 38 and 44 were added.

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. randomi#ed.ab.
4. placebo.ab,ti.
5. drug therapy.fs.
6. randomly.ab,ti.
7. trial.ab,ti.
8. groups.ab,ti.
9. or/1-8
10. (animals not (humans and animals)).sh.
11. 9 not 10
12. dorsalgia.ti,ab.
13. exp Back Pain/
14. backache.ti,ab.
15. (lumbar adj pain).ti,ab.
16. coccyx.ti,ab.
17. coccydynia.ti,ab.
18. sciatica.ti,ab.
19. sciatic neuropathy/
20. spondylosis.ti,ab.
21. lumbago.ti,ab.
22. or/12-21
23. exp Spine/
24. discitis.ti,ab.
25. exp Spinal Diseases/
26. (disc adj degeneration).ti,ab.
27. (disc adj prolapse).ti,ab.
28. (disc adj herniation).ti,ab.
29. spinal fusion.sh.
30. (facet adj joints).ti,ab.
31. intervertebral disc.sh.
32. postlaminectomy.ti,ab.
33. arachnoiditis.ti,ab.
34. (failed adj back).ti,ab.
35. or/23-34
36. 22 or 35
37. exp Radio Waves/
38. exp Pulsed Radiofrequency Treatment/
39. radiofrequency.mp.
40. radio frequency.mp.
41. exp Electrocoagulation/
42. electrocoag$.mp.
43. thermocoag$.mp.
44. (neurotom$ or neuroly$).mp.
45. or/37-44

46.11 and 36 and 45

2013 strategy. Lines 37 to 39 were removed for the 2014 update.

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. randomized.ab.
4. placebo.ab,ti.
5. drug therapy.fs.
6. randomly.ab,ti.
7. trial.ab,ti.
8. groups.ab,ti.
9. or/1-8
10. (animals not (humans and animals)).sh.
11. 9 not 10
12. dorsalgia.ti,ab.
13. exp Back Pain/
14. backache.ti,ab.
15. (lumbar adj pain).ti,ab.
16. coccyx.ti,ab.
17. coccydynia.ti,ab.
18. sciatica.ti,ab.
19. sciatic neuropathy/
20. spondylosis.ti,ab.
21. lumbago.ti,ab.
22. or/12-21
23. exp Spine/
24. discitis.ti,ab.
25. exp Spinal Diseases/
26. (disc adj degeneration).ti,ab.
27. (disc adj prolapse).ti,ab.
28. (disc adj herniation).ti,ab.
29. spinal fusion.sh.
30. spinal neoplasms.sh.
31. (facet adj joints).ti,ab.
32. intervertebral disc.sh.
33. postlaminectomy.ti,ab.
34. arachnoiditis.ti,ab.
35. (failed adj back).ti,ab.
36. or/23-35
37. Oswestry.tw.
38. Roland-Morris.tw.
39. or/37-38
40. 22 or 36 or 39
41. exp Radio Waves/
42. radiofrequency.mp.
43. radio frequency.mp.
44. exp Electrocoagulation/
45. electrocoag$.mp.
46. thermocoagulation.mp.
47. or/41-46
48. 11 and 40 and 47
49. limit 48 to yr="2012 - 2013"

50.limit 48 to ed=20120301-20130529
51.49 or 50

Appendix 3. MEDLINE In-Process & Other Non-Indexed Citations search strategy

Last searched May 30, 2014.

1. randomi#ed controlled trial.ti,ab.
2. controlled clinical trial.ti,ab.
3. randomi#ed.ab.
4. placebo.ab,ti.
5. drug therapy.fs.
6. randomly.ab,ti.
7. trial.ab,ti.
8. groups.ab,ti.
9. or/1-8
10. dorsalgia.ti,ab.
11. Back Pain.ti,ab.
12. backache.ti,ab.
13. (lumbar adj pain).ti,ab.
14. coccyx.ti,ab.
15. coccydynia.ti,ab.
16. sciatic$.ti,ab.
17. spondylosis.ti,ab.
18. lumbago.ti,ab.
19. or/10-18
20. (spine or sacrum or lumbar vertebrae or intervertebral disc$).ti,ab.
21. discitis.ti,ab.
22. (disc adj degeneration).ti,ab.
23. (disc adj prolapse).ti,ab.
24. (disc adj herniation).ti,ab.
25. spinal fusion.ti,ab.
26. (facet adj joints).ti,ab.
27. postlaminectomy.ti,ab.
28. arachnoiditis.ti,ab.
29. (failed adj back).ti,ab.
30. or/20-29
31. 19 or 30
32. (radiowave$ or radio wave$).ti,ab.
33. (radiofrequency or radio frequency).ti,ab.
34. electrocoag$.ti,ab.
35. thermocoag$.ti,ab.
36. (neurotom$ or neuroly$).ti,ab.
37. or/32-36
38. 9 and 31 and 37

Appendix 4. EMBASE search strategy

Last searched May 29, 2014. The study design filter, disorder and intervention terms were revised.

1. Clinical Trial/
2. Controlled clinical trial/
3. Controlled Study/
4. Randomized Controlled Trial/
5. Double Blind Procedure/

6. Single Blind Procedure/
7. crossover procedure/
8. placebo/
9. allocat$.ti,ab.
10. assign$.ti,ab.
11. blind$.ti,ab.
12. (clinic$ adj25 (study or trial)).ti,ab.
13. (crossover or cross-over).ti,ab.
14. factorial$.ti,ab.
15. (followup or follow-up).ti,ab.
16. prospectiv$.ti,ab.
17. placebo$.ti,ab.
18. random$.ti,ab.
19. ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab.
20. volunteer$.ti,ab.
21. or/1-20
22. exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/
23. human/ or normal human/ or human cell/
24. 22 and 23
25. 22 not 24
26. 21 not 25
27. dorsalgia.mp.
28. back pain.mp.
29. exp BACKACHE/
30. (lumbar adj pain).mp.
31. coccyx.mp.
32. coccydynia.mp.
33. sciatica.mp.
34. ISCHIALGIA/
35. spondylosis.mp.
36. lumbago.mp.
37. back disorder$.mp.
38. or/27-37
39. exp SPINE/
40. (discitis or diskitis).mp.
41. exp Spine Disease/
42. (disc adj degeneration).mp.
43. (disc adj prolapse).mp.
44. (disc adj herniation).mp.
45. spinal fusion.mp.
46. (facet adj joints).mp.
47. (intervertebral disk or intervertebral disc).mp.
48. postlaminectomy.mp.
49. arachnoiditis.mp.
50. (failed adj back).mp.
51. or/39-50
52. 38 or 51
53. exp pulsed radiofrequency treatment/
54. exp radiofrequency/
55. exp radiofrequency radiation/
56. (radiofrequency or radio-frequency).mp.
57. exp THERMOCOAGULATION/ or thermocoag$.mp.

58.exp ELECTROCOAGULATION/ or electrocoag$.mp.
59.(neurotom$ or neuroly$).mp.
60.or/53-59
61.26 and 52 and 60

2013 strategy.

1. Clinical Article/
2. exp Clinical Study/
3. Clinical Trial/
4. Controlled Study/
5. Randomized Controlled Trial/
6. Major Clinical Study/
7. Double Blind Procedure/
8. Multicenter Study/
9. Single Blind Procedure/
10. Phase 3 Clinical Trial/
11. Phase 4 Clinical Trial/
12. crossover procedure/
13. placebo/
14. or/1-13
15. allocat$.mp.
16. assign$.mp.
17. blind$.mp.
18. (clinic$ adj25 (study or trial)).mp.
19. compar$.mp.
20. control$.mp.
21. cross?over.mp.
22. factorial$.mp.
23. follow?up.mp.
24. placebo$.mp.
25. prospectiv$.mp.
26. random$.mp.
27. ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).mp.
28. trial.mp.
29. (versus or vs).mp.
30. or/15-29
31. 14 and 30
32. exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/
33. human/ or normal human/ or human cell/
34. 32 and 33
35. 32 not 34
36. 31 not 35
37. neck muscles.mp.
38. exp NECK/
39. whiplash injuries.mp.
40. neck.mp.
41. or/37-40
42. exp SPINE/
43. discitis.mp.
44. exp Spine Disease/
45. (disc adj degeneration).mp.
46. (disc adj prolapse).mp.

47.(disc adj herniation).mp.
48.spinal fusion.mp.
49.spinal neoplasms.mp.
50.(facet adj joints).mp.
51.intervertebral disk.mp.
52.postlaminectomy.mp.
53.arachnoiditis.mp.
54.(failed adj back).mp.
55.or/42-54
56.radiofrequency denervation.mp.
57.exp RADIOFREQUENCY/
58.radiofrequency.mp.
59.denervation.mp. or exp DENERVATION/
60.57 or 58
61.59 and 60
62.exp THERMOCOAGULATION/
63.exp ELECTROCOAGULATION/
64.56 or 61 or 62 or 63
65.41 or 55
66.36 and 64 and 65
67.limit 66 to yr="2012 - 2014"
68.limit 66 to em=201212-201321
69.67 or 68

Previous searches used the following animal filter.

31 14 and 30

32 human/

33 Nonhuman/

34 exp ANIMAL/

35 Animal Experiment/

36 33 or 34 or 35

37 32 not 36

38 31 not 36

39 37 and 38

40 38 or 39

Appendix 5. CINAHL search strategy

Last searched May 30, 2014. The intervention terms were revised.

S56 S49 AND S55

S55 S50 OR S51 OR S52 OR S53 OR S54

S54 (MH "Radio Waves")

S53 neurotom* or neuroly*

S52 (MH "Electrocoagulation+") or electrocoag*

S51 thermocoag*

S50 radiofrequency or radio-frequency

S49 S28 and S48

S48 S35 or S43 or S47

S47 S44 or S45 or S46

S46 "lumbago"

S45 (MH "Spondylolisthesis") OR (MH "Spondylolysis")

S44 (MH "Thoracic Vertebrae")

S43 S36 or S37 or S38 or S39 or S40 or S41 or S42

S42 lumbar N2 vertebra

S41 (MH "Lumbar Vertebrae")

S40 "coccydynia"

S39 "coccyx"

S38 "sciatica"

S37 (MH "Sciatica")

S36 (MH "Coccyx")

S35 S29 or S30 or S31 or S32 or S33 or S34

S34 lumbar N5 pain

S33 lumbar W1 pain

S32 "backache"

S31 (MH "Low Back Pain")

S30 (MH "Back Pain+")

S29 "dorsalgia"

S28 S26 NOT S27

S27 (MH "Animals")

S26 S7 or S12 or S19 or S25

S25 S20 or S21 or S22 or S23 or S24

S24 volunteer*

S23 prospectiv*

S22 control*

S21 followup stud*

S20 follow-up stud*

S19 S13 or S14 or S15 or S16 or S17 or S18

S18 (MH "Prospective Studies+")

S17 (MH "Evaluation Research+")

S16 (MH "Comparative Studies")

S15 latin square

S14 (MH "Study Design+")

S13 (MH "Random Sample")

S12 S8 or S9 or S10 or S11

S11 random*

S10 placebo*

S9 (MH "Placebos")

S8 (MH "Placebo Effect")

S7 S1 or S2 or S3 or S4 or S5 or S6

S6 triple-blind

S5 single-blind

S4 double-blind

S3 clinical W3 trial

S2 "randomi?ed controlled trial*"

S1 (MH "Clinical Trials+")

2011 strategy.

S55 S49 and S53 20100101-20111231

S54 S49 and S53

S53 S50 or S51 or S52

S52 "electrocoagulation"

S51 thermocoagulation

S50 "radiofrequency denervation"

S49 S28 and S48

S48 S35 or S43 or S47

S47 S44 or S45 or S46

S46 "lumbago"

S45 (MH "Spondylolisthesis") OR (MH "Spondylolysis")

S44 (MH "Thoracic Vertebrae")

S43 S36 or S37 or S38 or S39 or S40 or S41 or S42

S42 lumbar N2 vertebra

S41 (MH "Lumbar Vertebrae")

S40 "coccydynia"

S39 "coccyx"

S38 "sciatica"

S37 (MH "Sciatica")

S36 (MH "Coccyx")

S35 S29 or S30 or S31 or S32 or S33 or S34

S34 lumbar N5 pain

S33 lumbar W1 pain

S32 "backache"

S31 (MH "Low Back Pain")

S30 (MH "Back Pain+")

S29 "dorsalgia"

S28 S26 NOT S27

S27 (MH "Animals")

S26 S7 or S12 or S19 or S25

S25 S20 or S21 or S22 or S23 or S24

S24 volunteer*

S23 prospectiv*

S22 control*

S21 followup stud*

S20 follow-up stud*

S19 S13 or S14 or S15 or S16 or S17 or S18

S18 (MH "Prospective Studies+")

S17 (MH "Evaluation Research+")

S16 (MH "Comparative Studies")

S15 latin square

S14 (MH "Study Design+")

S13 (MH "Random Sample")

S12 S8 or S9 or S10 or S11

S11 random*

S10 placebo*

S9 (MH "Placebos")

S8 (MH "Placebo Effect")

S7 S1 or S2 or S3 or S4 or S5 or S6

S6 triple-blind

S5 single-blind

S4 double-blind

S3 clinical W3 trial

S2 "randomi?ed controlled trial*"

S1 (MH "Clinical Trials+")

2010 strategy. Lines 24 to 29 were removed and the disorder terms were revised in 2011.

S47 S23 and S45 and S46

S46 S30 or S41

S45 S42 or S43 or S44

S44 "electrocoagulation"

S43 thermocoagulation

S42 "radiofrequency denervation"

S41 S40 or S39 or S38 or S37 or S36 or S35 or S34 or S33 or S32 or S31

S40 ""failed W1 back""

S39 (MH "Laminectomy")

S38 ""facet W1 joint""

S37 (MH "Spinal Fusion")

S36 ""disc W5 herniation""

S35 ""disc W5 prolapse""

S34 ""disc W5 degeneration""

S33 (MH "Spinal Diseases+")

S32 (MH "Intervertebral Disk")

S31 (MH "Spine+")

S30 S29 or S28 or S27 or S26 or S25 or S24

S29 (MH "Whiplash Injuries")

S28 (MH "Cervical Vertebrae")

S27 (MH "Neck Pain")

S26 (MH "Neck")

S25 "neck muscles"

S24 (MH "Neck Muscles")

S23 S21 not S22

S22 (MH "Animals+")

S21 S20 or S19 or S18 or S17 or S16 or S15 or S14 or S13 or S12 or S11 or S10 or S9 or S8 or S7 or S6 or S5 or S4 or S3 or S2 or S1

S20 "volunteer*"

S19 prospectiv*

S18 "control*"

S17 "follow-up stud*"

S16 (MH "Prospective Studies+")

S15 (MH "Evaluation Research+")

S14 (MH "Comparative Studies")

S13 "latin square"

S12 (MH "Study Design+")

S11 (MH "Random Sample+")

S10 "random*"

S9 "placebo*"

S8 (MH "Placebos")

S7 (MH "Placebo Effect")

S6 "triple-blind"

S5 "single-blind"

S4 "double-blind"

S3 ""clinical W8 trial""

S2 "randomi?ed controlled trial*"

S1 (MH "Clinical Trials+")

Appendix 6. PsycINFO search strategy

Last searched May 30, 2014. The intervention terms were revised.

1. clinical trials/
2. controlled trial.mp.
3. RCT.mp.
4. (Random$ adj3 trial).mp.
5. (clin$ adj3 trial).mp.
6. (sing$ adj2 blind$).mp.
7. (doub$ adj2 blind$).mp.
8. placebo.mp. or exp Placebo/
9. latin square.mp.
10. (random$ adj2 assign$).mp.
11. prospective studies/
12. (prospective adj stud$).mp.
13. (comparative adj stud$).mp.
14. treatment effectiveness evaluation/
15. (evaluation adj stud$).mp.
16. exp Posttreatment Followup/
17. follow?up stud$.mp.
18. or/1-17
19. back pain/
20. lumbar spinal cord/
21. (low adj back adj pain).mp.
22. (back adj pain).mp.
23. spinal column/
24. (lumbar adj2 vertebra$).mp.
25. coccyx.mp.
26. sciatica.mp.
27. lumbago.mp.
28. dorsalgia.mp.

29.back disorder$.mp.
30."back (anatomy)"/
31.((disc or disk) adj degenerat$).mp.
32.((disc or disk) adj herniat$).mp.
33.((disc or disk) adj prolapse$).mp.
34.(failed adj back).mp.
35.or/19-34
36.(radiofrequency or radio frequency).mp.
37.thermocoag$.mp.
38.electrocoag$.mp.
39.(neurotom$ or neuroly$).mp.
40.or/36-39
41.18 and 35 and 40

2012 strategy.

1. clinical trials/
2. controlled trial.mp.
3. RCT.mp.
4. (Random* adj3 trial).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
5. (clin* adj3 trial).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
6. (sing* adj2 blind*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
7. (doub* adj2 blind*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
8. placebo.mp. or exp Placebo/
9. latin square.mp.
10.(random* adj2 assign*).mp.
11.prospective studies/
12.(prospective adj stud*).mp.
13.(comparative adj stud*).mp.
14.treatment effectiveness evaluation/
15.treatment effectiveness evaluation/
16.(evaluation adj stud*).mp.
17.exp Posttreatment Followup/
18.follow?up stud*.mp.
19.or/1-18
20.back pain/
21.lumbar spinal cord/
22.(low adj back adj pain).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
23.(back adj pain).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
24.spinal column/
25.(lumbar adj2 vertebra*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
26.coccyx.mp.
27.sciatica.mp.
28.lumbago.mp.
29.dorsalgia.mp.
30.back disorder*.mp.
31."back (anatomy)"/
32.((disc or disk) adj degenerat*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
33.((disc or disk) adj herniat*).mp.
34.((disc or disk) adj prolapse*).mp.
35.(failed adj back).mp.
36.or/20-35
37.radiofrequency denervation.mp.

38.radiofrequency.mp.
39.thermocoagulation.mp.
40.electrocoagulation.mp.
41.or/37-40
42.19 and 36 and 41
43.limit 42 to yr="2011 - 2012"

2010 strategy, Cambridge Scientific Abstracts (CSA) database

((KW=(Randomi?ed controlled trial*) OR KW=(clinical trial*) OR KW=(clin* near trail*) OR KW= (sing* near blind*) OR KW=(sing* near mask*) OR (doub* near blind*) OR KW=(doubl* NEAR mask*) OR KW=(trebl* near mask*) OR KW=(trebl* near mask*) OR KW=(tripl* near blind*) OR KW=(tripl* near mask*) OR KW=(placebo*) OR KW=(random*) OR DE=(research design) OR KW=(Latin square) OR KW=(comparative stud*) OR KW=(evaluation stud*) OR KW=(follow up stud*) OR DE=(prospective stud*)OR KW=(control*) OR KW=(prospective*) OR KW=(volunteer*)) AND (DE=(back) OR DE=(back pain) OR DE=(neck))) AND ((KW=(radiofrequency denervation)) OR (KW=radiofrequency) OR (KW=thermocoagulation) OR (KW=electrocoagulation))

Date Range: 2010 to 2011

Appendix 7. Clinicaltrials.gov search strategy

Last searched May 29, 2014.

basic search: "back pain" and "radiofrequency"

2011 search.

Condition =back pain

AND

Intervention= radiofrequency OR electrocoagulation OR thermocoagulation

Appendix 8. WHO ICTRP search strategy

Last searched May 29, 2014.

basic search: "back pain" and "radiofrequency"

2011 search.

Condition =back pain

AND

Intervention= radiofrequency OR electrocoagulation OR thermocoagulation

Appendix 9. Assessment of risk of bias

Criteria for a judgement of 'yes' for sources of risk of bias (Furlan 2009).

1. Was the method of randomization adequate? Yes/No/Unsure
Random (unpredictable) assignment sequence. Examples of adequate methods include coin toss (for studies with 2 groups), rolling a dice (for studies with 2 or more groups), drawing of balls of different colors, drawing of ballots with study group labels from a dark bag, computer-generated random sequence, pre-ordered sealed envelopes, sequentially ordered vials, telephone calls to a central office and pre-ordered list of treatment assignments. Examples of inadequate methods include alternation, birth date, social insurance/security number, date on which they were invited to participate in the study and hospital registration number.

2. Was the treatment allocation concealed? Yes/No/Unsure
Assignment generated by an independent person not responsible for determining eligibility of patients. This person has no information about persons included in the trial and has no influence on assignment sequence nor on the decision about eligibility of the patient.

3. Was the patient blinded to the intervention? Yes/No/Unsure
This item should be scored “yes” if index and control groups were indistinguishable for participant, or if the success of blinding was tested among participants, and blinding was found to be successful.

4. Was the care provider blinded to the intervention? Yes/No/Unsure

This item should be scored “yes” if index and control groups were indistinguishable for care providers, or if the success of blinding was tested among care providers, and blinding was found to be successful.

5. Was the outcome assessor blinded to the intervention? Yes/No/Unsure

Adequacy of blinding should be assessed for primary outcomes. This item should be scored “yes” if the success of blinding was tested among outcome assessors, and blinding was found to be successful or:

- for participant reported outcomes for which the participant was the outcome assessor (e.g. pain, disability): The blinding procedure was adequate for outcome assessors if participant blinding was scored “yes”;
- for outcome criteria assessed during scheduled visit and that suppose contact between participants and outcome assessors (e.g. clinical examination): The blinding procedure was adequate if participants were blinded, and if treatment or adverse effects of treatment could not be noticed during clinical examination;
- for outcome criteria that do not suppose contact with participants (e.g. radiography, magnetic resonance imaging): The blinding procedure was adequate if treatment or adverse effects of treatment could not be noticed when the main outcome was assessed;
- for outcome criteria that were clinical or therapeutic events that would be determined by the interaction between participants and care providers (e.g. co-interventions, hospitalisation length, treatment failure), for which the care provider was the outcome assessor: The blinding procedure was adequate for outcome assessors if item “4” (caregivers) was scored “yes”; and
- for outcome criteria that were assessed from data on medical forms: The blinding procedure was adequate if treatment or adverse effects of treatment could not be noticed from extracted data.

6. Was the dropout rate adequately addressed? Yes/No/Unsure
The number of participants who were included in the study but did not complete the observation period or were not included in the analysis must be described and reasons given. If the percentage of withdrawals and dropouts does not exceed 20% for short-term follow-up and 30% for long-term follow-up, and does not lead to substantial bias, a “yes” is scored. (N.B. these percentages are arbitrary and are not supported by literature).

7. Were all randomly assigned participants analysed in the group to which they were allocated? Yes/No/Unsure
All randomly assigned participants were reported/analysed in the groups to which they were allocated by randomisation for the most important moments of effect measurement (minus missing values), irrespective of non-compliance and co-interventions.

8. Are reports of the study free of the suggestion of selective outcome reporting? Yes/No/Unsure
To assign a “yes”, the review author determines whether all results from all prespecified outcomes have been adequately reported in the published report of the trial. This information can be obtained by comparing the protocol versus the report or, in the absence of the protocol, by assessing that the published report includes enough information to permit this judgement.

9. Were the groups similar at baseline regarding the most important prognostic indicators? Yes/No/Unsure
To receive a “yes”, groups have to be similar at baseline regarding demographic factors, duration and severity of complaints, percentage of participants with neurological symptoms and the value of main outcome measure(s).

10. Were co-interventions avoided or similar? Yes/No/Unsure
This item should be scored “yes” if no co-interventions were provided, or if they were similar between index and control groups.

11. Was compliance acceptable in all groups? Yes/No/Unsure
The review author determines whether compliance with interventions is acceptable, based on reported intensity, duration, number and frequency of sessions for both index intervention and control intervention(s). For example, physiotherapy treatment usually is administered over several sessions; therefore, it is necessary to assess how many sessions each participant attended. For single-session interventions (e.g. surgery), this item is irrelevant.

12. Was the timing of outcome assessment similar in all groups? Yes/No/Unsure
Timing of outcome assessment should be identical for all intervention groups and for all important outcome assessments.

Appendix 10. Assessment of clinical relevance

Questions to determine whether results are clinically relevant (Furlan 2009).

Based on the data provided, can you determine whether the results will be clinically relevant?

1. Are participants described in detail, so that you can decide whether they are comparable with those seen in your practice? Yes/No/Unsure

2. Are interventions and treatment settings described well enough that you can provide the same for your patients? Yes/No/Unsure

3. Were all clinically relevant outcomes measured and reported? Yes/No/Unsure

4. Is the size of the effect clinically important? (30% on VAS/NRS; 8% to 12% for function)? Yes/No/Unsure

5. Are likely treatment benefits worth the potential harms? Yes/No/Unsure

WHAT'S NEW

Date	Event	Description
19 December 2014	New citation required but conclusions have not changed	Since the original review in 2003, 19 new studies about radiofrequency (RF) denervation for chronic low back pain have been published. The original review shows conflicting evidence for the effectiveness of facet joint RF denervation. In the current review, evidence remains conflicting; however, moderate evidence supports short-term effects on pain favouring RF denervation compared with placebo, and low evidence supports effects of RF denervation on function. In 2003, limited evidence showed that intra discal RF denervation may not be effective for discogenic pain. This review supports these results over the short term and over the intermediate term, but evidence of moderate quality shows small effects favouring RF denervation over the long term. The clinical plausibility of evidence of effectiveness only over the long term may be questioned. The current review found greater variation in control groups, most of which do not show significant differences compared with the RF denervation group. Only low-quality evidence supports effects favouring RF denervation compared with steroid injections for facet joint pain. The inadequate quality and size of the original studies did not allow inferences on the safety of RF denervation
19 December 2014	New search has been performed	This review is an update of a previous review that focused on both back pain and neck pain. This review incorporated 19 new trials about radiofrequency therapy for chronic low back pain. The search was updated in June 2015. One trial report was added to 'Studies awaiting classification' (Hashemi 2014) and three trial reports were added to 'Ongoing studies' (Albareeq 2015; Meckhail 2013; Mekhail 2015)
6 June 2010	Amended	The original review (Niemisto 2003) (Niemisto L, Kalso EA, Malmivaara A, Seitsalo S, Hurri H. Radiofrequency denervation for neck and back pain. Cochrane Database of Systematic Reviews 2003, Issue 1. Art. No.: CD004058. DOI: 10.1002/14651858.CD004058.) was split into separate reviews for neck pain and back pain, and the literature search was updated

CONTRIBUTIONS OF AUTHORS

L Niemisto, J Jousimaa, H Hurri and A Malmivaara were the authors of the original review: Radiofrequency denervation for neck and back pain, published in 2003. All participated in interpretation and writing of this update.

ET Maas participated in collection, extraction and analyses of the data; assessment of methodological quality, discussion of core ideas and writing of the paper.

RWJG Ostelo participated in extraction and analyses of the data; assessment of methodological quality; discussion of core ideas and interpretation and writing of the paper.

MW van Tulder participated in extraction of data, discussed core ideas, assessed methodological quality and participated in interpretation and writing of the paper.

DECLARATIONS OF INTEREST

ET Maas: none.

RWJG Ostelo: none.

L Niemisto: none.

J Jousimaa: none.

H Hurri: working for and leading the Rehabilitation Unit and Hospital of Orton, where radiofrequency is applied as well.

A Malmivaara: working as a scientific expert in the Research Unit of Orton.

MW van Tulder: none.

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Internal sources

- Dextra Medical Center, Finland.

External sources

- Finnish Office for Health Technology Assessment / Finohta, National Institute for Health and Welfare / THL, Finland.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In this review, we did not consider “ability to work” - an imperative criterion - as it is not always relevant among patients with CLBP. Only one study assessed treatment-related costs (Van Wijk 2005).

A description of the plan to analyse types of participants separately was added to the section Subgroup analysis and investigation of heterogeneity.

A description of the plan to perform sensitivity analyses was added to the section Sensitivity analysis.

INDEX TERMS

Medical Subject Headings (MeSH)

Catheter Ablation [*methods]; Chronic Pain [etiology] [*surgery]; Denervation [*methods]; Low Back Pain [etiology] [*surgery]; Randomized Controlled Trials as Topic

MeSH check words

Female; Humans; Male; Middle Aged