Systematic Review

Radiofrequency Ablation's Effectiveness for Treating Abdominal and Thoracic Chronic Pain Syndromes: A Systematic Review of the Current Literature

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Background: Many patients suffer from abdominal and thoracic pain syndromes secondary to numerous underlying etiologies. Chronic abdominal and thoracic pain can be difficult to treat and often refractory to conservative management. In this systematic literature review, we evaluate the current literature to assess radiofrequency ablation's (RFA) efficacy for treating these debilitating chronic pain conditions in the thoracic and abdominal regions.

Objectives: The objective of this study is to determine the pain relief efficacy of RFA on chronic thoracic and chronic abdominal disease states.

Study Design: This study is a systematic literature review that uses the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method to gather academic literature articles through a methodical approach. The numbers obtained from each academic manuscript were then used to calculate the percent efficacy of radiofrequency ablation on thoracic and abdominal pain relief.

Methods: Articles from 1992 through 2022 were gathered using PRISMA guidelines. The search terms "Radiofrequency Ablation Thoracic Pain" and "Radiofrequency Ablation Abdominal Pain" were used to identify articles to include in our study. Our search yielded a total of 575 studies, 32 of which were included in our study. The articles were then categorized into pain causes. The efficacy of RFA for each qualitative study was then quantified. Risk of bias was also assessed for articles using the Cochran Risk of Bias tool, as well as a tool made by the National Institutes of Health.

Results: The PRISMA search yielded a total of 32 articles used for our study, including 16 observational studies, one cohort study, 6 case reports, 6 case series, and 3 clinical trials. Twenty-five articles were labeled good quality and one article was labeled fair quality according to the risk of bias assessment tools. The studies examined RFA efficacy on chronic abdominal and chronic pain syndromes such as spinal lesions, postsurgical thoracic pain, abdominal cancers, and pancreatitis. Among these etiologies, RFA demonstrated notable efficacy in alleviating pain among patients with spinal osteoid osteomas or osteoblastomas, lung cancer, and pancreatic cancer. The modes of RFA used varied among the studies; they included monopolar RFA, bipolar RFA, pulsed RFA, and RFA at different temperatures. The average efficacy rate was 84% ranging from 55.8% - 100%. A total of 329 males and 291 females were included with ages ranging 4 to 90 years old.

Limitations: Limitations of this review include the RFA not being performed at the same nerve level to address the same pathology and the RFA not being performed for the same duration of time. Furthermore, the efficacy of RFA was evaluated via large case series and single cohort observational studies rather than control group observational studies and clinical trial studies.

Conclusion: A systematic review of the literature supports RFA as a viable option for managing abdominal and thoracic pain. Future randomized controlled trials are needed to investigate the efficacy of the various RFA modalities to ensure RFA is the source of pain relief as a large body of the current literature focuses only on observational studies.

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In 2019, the United States (US) Centers for Disease Control and Prevention conducted a survey and found up to 20% of US adults suffer from chronic pain; over a third of these adults had limited functional capacity due to their chronic pain (1). Thoracic and abdominal pain particularly has many causes, including tumor infiltration, ulcers, trauma, and focal neuralgia (2,3). Given the chronic and debilitating nature, these pain syndromes are associated with a significantly decreased quality of life (4,5). Often, a multidisciplinary approach is necessary to manage the pain (6). This makes these conditions both resource and financially intensive on the US health care system.

Treatment may include escalating opioid medication regimens for extended periods with limited pain control in combination with other prescribed multimodal and over-the-counter medications and physical therapy (7). This is concerning considering that there is an astounding 10.1 million people who misused opioid prescriptions in 2019 within the US alone (8). Even among patients who take opioid medications as prescribed, side effects such as constipation, nausea, vomiting, and respiratory depression are not uncommon as well as more nuanced physiologic effects, like opioid-induced endocrinopathy and hyperalgesia (9). Addressing thoracic and abdominal pain syndromes can be made further challenging because these conditions are often refractory to traditional pharmacologic therapy (10). If patients do not find pain relief, they may resort to more invasive techniques, such as radiofrequency ablation (RFA) (11). This procedure makes use of radiofrequency waves in the range of 350 - 500 kHz to thermally destroy tissue and can be used to reduce the size of abnormal growths (12). When applied to nerves, it prevents pain signals from being conveyed, thus reducing the amount of pain a patient experiences (13,14).

There are currently multiple types of RFA utilized under image guidance. The most common modalities including continuous radiofrequency ablation (CRFA), pulsed radiofrequency ablation (PRFA), and water-cooled radiofrequency ablation (WCRFA).

CRFA has been used since the mid 1970s (15). The magnitude of tissue destruction by this type of RFA is dependent on the temperature, size of the electrode, and duration of the procedure. On the other hand, PRFA has only recently been widely used (16). PRFA uses radiofrequency in short, but high-powered bursts. Additionally, PRF allows for pain control through neuromodulation methods instead of tissue destruction (17). A silent period that follows this burst keeps the target tissue below 40°C. WCRFA is similar to conventional RFA but uses a continuous flow of water within the needle to prevent the immediately adjacent tissue from reaching as high a temperature as conventional RFA, thus reducing tissue impedance to radiofrequency waves and generating greater sized lesions (18).

The goal of our study was to investigate how effective RFA is in managing chronic abdominal and thoracic pain while also measuring secondary outcomes, such as quality of life and mood pre- and post-procedure.

Methods

Study Design

In order to retrieve the articles used for our study, the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method was used (19). A comprehensive search of the PubMed (MEDLINE) database was employed to execute this study; articles were restricted to those in English. Articles were selected for inclusion based on relevance in accordance with the PRISMA methodology guidelines. The database searches consisted of using a broad keyword search, with the phrases "Radiofrequency Ablation Thoracic Pain" and "Radiofrequency Ablation Abdominal Pain" producing a total of 575 articles dating from 1992 through 2022. The criteria for inclusion and exclusion are shown in Fig.1.

Study Selection

Before screening the articles, 9 duplicates were removed. The remaining 566 articles were then screened based on the title of the article and the abstract. We excluded 461 articles during this process, leaving 105 articles remaining. The next step was to evaluate the full text of the manuscripts to assess its relevance to this systematic review. However, 7 of them could not be obtained because the full manuscript was not written in English or it could not be found. The full text of

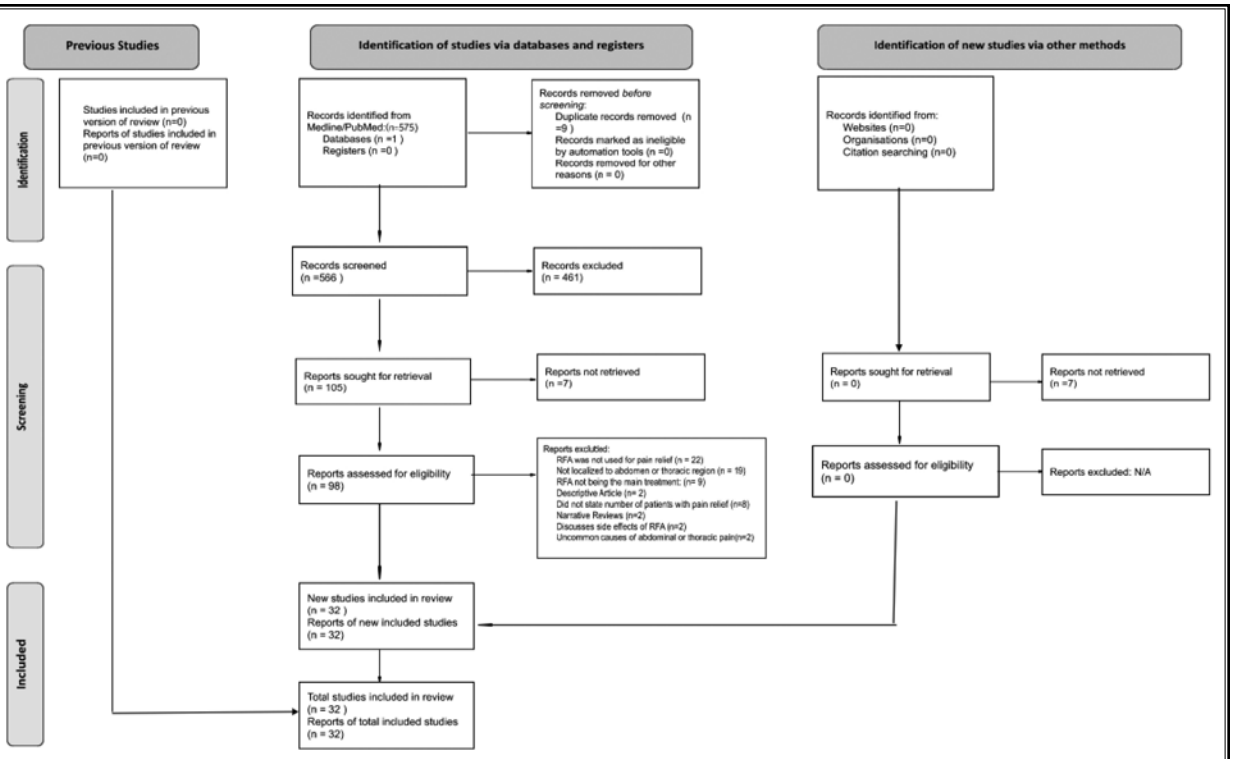

Fig. 1. Study flow chart.

98 articles were then evaluated and 66 of them were removed, for a final total of 32 manuscripts that were used in our systematic review. These 66 reports were excluded because they either examined procedures that were not RFA, RFA was not localized to the abdomen or thoracic region, or did not contain information relevant to our meta-analysis. The screening process is shown in Fig. 1.

After selecting the final articles, the manuscripts were then divided into their assessment topics. The 2 main categories included Radiofrequency Ablation in Patients with Thoracic Pain and Radiofrequency Ablation in Patients with Abdominal Pain. Among the data throughout the manuscripts, patients' pain levels were considered to be reduced if there was a statistically significant decrease as measured by evaluation surveys or by a significant reduction in opioid medication use. These numbers were then used to calculate the percentage of successful procedures among patients who underwent RFA for thoracic pain and abdominal pain.

Quality Assessment and Data Extraction

To assess quality and bias within the clinical trials identified in this study, the Cochran Risk of Bias tool was used to classify the trial as "high," "medium," or "low" bias across 6 domains (Fig. 2). The domains were treatment allocation blinding, missing data, selective reporting, imbalance dropout, similar groups at baseline, and allocation concealment and randomization (20).

To assess quality and bias of the observational and case series studies, we used the National Institutes of Health recommended tool used to assess for quality (Table 1). The quality assessment of these trials is shown in Table 2. The study quality assessment tool provided by the National Institutes of Health consists of 9 questions. We used it to evaluate the credibility of the studies used in our systematic literature review. The score from this survey determines a study's quality, with a score between 7-9 being good, 4-6 being fair, and 0-3 being poor (21).

Definitions

For measuring pain, the selected studies used either the Numeric Rating Scale (NRS-11) or the Visual Analog Scale (VAS). In the NRS-11 method, the patient specifies the amount of pain experienced by choosing a

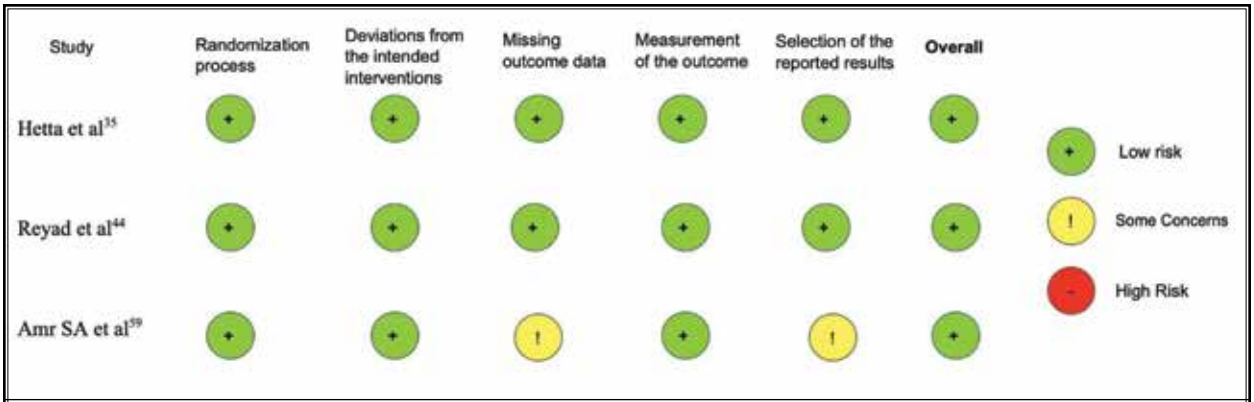

Fig.2. Cochrane risk of bias tool for randomized control trials assessment.

Table 1. *Quality Assessment Tool for Clinical Case Series (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools).*

Criteria	Yes	No
Was the study question or objective clearly stated?		
Was the study population clearly and fully described, including a case definition?		
Were the cases consecutive?		
Were the subjects comparable?		
Was the intervention clearly described?		
Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?		
Was the length of follow-up adequate?		
Were the statistical methods well-described?		
Were the results well-described?		

number between a range such as 0-10. Zero usually represents no pain being experienced and 10 usually represents the worst pain possible (22). On the other hand, the Verbal Rating Scale (VRS) uses a more categorical approach to rating pain, in which patients are asked to mark an adjective that best describes their pain.

Results

In the current literature, there have been multiple observational studies that tested the success of RFA for pain management in the thoracic and abdominal regions, including case series and case reports. To date, there are only 2 available randomized controlled clinical trials addressing the thoracic region and one clinical trial that is available for RFA in patients with abdominal pain. There were various causes of pain in these areas, as illustrated by the articles used in our study.

Study Screening

The broad search phrases used to gather relevant studies for our systematic literature review yielded a total of 98 articles with relevant titles and abstracts. We removed 66 of these articles after reading the full manuscript. The reasons for removal included RFA not being used for pain relief, the procedure not being localized to the thoracic or abdominal region, and RFA not being the main treatment. This screening left 32 articles for our systematic review

Study Quality

Twenty-five of the articles in our meta-analysis were labeled good quality and one was labeled fair quality according to the Cochrane Risk of Bias tool and the National Institutes of Health tool (23-57). The risk of bias assessment was not applied to 6 of the manuscripts because there was no tool available to assess case reports. The study by Amr et al (58) was labeled good quality, however, there were some concerns regarding the outcome data and the reported results (Fig. 2). One piece of data that was missing was the Karnofsky score

Table 2. *Quality assessment of case series using the National Institutes of Health tool.*

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Final Quality Score	Rating
Abdelgawaad et al (26)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Abd-Elsayed et al (47)	Y	Y	N	Y	Y	Y	Y	N	Y	7	Good
Beyer et al (32)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Cohen et al (39)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9	Good
Engel (49)	Y	Y	N	Y	Y	Y	N	N	Y	6	Fair
Garcea et al (62)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Grigoriadis et al (55)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Grönemeyer et al (27)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Hu et al (41)	Y	Y	N	Y	Y	Y	N	Y	Y	7	Good
Kim (50)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Lane et al (31)	Y	Y	N	Y	Y	Y	N	Y	Y	7	Good
Luo et al (48)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Munk et al (28)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Papadopoulos et al (57)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Sandri et al (30)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Speldewinde (51)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9	Good
Uchida (38)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
van der Linden et al (29)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
van Kleef et al (52)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
vanSonnenberg et al (43)	Y	Y	N	Y	Y	Y	Y	N	Y	7	Good
Yang et al (53)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9	Good
Zhang et al (56)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good
Zhou et al (40)	Y	Y	N	Y	Y	Y	Y	Y	Y	8	Good

Q1: Was the study question or objective clearly stated? Q2: Was the study population clearly and fully described, including a case definition? Q3: Were the cases consecutive? Q4: Were the subjects comparable? Q5: Was the intervention clearly described? Q6: Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants? Q7: Was the length of follow-up adequate? Q8: Were the statistical methods well-described? Q9: Were the results well-described? Quality score of 7-9 = Good, Quality score of 4-6 = Fair, Quality score of 0-3 = Poor

posttreatment, although the score was measured prior to the intervention. Amr et al (58) stated the reason for this missing data is because they used opioid use and quality of life to measure the efficacy of the intervention. Additionally, there were some concerns regarding the choice of results reported, such as the individual VAS scores of each patient involved in the study. They did not disclose individual VAS scores or mean values, only median values pre- and post-RFA.

Study Characteristics

In the 32 manuscripts used in our study, there were a total of 690 patients treated for either thoracic or abdominal pain with RFA. The various article types in our study includes 16 observational studies, one cohort study, 6 case reports, 6 case series, and 3 clinical trials. The median number of patients in the studies was 10; the average number of patients per study was 21.6. Of the 690 total patients, 582 experienced pain relief resulting in an average of 84% efficacy rate, ranging from 55.8% - 100%. A total of 329 males and 291 females were included in the study, which is not inclusive of all studies as some studies did not reveal the genders of their participants. Patient ages ranged between 4 to 90 years (most studies had inclusion criteria of greater than 18 years of age, but the study by Beyer et al [32] contained no such criteria).

Thoracic Pain Syndromes

The source of a large portion of thoracic pain was cancer. Studies by Abedelgawaad et al (26), Munk et al (28), Grönemeyer et al (27), Sandri et al (30), van der Linden et al (29), Lane et al (31), and Beyer et al (32) treated patients with lesions in the spine with RFA. A total of 177 patients were treated in these studies; 163

of them experienced pain relief according to their VAS scores. Studies were done by Zhou et al (40), Hu et al (41), and Halpin et al (42), to investigate the effects of RFA on thoracic pain due to non-small cell lung cancer. They demonstrated that 40 out of 53 patients had pain relief post-RFA. One study by vanSonnenberg et al (43) showed that 11 out of 11 patients with diverse thoracic cancers achieved pain relief post-RFA.

Other sources of pain include intercostal neuralgia, surgery, and thoracic facet syndrome. Hetta et al (37), Uchida (38), and Cohen et al (39) studied postsurgical thoracic pain; 40 out of the 61 patients experienced pain relief with RFA. Abd-Elsayed et al (47), Luo et al (48), and Engel et al (49) found in their studies that RFA reduced thoracic pain in 64 out of 80 patients with intercostal neuralgia. Regarding thoracic pain due to thoracic facet syndrome, Kim (50) performed one study and Speldewinde (51) another study; RFA reduced pain in 35 out of 55 patients. Finally, 2 studies, one done by van Kleef et al (52) and one by Yang et al (53) reported that 36 out of 58 patients with various causes of thoracic pain had pain relief post-RFA. Out of all of the studies that researched the efficacy of RFA on thoracic pain relief, it was successful in 389 out of 495 patients (78.6%). The type of RFA as well as the approach that was used in each study was also noted. These results are shown in Table 3.

Abdominal Pain Syndromes

Similar to thoracic pain syndromes, much of the cause of abdominal pain in the patients in our study was cancer. The studies by Noor et al (54), Grigoriadis et al (55), Zhang (56), Papadopoulos et al (57), Jin et al (59), and Amr et al (58) all contained quantitative information regarding the efficacy of RFA in patients with abdominal pain caused by pancreatic cancer (Table 4).

Noor et al (54) studied RFA in a 61-year-old patient with pancreatic cancer and a concurrent malignant carcinoid tumor in which RFA resulted in 80% pain relief after a follow-up of more than one month. Grigoriadis et al (55) examined the pain levels of 30 patients with pancreatic cancer post-RFA. They found that RFA significantly decreased pain levels after one week and that the levels remained decreased for 12 months. Zhang et al (56) studied the efficacy of RFA in 3 patients with pancreatic cancer. Pain levels were significantly decreased post-RFA for up to 12 weeks postprocedure. Additional studies that used RFA to decrease pain caused by pancreatic cancer include one by Papadopoulos et al (57). They found that 35 patients experienced decreased pain scores post-RFA. A study by Jin et al (59) reported one patient who had a decrease in pain scores while a noninferiority randomized controlled trial by Amr et al (58) reported 10 patients experienced reduced pain. There were a total of 80 patients in these studies, 78 of which experienced significantly lower pain levels post-RFA. This yields a 97.5% effectiveness rating for RFA in patients with pancreatic cancer. Garcea et al (60) conducted a similar study that investigated the efficacy of RFA in patients with chronic pancreatitis (Table 4). All 10 of their patients experienced significantly reduced pain levels, yielding an effectiveness rating of 100%.

Zaky et al (61) investigated the use of RFA in a 50-year-old patient with abdominal pain resistant to medications and steroid injections (Table 4). Post-RFA, the patient experienced a 50% reduction in her pain that lasted 5 months. A repeat RFA after 5 months improved the pain to 60%. Gambaro et al (62) conducted a case study in which RFA was used on a 40-year-old patient with loin pain hematuria syndrome (Table 4). This patient was reported to be pain-free on a scale of 0-10 6 months post-RFA. In another loin pain hematuria syndrome case study by Moeschler et al (63), a 50-year-old man experienced total pain relief in his right flank for 6 months post-PRFA. Zhang et al (56) studied the effect of RFA in 2 patients with cervical carcinoma, one patient with cholangiocarcinoma, and one patient with esophageal cancer (Table 4). Not only did they find that all of these patients had significantly reduced pain post-RFA, but they also found that these effects lasted for up to 12 weeks postprocedure. In the studies concerning RFA and its effect on patients with abdominal pain, 49 out of 51(96%) experienced significantly decreased pain levels. The type of RFA used to treat abdominal pain and the approach is shown in Table 4. Among the 546 patients with either chronic abdominal or thoracic pain, RFA was effective in 438 patients (80%).

Discussion

Although RFA was first described in 1931, it was not until 1975 that RFA was first used as a therapy for chronic pain (23,64). RFA is now typically used near or directly at peripheral nerves along the spinal cord to treat chronic back and neck pain (24). RFA has also been used for facet joint-mediated pain and discogenic back pain (25). The literature has less frequently demonstrated the utility of RFA in thoracic and abdominal pain. In this study, therefore, we chose articles that contained information on the efficacy of RFA on chronic thoracic and abdominal pain and investigated the efficacy of RFA on these conditions.

Table 3 *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Abdelgawaad et al (26)	Retrospective Observational Study	2020	Lesions in either the thoracic spine or lumbar spine	60	50	83.3%	Bipolar cooled RFA at 70°C	Bi-pedicular approach, unipedicular approach, and bipolar approach	Painful Spine Metastases	VAS score significantly decreased 3 days and 6 months after the procedure.	Pt's had either lesions in the thoracic spine or in the lumbar region. 29/46 had lesions in the thoracic region while the rest had lesions in the lumbar	Good
Abd-Elsayed et al (47)	Case Series	2018	Intercostal nerves at ribs 4,5,6, and 7 and intercostal nerves at ribs 9-12	2	2	100%	Thermal radiofrequency ablation at 80°C	Fluoroscopy to position needle under the inferior border of the intercostal space	Intercostal neuralgia	Both patients were completely resolved of pain.	Case studies	Good
Beyer et al (32)	Multicenter, Case Series	2019	Nidus in the cervical, thoracic, lumbar, or sacral spine. Specific location not noted.	87	86	98.9%	Monopolar RFA at 90 °C	Interlaminar approach	Spinal osteoid osteomas and osteoblastomas	Decrease in VAS score.	Patients with either osteoid osteomas or osteoblastomas in the spine were treated with CT-guided RFA. Locations include cervical, thoracic, lumbar, and sacral spine.	Good
Cohen et al (39)	Retrospective Observational Study	2006	Dorsal root ganglia or intercostal nerve.	28	12	42.9%	Pulsed RFA at 42°C	Electrode was fluoroscopy-guided through the thoracic intervertebral foramen targeting the DRG. For the ICN, the fluoroscopy guided electrode approached the bottom of the rib lateral to the vertebral body.	Chronic post surgical thoracic pain	Pain was measured at 6 weeks and at 3 months. Patients who had radiofrequency ablation in the dorsal root ganglia had higher pain relief than the intercostal nerve.	Retrospective study. The radiofrequency location was different. One was on dorsal root ganglia while the other was on intercostal nerves. Also, they tested pain at 6 weeks and 3 months and there can be variations in data due to this.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Engel (49)	Case Series	2012	Right 8th,9th, and 10th intercostal nerve; left 11th and 12th intercostal nerve; left 6th and 7th intercostal nerve; left 10th, 11th, and 12th intercostal nerve; left 4th, 5th, 6th, 7th, and 8th intercostal nerve; left 9th and 10th intercostal nerve	6	6	100%	Conventional thermal radiofrequency ablation	Repositioned needle from rib to intercostal groove using fluoroscopy	Thoracic Facet Disease	All patients experienced pain relief but 2 of them had their pain return.	Patients that have chest pain due to trauma were treated with RFA. All 6 patients had pain relief but 2 patients experienced more pain after a fusion surgery and the other required an additional treatment. Limited due to case study	Fair
Grönemeyer et al (27)	Case Series	2002	Location of the metastases in T3,T4, T8, T10,T11, T12	4	3	75%	RFA at 50°C-120°C	Transpedicular approach into the tumor	Spine Metastases	Average of 74% decrease in pain according to the VAS scale.	Patients were treated for metastatic lesions in the lumbar, thoracic, or sacral region. 9 out of 10 of them found pain relief but only the patients treated with thoracic lesions were included in our study. Vertebroplasty was used in some of the patients. Prospective observational study.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Halpin et al (42)	Case Report	2004	Lesions at T9	1	1	100%	RFA at 100°C	Fluoroscopically guided needle placement into vertebral body of T9	Metastatic non-small cell lung cancer	2 months after the treatment, the pt reported pain relief and halting intake of pain medication.	Case study where pt had back pain in the thoracic region due to non-small cell lung cancer. RFA was performed as well as vertebroplasty.	N/A
Hetta et al (37)	Randomized Clinical Control Trial	2021	T2, T3, and T4 sympathetic ganglia.	30	25	83.3%	RFA at 80°C	Posterior third of the vertebral body shadow below the pedicle	Post-mastectomy pain syndrome	50% decrease in VAS score 6 months after the treatment	Pt's with post-mastectomy pain received thoracic sympathectomy and their VAS score was measured after. 25/30 had more than 50% pain relief.	Good
Hu et al (41)	Retrospective Observational Study	2015	Location of the tumor in the ribs.	12	12	100%	RFA between 80°C-90°C	CT was used to identify lesion location prior to RFA	Rib metastasis of non-small cell lung cancer	Average VAS score decreased 24 hours after the radiofrequency ablation.	Patients with non-small lung cancer present with pain in the ribs.	Good
Kim (50)	Case Series	2014	L1, T2-T9 facet joints.	9	6	66.7%	Bipolar RFA at 80°C	Inferior aspect of thoracic facet joint using the ISIS approach	Thoracic facet disease	100%-60% decrease in VAS score.	Patients with mid-back pain underwent bipolar radiofrequency thermocoagulation at the thoracic facet joint.	Good
Lane et al (31)	Retrospective Observational Study	2011	L1, L2, T6-T12	10	9	90%	RFA at 95°C	Uni or bi transpedicular route for vertebral lesions	Neoplastic bone metastasis	VAS score decreased in all but 1 of the patients with lesions in the thoracic region.	Patients were treated with RFA and cementoplasty for painful metastasis in the various bone regions. Patients with lesions in the thoracic region were chosen to be in our study.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Luo et al (48)	Retrospective Observational Study	2020	Thoracic nerve root	72	56	77.8%	Bipolar RFA 40°C-70°C	Introducer needle targeted the upper edge of intervertebral foramen using CT-guidance	Postherpetic neuralgia	Average VAS scores decreased post-ablation.	Coblation used on the thoracic segment for patients with postherpetic neuralgia.	Good
Munk et al (28)	Retrospective Observational Study	2009	T9 and T12	3	3	100%	Cooled RFA	Transpedicular approach in the vertebra, Anterolateral approach in the acetabulum, Posteroinferior approach in the sacrum	Prostate, lung (non-small cell lung cancer), and pheochromo-cytoma	Decreased VAS score	3 patients out of the 19 had lesions in the thoracic vertebrae.	Good
Reyad et al (46)	Clinical Trial	2019	Thoracic dorsal root ganglia	78	78	100%	Thermal ra-diofrequency ablation at 80°C	Thoracic root ganglia transforaminal approach	Lung cancer, mesothelioma, chest wall tumor, and chest metastasis	Average VAS score decreased in both groups, however, the manuscript did not note if there were patients that did not have pain relief.	VAS score, improvement in function, patient's impression regarding the treatment, and pregabalin and oxycodone intake were compared between the two groups. The Two groups were Xper guided CT fluoroscopy guidance and fluoroscopy guidance only.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Sandri et al (30)	Retrospective observational study	2010	Lesions on T6, T7,T8,T9,T10, T12	9	9	100%	RFA between 80°C and 100°C	Extrapedicular approach above T10 and transpedicular approach below T10	Kidney neoplasm, thyroid neoplasm, and multiple myeloma,	Average VAS score decreased compared before the treatment at 72 hrs and 6 weeks after the RFA.	Patients that were treated had metastases at the cervical, lumbar, and thoracic regions. Only patients with thoracic metastases were collected. Radiofrequency was combined with kyphoplasty	Good
Speldewinde (51)	Retrospective Cohort Study	2021	Thoracic medial branch nerve from T1 to L1.	46	29	63%	Thermal radiofrequency at 80°C	Fluoroscopically guided, superior to the transverse process	Thoracic zygapophyseal joint pain	Pain was measured at 3 and 6 months, and the study discovered that patients had an average of 7.8 months of more than 50% pain relief.	Retrospective study. Targeted at different thoracic joints and the pain was measured at different times. The article does not state what it used for measuring pain.	Good
Uchida (38)	Case Series	2009	Thoracic paravertebral nerve at T2, T3, and T4 for 2 of the patients. T2-T6 for one of the patients.	3	3	100%	RFA at 90°C	Laterodorsal approach to place needle in posterior aspect of intervertebral foramen	Neuropathic pain after breast cancer surgery	All patients had reduced VAS scores	Case Studies Patients were treated with glucocorticoids as well.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain.*

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
van der Linden et al (29)	Retrospective Observational Study	2007	Tumor on TH4, TH8, TH9, and TH12	4	3	75%	RFA at 100°C or cooled RFA	Unipedicular or bipedicular approach	Vertebral tumor	Average VAS score significantly decrease after 1 week and 3 months after the procedure.	RFA was treated with vertebroplasty as well. Patients had lumbar, thoracic, and cervical spine pain but individual patients were picked out with thoracic pain. Not a lot of patients in the study. Also deceased patients, long term effects difficult to evaluate. All patients had damage to their posterior wall.	Good
van Kleef et al (52)	Observational Study (follow-up study)	1995	Dorsal root ganglion below and above T7, depending on where the prognostic nerve block was most effective.	43	24	55.8%	Type of RFA not specified	Dorsal root ganglion was targeted through craniodorsal part of intervertebral foramen	Posttraumatic segmental neuralgia, collapsed vertebrae, slipping rib syndrome, twelfth rib syndrome, pain of spinal origin, and segmental peripheral neuralgia.	Pain scores were measured 8 weeks and more than 36 weeks after treatment. There was a higher percentage of patients with relief at 8 weeks than at more than 36 weeks.	Pain relief was measured at 8 weeks and at 36 or more weeks after radiofrequency ablation was performed on dorsal root ganglion. Different amounts of pain relief due to depending on the time post-treatment.	Good

Table 3 cont. *Radiofrequency ablation in patients with thoracic pain*.

Article	Study Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
vanSonnenberg et al (43)	Prospective Observational Study	2005	Ablation was performed at the location of the lesion in the lungs, pleura, and ribs	11	11	100%	Cooled RFA	Extrapulmonary approach, transosseous approach, and transcartilaginous approach	Primary lung cancers, secondary lung cancers, and mesothelioma.	4 patients had their pain resolved and 7 of them had decreased pain/	30 patients with thoracic tumors underwent radiofrequency ablation for reasons such as cure, tumor control, and pain. 11 of the patients came in for pain. One thing to note is that some patients underwent adjunctive procedures such as nerve blocks to facilitate the treatment.	Good
Yang et al (53)	Prospective observational study	2017	Thoracic Paravertebral Nerve	15	12	80%	Bipolar RFA at 10°C-40°C	Paravertebral nerve exiting the intervertebral foramen	Postherpetic neuralgia, post-thoracotomy pain, and post-thoracic trauma pain.	VAS score had significantly decreased at 1 week, 1 month, 3 months, and 6 months after coblation.	Coblation was localized to the thoracic paravertebral nerve. The Causes of pain in the patients vary from postherpetic neuralgia, post-thoracotomy pain, and post-thoracic trauma pain.	Good
Zhou et al (40)	Retrospective observational study	2021	Tumor in the chest wall, vertebral body, rib, and periphery tumor nodule	40	27	67.5%	Type of RFA not specified	Ultrasound or CT was used to guide RFA towards the multiple ablation zones of the tumor.	Non-small cell lung cancer	Average VAS score decreased at 25 hrs, 72 hrs, and 4 weeks post radiofrequency ablation. .	Patients with non small cell lung cancer There were a couple of complications after treatment such as infection, pleural effusion, and pneumothorax. .	Good

Table 4. *Radiofrequency ablation in patients with abdominal pain.*

Article	Article Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Amr et al (58)	Clinical trial	2018	Bilateral splanchnic nerve block at T10 and T11	30	30	100%	Monopolar RFA at 85°C	Retrocrural approach at T10 and T11	Duodenal cancer, gallbladder cancer, hepatocellular carcinoma, hepatic focal lesion, esophageal cancer, pancreatic cancer, retro-peritoneal mass, right colon cancer, stomach cancer, suprarenal mass.	VAS decreased by 85.71% for patients who underwent RFA neurolysis	RFA neurolysis was compared between chemical neurolysis and was found to be more effective at reducing pain with abdominal pain. Although it did not say the amount of patients in the study with pain relief, it is assumed that all 30 patients had pain relief due to the median VAS decreasing by 85.71%	Good
Gambaro et al (63)	Case Report	2013	Right renal artery, arterial wall near the renal hilum	1	1	100%	Type of RFA not specified	Percutaneous femoral access to target right renal artery	Loin pain haematuria syndrome	Patient reports to be pain free on a scale of 1-10 6 months post procedure	Case report, loin pain hematuria syndrome	N/A
Garcea et al (62)	Retrospective observational study	2005	Splanchnic nerve at T12	10	10	100%	RFA at 80°C	Percutaneous RFA on splanchnic nerve	Chronic pancreatitis or chronic abdominal pain due to unknown cause	All patients experienced pain alleviation after RFA. Ratings were significantly lower after RFA at its worst, at best, and at average	Retrospective observational study, chronic abdominal pain(chronic pancreatitis). Patients scored pain before and after RFA on a scale of 0-10 (10 being worst pain) at its best, worst, and average intensity of pain. RFA also improved other parameters such as anxiety, daily activity, and mood	Good

Table 4 cont. *Radiofrequency ablation in patients with abdominal pain.*

Article	Article Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Grigoriadis et al (55)	Prospective Observational study	2021	Splanchnic nerve at T12	30	28	93.3%	RFA at 85°C	Percutaneous neurolysis using the bilateral retrocrural paravertebral approach	Pancreatic cancer	NVS significantly decreased after 1 week and remained at similar level for 12 months	Pain decreased regardless of age or gender in patients with pancreatic cancer. Significantly reduced analgesic usage reported in 28/30 patients. 13 and 19 patients out of 30 died due to disease progression at 6 and 12 months respectively.	Good
Jin et al (59)	Case Report	2014	Celiac ganglion	1	1	100%	Type of RFA not specified	Approach not specified.	Pancreatic cancer	VAS score decreased from 8 to 2	Patients with pancreatic cancer treated with RFA to relieve pain.	N/A
Moeschler et al (64)	Case Report	2013	Splanchnic nerves bilaterally at T12, L1	1	1	100%	RFA temperature never exceeded 42°C	Retrocrural approach	Loin pain hematuria syndrome	95% improvement in right flank pain even after 6 months, left side flank pain returned after two months	Case report, loin pain hematuria syndrome Improvement in functionality, decreased opioid medications	N/A
Noor et al (54)	Case Report	2020	Splanchnic nerve at T11, superior hypogastric plexus at L5	1	1	100%	RFA at 60°C	Needle was applied dorsal to the anterior vertebral body and caudad to the transverse process.	Malignant carcinoid tumor of the anterior duodenum and pancreatic cancer	80% pain relief in both mid-epigastric and lower abdomen	Case Study, carcinoid tumor and pancreatic cancer	N/A

Table 4 cont. *Radiofrequency ablation in patients with abdominal pain.*

Article	Article Type	Year	Nerve Targets	Number of Patients Treated	Number of Patients With Pain Relief	Total Percent With Pain Relief	Mode of RFA	Approach	Entity Treated	RFA Efficacy	Main Findings	Risk of Bias Assessment
Papadopoulos et al (57)	Retrospective observational study	2013	T11 and T12 vertebra	35	35	100%	Monopolar RFA at 85°C	Needle was placed at the lateral border of the vertebra and below the costovertebral angle.	Pancreatic cancer	NRS Pain scores displayed a significant decrease post-operatively and throughout the follow up except at month 5	35 patients with abdominal pain caused by pancreatic cancer were treated with RFA. NRS scores were measured as well as their opioid consumption and quality of life scores were measured pre and post operatively.	Good
Zaky et al (65)	Case report	2017	Anterolateral aspect of T11, T12	1	1	100%	Thermal RFA at 80°C	Anterolateral aspect of T11 and T12 using fluoroscopy.	Resistant abdominal pain after cholecystectomy	50% reduction in pain for 5 months, repeat RFA with pain reduction of 60%	Case Study, resistant abdominal pain	N/A
Zhang et al (56)	Prospective Observational Study	2018	Abdominal aorta close to the origin of celiac artery and superior mesenteric artery	7	7	100%	RFA at 60°C	Aortography-guided transfemoral approach	Pancreatic cancer, cervical carcinoma, cholangiocarcinoma, and esophageal cancer	Pain scores at 1, 2, 4, 8, and 12 weeks were all significantly lower than before the RFA procedure. The average VAS score decreased by at least 3 points in all patients	All patients in this study were cancer patients. 3 had pancreatic cancer, 2 cervical carcinoma, 1 cholangiocarcinoma, and 1 esophageal cancer Patients' quality of life improved significantly	Good

Thoracic Pain

Spinal Lesions

Six retrospective studies and one prospective study tested the efficacy of RFA for pain relief for patients with spinal lesions (26-32). A total of 177 patients were treated with RFA for their spinal metastasis; 163 (92%) of them had pain relief.

The type of radiofrequency used was cooled bipolar RFA in the Abedelgawaad et al study (26). The studies by Abedelgawaad et al (26) and Sandri et al (30) suggest that radiofrequency paired with kyphoplasty is effective for managing pain, however, there was no control group; therefore, the cause of pain relief is unknown. In the Grönemeyer et al study (27), some of the patients were treated with vertebroplasty combined with RFA. All of the patients were treated with vertebroplasty combined with RFA in van der Linden et al (29), and patients were treated with vertebroplasty in addition to RFA in the Munk et al (28) study, and the Lane et al (31) study.

It is important to note that in the Grönemeyer et al (27), Munk et al (28), van der Linden et al (29), Sandri et al (30), and Lane et al (31), studies only the patients with thoracic pain were included in our systematic review because a portion of the patients had pain located in other regions besides the thoracic region. All of the patients in the Abdelgawaad et al (26) and Beyer et al (32) studies were included in our systematic review because the patients with pain in other regions besides the thoracic region were not specified. Additionally, patients in the van der Linden et al (29) study had damage to their posterior vertebral wall.

Many studies have supported the use of RFA for pain caused by thoracic lesions in the spine. A study by Zheng et al (33) demonstrated a decrease in VAS post-RFA and kyphoplasty. However, their study did focus on RFA in the lumbar and sacral regions as well. One study by Mayer et al (34) was also able to support the efficacy of bipolar RFA on spinal lesions by obtaining results that reported 80% of the metastases (16/20) treated resulted in pain relief according to the decrease in average VAS score. However, these results were not exclusive to the thoracic spine tumors because patients with lumbar, sacral, and cervical tumors were included as well. Another study by Sayed et al (35) reported an average decrease in NRS-11 scores for patients with a metastasis or metastases in the lumbar or thoracic region post-bipolar RFA, however, this study added cement vertebral augmentation to the treatment as well. Also, the patients involved were only treated on no more than 2 segment levels (35). Another study by Bagla et al (36) supported the efficacy of RFA with cement augmentation by showing improvement in average pain and quality of life in patients with painful vertebral body metastases.

Postsurgical Thoracic Pain

One prospective randomized clinical trial, one retrospective study, and one case study analyzed the effect of radiofrequency ablation on pain caused by surgery (37-39). A total of 40 out of 61 patients treated experienced pain relief. Approximately 65% of the patients were able to manage their pain from radiofrequency treatment. Although the percentage is low, the studies by Hetta et al (37) and Uchida (38) had a success rate of 100% and 83.3% respectively. These 2 papers had a high success rate, but the study by Cohen et al (39) did not, with only a success rate of 42%. This percentage emphasizes the importance of the location of radiofrequency treatment because the success rate was higher when treatment was concentrated on the dorsal root ganglion (53.8%) instead of the intercostal nerve (6.7%). Additionally, the study written by Hetta et al (37) reported a reduced use of analgesic medications, which suggests a significantly reduced pain level experienced by the patients.

Non-small Cell Lung Cancer

Two retrospective studies and one case study evaluated radiofrequency treatment on patients with pain due to non-small cell lung cancer (40,41,42). A total of 40 patients out of 53 (75%) had their pain alleviated by radiofrequency. The results from all of the studies suggest that RFA can be used to treat pain caused by nonsmall cell lung cancer. It is also important to note that in the Zhou et al (40) study, the amount of opioid use was reduced by 92.5%. Additionally, the case study written by Halpin et al (42) noted that the patient received vertebroplasty treatment in addition to RFA. Because both treatments complemented each other, there exists the confounding factor of whether RFA or vertebroplasty was the source of pain relief.

Other Cancers

A study by van Sonnenberg et al (43) examined the effects of RFA on thoracic lesions caused by various cancers. RFA was performed for either tumor control or pain control. Out of the 11 patients that were treated for pain control, all of them had their pain decrease.

Although RFA seemed to be effective in their study, it is important to note that some of the patients had additional treatments (43).

A study by Oh et al (44) concurred with the efficacy of RFA for thoracic pain caused by cancer. The median NRS-11 score was reduced by 40% one week after the thoracic nerve root was ablated. Additionally, they reported a 10% reduction in opioid use. A limitation of this study is the pain score was not specific to only chest pain, therefore, the amount of chest pain relieved from the procedure may not be accurate (44).

A study by Grieco et al (45) demonstrated the efficacy of RFA when 44 various tumors causing chest pain were ablated. A total of 31 of these patients experienced decreased pain. Some limitations of their study include that 6 of the 44 ablations were performed with microwave or cryoablation instead of RFA. Also, many of the patients had radiotherapy in addition to the ablation (45). A study by Reyad et al (46) also supported RFA by showing a decrease in average VAS scores in 78 patients with chest malignancies. They were even able to show some improvements to RFA using combined computed tomography and fluoroscopy compared to RFA guided solely by conventional fluoroscopy.

Intercostal Neuralgia

Regarding using RFA to treat pain due to intercostal neuralgia, one retrospective study, and 2 case studies were collected (47-49). A total of 64 out of the 80 patients (80%) had their pain decreased. All of the studies concluded that RFA is effective for intercostal neuralgia pain management. In Luo et al (48), patients not only had pain relief according to their VAS scores, but they also had decreased usage of anticonvulsants and analgesics. The study also reported an improved quality of life (QoL) according to the decrease in QoL scores.

Thoracic Facet Syndrome

One pilot study and one retrospective study analyzed the results of radiofrequency treatment on patients with pain in their thoracic facet joints (50,51). A total of 35 out of 55 patients (64%) had pain relief. Both studies suggest that their form of radiofrequency treatment may be reasonable for treating pain of thoracic facet origin. Additionally, in the study by Speldewinde (51), QoL improved in 36% of the patients treated with radiofrequency according to the decrease in functional rating index. It is also important to note that in the study by Kim (50), the radiofrequency used was bipolar radiofrequency thermocoagulation.

Miscellaneous

One study and one pilot study evaluated the efficacy of RFA for relieving thoracic pain of various causes (52,53). Out of the 58 patients involved in both studies, 36 (62%) of them had their pain alleviated. Of note, in the van Kleef et al study (52), the treatment was more effective in patients when the pain was localized on no more than 2 segments. Both studies suggest that RFA may be an effective treatment, however, the location of the ablation was different between the 2 studies. The radiofrequency treatment was applied near the dorsal root ganglion in the van Kleef et al study (52) while in the Yang et al study (53), the treatment was applied to the thoracic paravertebral nerve.

Out of all the studies, there was no singular type of RFA or approach that was used to treat the conditions that caused the chronic thoracic pain. Different types of RFA, such as monopolar RFA, bipolar RFA, pulsed RFA, and RFA at different temperatures, were used to treat the various pain-causing conditions. Additionally, the RFA was applied to different targets for pain relief.

Abdominal Pain

Abdominal Cancers

Two prospective cohort studies, one retrospective observational case study, one randomized clinical control study and 2 case studies investigated the efficacy of RFA in patients suffering from abdominal pain due to pancreatic cancer (54-59). A total of 80 patients with pancreatic cancers underwent RFA. Of these patients, 78 (98%) experienced significantly lower pain scores. In the study by Grigoriadis et al (55), patients reported significantly decreased pain one week post-RFA of the splanchnic nerve at T12, with the relief lasting for 12 months. However, it is important to note that 30 of these patients died within one year of the study (55). Among the 3 patients with pancreatic cancer studied by Zhang et al (56), pain scores at one, 2, 4, 8, and 12 weeks were all significantly lower post-RFA at the level of the abdominal aorta. Papadopoulos et al (57) examined the effect of RFA targeting splanchnic nerves on 35 patients with end-stage pancreatic cancer. They found that pain levels were reduced for up to 5 months postprocedure. In a randomized controlled trial by Amr et al (58), RFA was performed on 10 patients with pancreatic cancer at the splanchnic nerves at T10 and T11. The median VAS decreased by 85.71% after one week of treatment. Patients had reduced pain for 3 months post-RFA (58). The patient in the Jin et al (59) case study

also had a decrease in pain level, however, he died of an unspecific dyscrasia at 3 months posttreatment. Altogether, this suggests that RFA may be an effective treatment for abdominal pain due to pancreatic cancer for up to 12 months, but offers limited longevity benefits due to the aggressive nature of pancreatic cancer (65). Furthermore, a majority of the patients from these articles reported an improvement in their QoL.

A randomized controlled trial compared the use of RFA to celiac plexus neurolysis in patients with locally advanced or metastatic pancreatic cancer (66). They specifically found that RFA resulted in significantly reduced pain levels at 4 weeks when compared to celiac plexus neurolysis. This suggests that RFA can potentially perform at a level comparable to, if not better, than celiac plexus neurolysis. However, higher powered studies are needed to prove this claim.

The study by Zhang et al (56) investigated RFA for abdominal pain management in other types of cancers as well. Specifically, 2 patients had cervical carcinoma, one had cholangiocarcinoma, and one had esophageal cancer. Each of these patients reported significantly reduced pain scores at one, 2, 4, 8 and 12 weeks post-RFA in comparison to baseline levels before RFA. All patients underwent RFA at the level of the abdominal aorta (56). In Amr et al (58), RFA was performed in 20 patients with abdominal cancer other than pancreatic cancer, resulting in effective pain control. Not only did RFA reduce pain scores compared to the control group, but there were also no major complications and it reduced daily opioid consumption (58). This suggests that RFA is useful in managing pain caused by abdominal cancers other than pancreatic cancer.

Chronic Pancreatitis

One retrospective observational study investigated the effect of RFA on 10 patients with abdominal pain due to chronic pancreatitis (60). RFA at the splanchnic nerve at T12 was 100% effective in these patients. Specifically, they experienced significantly decreased pain levels post-RFA at their pain's worst, best, and average. Furthermore, these patients also reported less analgesia use, increased daily activity, and better mood.

Loin Pain Hematuria Syndrome (LPHS)

One case report by Gambaro et al (63) was reviewed for our systematic review. They specifically studied a 40-year-old woman with loin pain hematuria syndrome (LPHS) that was refractory to medications. Post-RFA to the right renal artery, the patient reported being pain-free for 6 months. Another case report by Moeschler et al (63) examined a 50-year-old man with LPHS. Post-RFA at the splanchnic nerves bilaterally at T12 and L1, there was a 95% improvement in right flank pain for 6 months, although left-sided flank pain returned after just 2 months. Although these studies suggest that RFA can be used in patients with LPHS, more studies need to be performed with larger sample sizes.

Miscellaneous

Zaky et al (61) investigated the use of RFA in a 50-year-old woman with pain that persisted for 2 years postcholecystectomy. A bilateral splanchnic nerve block with steroid injection was used. Although this resulted in significant pain relief, it only lasted for 3 weeks. The patient underwent RFA at the splanchnic nerves at T11 and T12 after pain recurred. The patient reported a 50% reduction in pain which continued for 5 months. A repeat RFA was performed after 5 months, providing the patient 60% pain relief (61). Although this suggests that RFA can be used in patients with postsurgical abdominal pain, more studies are needed to support this claim. Overall, there are various RFA methods used to treat abdominal pain and the location the RFA is applied varies.

Limitations

RFA has notable applications but it has a few limitations. Specifically, our study's limitations include the inconsistency with which RFA was targeted to certain nerves for a given medical condition. For example, among the articles that studied RFA in patients with pancreatic cancer, one study tested RFA at the splanchnic nerve at T11, another at T12, and another at the level of the abdominal aorta.

Furthermore, studies differed in the duration RFA was applied for the destruction of nerves, ranging anywhere from 30 seconds to 12 minutes. These inconsistencies may have altered the findings of our data.

In addition, the sample from each article may not have been sufficient to make a conclusion. For example, all patients who underwent RFA for LPHS had an improvement in their pain, but only 2 patients were included to make this conclusion.

Another limitation of our study is the lack of a gold standard for chronic pain refractory to medications. Some studies, for example, compared RFA to celiac plexus neurolysis, while others compared RFA to splanchnic alcohol neurolysis. A different study used

RFA in conjunction with vertebroplasty with no control to compare. Without such a standard, it is difficult to quantify the results of RFA and to conclude whether it effectively reduces pain in these patients more than other therapies.

Although our study focuses on RFA and its role in reducing pain, it is also important to note that RFA may play a role in causing pain or exacerbating other symptoms. Within 15 days post-RFA, patients may experience post-RFA syndrome, which includes symptoms besides pain, such as nausea, vomiting, malaise, and myalgia (67). However, post-RFA syndrome is usually self-limited and lasts no longer than 10 days. A study by Wu and colleagues (68) documented that among 31 patients with malignant portal obstruction who underwent RFA, 26 (84%) experienced postoperative abdominal pain, while 3 did not have any improvement in their clinical manifestations. Another study by Tang and colleagues (68) found that among 421 patients who received RFA therapy for hepatic malignancies, 136 (32%) experienced abdominal pain. One article that compared postneurotomy pain with and without dexamethasone reported pain incidence without dexamethasone was 20/35 (57%) while the incidence of pain with dexamethasone was 3/35 (9%) (69). This study combined data of patients who underwent RFA along the spinal nerves (70). Another study found the incidence of neuropathic pain post-RFA at the third occipital nerve was 19% among 64 patients (71). Therefore, it is best to advise patients of the risks involved with RFA and engage in mutual decision-making before undergoing RFA.

Another limitation of our study was the use of only a single database, namely PubMed. However, PubMed includes MedLine, the US National Library of Medicine's premier database, and articles from many other databases, making it the largest database that lists the most studies (72). One study by Gusenabauer and Haddaway (73) evaluated the performance of various databases and noted that PubMed was one of the databases that can be used as a principal search system for systematic reviews. Nevertheless, future studies may want to investigate additional databases to ensure that no pertinent articles are missed. Future studies may also include more comprehensive articles. However, from our investigation, only 3 articles were randomized controlled trials, suggesting that not enough research has been done on the topic and that our search captured most of the relevant articles. We also attempted to reference previous similar studies to make sure relevant and recently published studies were included in this review. A review by Singh et al (74), for example, did not include the multicenter case series study by Beyer et al (32); however, our comprehensive search on PubMed did include this article.

Publication bias may adversely affect our review. If there were studies that did not yield significant results and went unpublished, for example, that may lead to a different outcome than we presented here. Furthermore, most of the studies included in our review were either case reports, large observational studies, or case series. Since not many randomized controlled trials were included in our study, our strength of evidence is arguably weaker.

A future area of investigation is the comparison and assessment of the different types of RFA. For example, a study that investigates the efficacy of water-cooled or cooled RFA compared to conventional RFA can be worthwhile in understanding which is most useful in addressing thoracic and abdominal pain syndromes. On the other hand, studying the effectiveness of RFA depending on which nerve is targeted may also be a worthy area of research. A splanchnic nerve ablation at T11, for example, may yield different results as opposed to a T12 nerve ablation. This process may ultimately isolate the nerve that yields the best result for any given pain syndrome. Since our study included a qualitative synthesis but not a quantitative synthesis, future studies can conduct a meta-analysis on the same topic.

Conclusion

Based on the studies presented, RFA has a clear role in the management of thoracic and abdominal pain syndromes. RFA specifically offers pain management that may be of particular use when medications or other forms of treatment are ineffective. One limitation of this study is that there are very few clinical trials and very few papers with control groups. To better evaluate the efficacy of RFA, more studies need to be done in a randomized controlled fashion. Although there was a lack of clinical trials in our study, the majority of the articles used were of good quality according to the risk of bias assessment which helps validate the efficacy of RFA. Areas for future investigation include studying the efficacy of the different types of RFA in patients with abdominal and thoracic pain syndromes and identifying which nerves give the best pain reduction when ablated.

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