TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
Website https://ejurnal.seminar-id.com/index.php/tin
DOI 10.47065/tin.v6i10.9507

Interventional Radiology Procedures for Chronic Pain and Palliative Care: A Systematic Review Focused on Ablation and Neurolysis (2015–2025)

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Abstract–Chronic and cancer-related pain impose substantial global health burdens and contribute to long-term opioid dependence. Image-guided percutaneous ablation and chemical neurolysis have emerged as important alternative option when pharmacologic therapy is insufficient or poorly tolerated, yet evidence remains heterogeneous across indications and techniques. Therefore, this systematic review aims to evaluate the efficacy, safety, and opioid-sparing effects of image-guided ablation and chemical neurolysis in oncologic and non-oncologic pain populations (2015–2025). Following PRISMA 2020 guidelines, a comprehensive search of major biomedical databases identified studies involving adult patients undergoing image-guided thermal ablation or chemical neurolysis. Major biomedical databases, including PubMed/MEDLINE, Cochrane Central Register of Controlled Trials, Science Direct and EuropePMC were searched. Eligible studies included adult populations undergoing image-guided ablation or neurolysis or neuromodulation. Risk of bias was assessed using RoB 2, ROBINS-I, and Joanna Briggs Institute tools. A narrative synthesis was performed. Forty-five studies (24 randomized controlled trials and 21 observational cohorts or case series) were included. Ablative techniques demonstrated clinically meaningful and, in selected indications, durable pain reduction across musculoskeletal and oncologic conditions. Chemical neurolysis showed significant benefit in visceral cancer pain and emerging applicability in selected non-oncologic settings. Across modalities, major procedure-related complications were uncommon, and no consistent procedure-related mortality was reported. Several studies documented reductions in opioid requirements following intervention. Conclusion: Image-guided ablation and neurolytic procedures provide effective pain relief with generally favorable safety profiles across diverse clinical contexts. These interventions may support opioid-sparing strategies and warrant structured integration into multidisciplinary pain management pathways.

Keywords: Interventional Radiology; Chronic Pain Management; Palliative Care; Ablation Therapy; Neurolysis; Systematic Review

1. INTRODUCTION

Over the past decade, there has been a paradigm shift in the treatment of chronic pain, especially in the palliative situation. The World Health Organization's (WHO) analgesic ladder, which stresses a gradual transition from non-opioids to strong opioids, has historically been a major tool in the management of severe pain (Ilfeld et al., 2022). However, a major public health catastrophe has been caused by this overuse of systemic drugs. Over 110,000 people died in the US alone in 2022 as a result of the opioid crisis, which is marked by rapidly rising rates of opioid use disorder, tolerance, opioid-induced hyperalgesia, and fatal overdoses (Alsaeid et al., 2025). Moreover, up to one-third of patients in the palliative oncology setting either experience dose-limiting, halting side effects like severe constipation, refractory nausea, somnolence, and cognitive impairment, which further deteriorate their remaining quality of life, or they are unable to obtain adequate pain relief with systemic analgesics (Wang et al., 2025). Currently, medical researchers are looking for more focused, targeted interventions due to the global opioid problem and the identification of dose-limiting systemic toxicities, including drowsiness, constipation, and respiratory depression.[1] Interventional radiology (IR) has emerged as a primary discipline during these changes, using percutaneous, image-guided techniques that specifically target the pain generators or the neural pathways responsible for nociceptive transmission (Manchikanti et al., 2025). Image-guided interventional procedures promote quick recovery and significant analgesia. These image-guided interventions generally divided into two main mechanistic categories: energy-based tissue ablation and chemical neurolysis (Nygaard et al., 2025).

Ablation uses intense physical force to destroy certain nerves or tissues. Among the eight modalities in this category is continuous thermal radiofrequency ablation (RFA), which uses a high-frequency alternating current to cause coagulative necrosis by producing frictional heat between 60°C and 90°C. As an alternative, short bursts of high-voltage current are delivered by pulsed radiofrequency, which limits tissue temperatures to a non-destructive 42°C. This results in neuromodulation rather than thermal destruction (Elashmawy et al., 2022). Microwave ablation (MWA) provides wider ablation zones and faster heating by using electromagnetic fields to rotate water molecules. More advanced versions, including cooled RFA and bipolar RFA, overcome the anatomical diversity of target nerves by producing stronger, more consistent electromagnetic fields. Cryoablation, on the other hand, uses the Joule-Thomson effect to produce extreme cold (down to -140^{o} C), which results in cell death through intracellular ice formation and vascular stasis (Thepsoparn et al., 2025). On the other hand, chemical neurolysis uses percutaneous, image-guided injection of sclerosing chemicals, primarily phenol or dehydrated ethanol (alcohol), to destroy sympathetic or somatic nerves. Without the need for pricey generator consoles, these medicines effectively stop the transmission of pain signals by causing instantaneous protein denaturation, cellular precipitation, and consequent Wallerian degeneration. The celiac plexus and superior hypogastric plexus are frequent targets for abdominal and pelvic malignancies, respectively (Thepsoparn et al., 2025). The accuracy and safety of these neurolytic blocks have been greatly enhanced by the development of imaging guidance, which moved from fluoroscopy-only to ultrasound (US), CT, and MRI-guided procedures (Giles et al., 2019).

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Even though the use of these procedures has increased rapidly, the information is still very diverse and segmented. Previous systematic reviews have mostly limited their analytical focus to single modalities, like cryoablation, or to particular anatomical targets. Four clear and important research gaps are identified by a preliminary scoping study of the present literature. The first is the widespread absence of a focused, integrated focus comparing the relative efficacies of ablation against neurolysis across similar indications. Second, there is a lack of integration between oncologic palliative care and chronic non-oncologic pain within a single, cohesive analytical framework, which hinders the exchange of methods across these connected domains. Third, there is a distinct absence of clinically significant outcomes, especially when it comes to standardizing opioid-sparing criteria and establishing Minimal Clinically Important Differences. Lastly, in a number of important anatomical regions, the relative advantages of these advanced procedures over conventional medical care or sham interventions are still unclear. Therefore, this systematic review aims to evaluate the clinical efficacy and safety of image-guided ablation and neurolysis procedures in adult patients with chronic pain and palliative care needs, encompassing literature published between the years 2015 and 2025.

2. RESEARCH METHODOLOGY

2.1 Protocol and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The study was designed to answer the primary research question: "In adults with chronic pain or receiving palliative care, do image-guided ablation or neurolysis procedures improve clinical pain outcomes and maintain safety compared to non-IR treatments or other comparators?".

2.2 Eligibility Criteria

The inclusion criteria were established using the PICO framework:

1. Population: Adults (age >= 18 years) suffering from chronic pain or receiving palliative care, including both cancer-related and non-cancer etiologies.
2. Interventions: Image-guided procedures involving thermal ablation (e.g., RFA, MWA, cryoablation, MRgHIFU) or nerve-targeted neurolytic and neuromodulatory techniques (e.g., chemical neurolysis with alcohol/phenol and pulsed radiofrequency).
3. Comparators: Standard medical management (pharmacotherapy), sham procedures, surgical interventions, or other non-image-guided procedures. For safety and descriptive synthesis, studies with no comparator (single-arm) were also included.
4. Outcomes: The primary efficacy outcome was the reduction in pain intensity measured by validated scales such as the Visual Analog Scale (VAS), Numeric Rating Scale (NRS), or Brief Pain Inventory (BPI). Secondary outcomes included the duration of analgesia, changes in opioid consumption (measured in oral morphine equivalent daily doses, or OMEDD), and procedure-related adverse events.

Exclusion criteria included paediatric populations, non-image-guided procedures (e.g., standard epidural steroid injections without IR involvement), case reports, case series with fewer than 10 patients (except for rare complications), and studies published outside the 2015–2025 window or in languages other than English.

2.3 Information Sources and Search Strategy

A systematic search was performed across major bibliographic databases, including PubMed/MEDLINE, Europe PMC, ScienceDirect, and Cochrane Central Register of Controlled Trials (CENTRAL). The search period was restricted to publications from January 1st, 2015, to December 27th , 2025. The final search was performed on December 27th, 2025. No language restrictions were applied. The search strategy employed a combination of controlled vocabulary (MeSH and Emtree terms) and free-text keywords. The search strings were iteratively refined to maximize sensitivity and specificity. An example PubMed search string utilized was:

a. (("Pain" OR pain[tiab] OR "chronic pain"[tiab] OR "palliative"[tiab] OR "palliative care"[tiab]) AND (("Ablation Techniques" OR ablat*[tiab] OR "radiofrequency ablation"[tiab] OR "microwave ablation"[tiab] OR "cryoablation"[tiab]) OR ("Neurolysis" OR neuroly*[tiab] OR "celiac plexus"[tiab] OR "superior hypogastric"[tiab]))).
b. For every database, the search approach was modified accordingly. In order to find additional eligible records that might have been overlooked during the database search, two independent reviewers manually searched the reference lists of all included studies and relevant systematic reviews.

2.4 Study Selection

The identified records were deduplicated after being imported into a reference management software. All identified records' titles and abstracts were independently checked against the eligibility requirements by two reviewers. After that, the whole texts of papers that might be qualified were obtained and evaluated separately before being included. Discrepancies were resolved through discussion until consensus was reached.

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2.5 Data Extraction

Data extraction was systematically performed utilizing a standardized, heavily piloted electronic extraction form (Excel/CSV format) to ensure consistency and comprehensive data capture across all included studies. Two reviewers independently extracted the data, reconciling any discrepancies through consensus. The extracted variables included study characteristics (primary author, publication year, country of origin, study design), population demographics (sample size, mean age, sex distribution, specific clinical indications, and baseline pain scores), and intricate intervention specifics (target nerve or tissue, specific ablation modality or neurolytic agent utilized, exact procedural parameters such as temperature and duration, and the specific image guidance modality). Furthermore, detailed data regarding the chosen comparator, the duration of follow-up, and all primary and secondary outcomes including opioid, and the type and severity of any complications. In instances of missing or ambiguous data, imputation methods following Cochrane guidance were considered, and corresponding sensitivity analyses were planned to assess the impact of such missingness.

2.6 Risk of Bias Assessment

The risk of bias in the included studies was assessed using tools appropriate for the study design:

1. Randomized Controlled Trials (RCTs): Evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, focusing on domains such as the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result.
2. Non-Randomized Comparative Studies: Assessed using the ROBINS-I (Risk Of Bias In Non-randomized Studies - of Interventions) tool.
3. Case Series and Cohort Studies: Evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklists for case series and cohort studies.

The evaluations were carried out independently by two reviewers. Discussions were held to settle disagreements until an agreement was reached. The narrative synthesis and the grading of the degree of evidence certainty were informed by the findings of the risk of bias evaluations. Table 2 displays the findings of the risk of bias assessment. The strength of the conclusions in the discussion section is informed by this open evaluation of the quality of the evidence.

2.7 Data Synthesis and Analysis

The results of the included research were compiled and analyzed using a narrative synthesis. The results were categorized by intervention type (e.g., radiofrequency ablation, cryoablation, microwave ablation, or neurolysis) and clinical indication (e.g., cancer vs. non-cancer pain). A quantitative meta-analysis was not conducted due to the anticipated clinical and methodological heterogeneity among studies concerning follow-up time, outcome measures, intervention procedures, and demographic characteristics. The study design, sample size, risk of bias assessment, and consistency of reported outcomes were taken into consideration when interpreting the results.

2.8 Study Selection

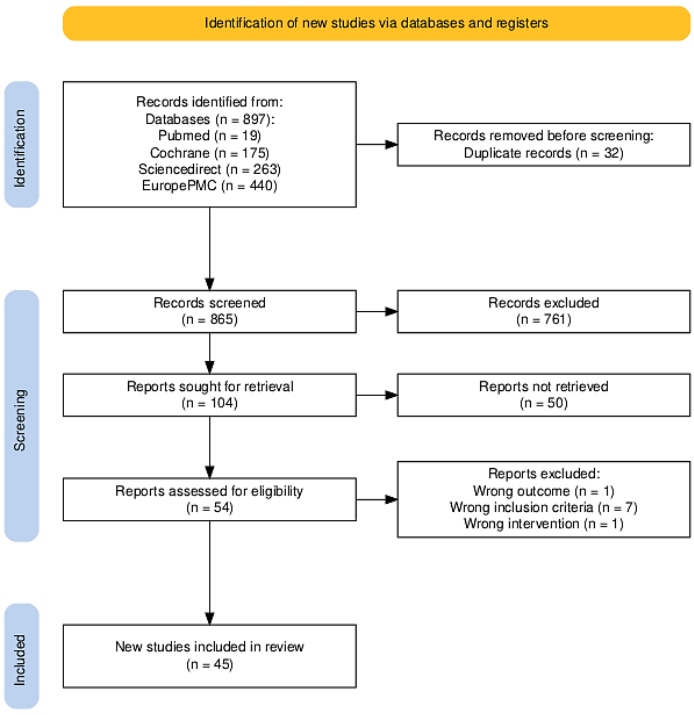

Figure 1. Study selection process according to PRISMA 2020 guidelines

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The initial execution of the comprehensive search strategy yielded a total of 897 records across the four primary databases (PubMed: 19, ScienceDirect: 263, Cochrane Library: 175, EuropePMC: 440). After removing 32 duplicate records, 865 records were screened based on title and abstract. A total of 819 records were excluded for failing to meet the inclusion criteria, primarily due to irrelevance to interventional radiology, lack of image guidance, or focus on non-ablative/non-neurolytic pharmacological management. Full-text assessment was performed on the remaining 54 articles. During this secondary phase, 9 studies were excluded due to incorrect outcome measures, utilization of off-target patient populations, or failure to meet the minimum sample size threshold for case series. Ultimately, 45 studies were included and eligible for final inclusion in the systematic review. The flowchart is shown in Figure 1: Study selection process according to the PRISMA 2020 guidelines.

3. RESULT AND DISCUSSION

3.1 Study Characteristics

The 45 included studies represent diverse geographic distribution, with research from the United States, United Kingdom, Italy, France, China, Japan, Egypt, Turkey, Poland, and Pakistan, thereby illustrating the global integration of these interventional techniques. The review include a several of trial design including 25 randomized controlled trials and 20 observational cohorts or retrospective case series. The clinical indications captured within the dataset are mainly divided into chronic degenerative or neuropathic pain syndromes and palliative oncologic pain syndromes.

All of the included studies used image guidance modalities, such as computed tomography, magnetic resonance imaging, fluoroscopy, and ultrasound, depending on the particular anatomical needs of the target tissue. Significant variation was seen in the follow-up periods, which ranged from brief 6-week post-procedural assessments to long-term longitudinal monitoring up to five years. Table 1 provides a thorough description of the included studies, including information on authors, designs, indications, treatments, and follow-up metrics.

Table 1. Characteristics of Included Studies (2015–2025)

Author (Year)	Study Design	N	Indication	Intervention	Target	Guidance	Follow-up
Knight M, et al (2022)	Obs. Cohort	52	Chronic low back pain	RFA	Cluneal nerves	Fluoroscopy	38.3 mos
Anwar S, et al (2025)	Open-label RCT	200	Knee osteoarthritis	RFA vs PRP	Genicular nerves	Fluoroscopy	24 mos
Ilfeld BM, (2022)[12]	Sham RCT	60	Post-mastectomy pain	Cryoneurolysis	Intercostal nerves	US	12 mos
Petroni GM, et al (2024)	Retrospective	44	Chronic hip pain	RFA	Articular branches	US	6 mos
Ilfeld BM, et al (2024)	RCT	144	Phantom limb pain	Cryoneurolysis	Femoral/sciatic	US	4 mos
Hu J, et al(2025)	Retro. Cohort	67	Cervical radicular pain	Nucleoplasty	Intervertebral disc	CT/Fluoro	12 mos
Mohamed RE, et al (2017)	Prospective	22	Pancreatic cancer	Chemical Neurolysis	Celiac plexus	CT	3 mos
Osman SM, et al (2018)	RCT	45	Visceral cancer pain	Neurolysis	Celiac/SHP	CT/US	12 wks
Mayer T, et al (2020)	Retrospective	31	Spinal metastases	Bipolar RFA	Vertebral bodies	CBCT/CT	3.4 mos
Gallusser N, et al (2019)	Case series	16	Bone metastases	Cryoablation	Bone mets	CT/US	12 mos
Giles SL, et all (2019)	Prospective	21	Bone metastases	MRgHIFU	Bone mets	MRI	90 days
Thepsoparn M, et al (2025)	Pilot RCT	21	Chronic shoulder pain	Cooled RFA	Articular nerves	Fluoroscopy	3 mos
Elashmawy M, et al (2022)	RCT	46	Knee osteoarthritis	Chemical Neurolysis	Genicular nerves	US	6 mos
Shi W, et al (2024)	Retrospective	73	Knee OA / Post-TKA	Thermal RFA	Genicular nerves	Fluoroscopy	6 mos
Levy J, et al (2020)	Prospective	100	Bone metastases	RFA	Bone mets	Fluoro/CT	3 – 6 mos

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Author (Year)	Study Design	N	Indication	Intervention	Target	Guidance	Follow-up
Cazzato RL, et al (2021)	Retrospective	23	Sacral bone mets	Thermal/Cryo	Sacral mets	CT	31 mos
Kamel MA, et al (2016)	RCT	30	Pelvic cancer pain	Chemical Neurolysis	SHP	Fluoro/US	3 mos
Abdelghaffar NA, et al (2022)	RCT	96	Pelvic cancer pain	Chemical Neurolysis	SHP	US/Fluoro	3 mos
Abdelghafar EM (2021)	RCT	60	Pelvic cancer pain	Chemical Neurolysis	SHP	US	12 wks
Hetta DF, et al (2020)	RCT	58	Pelvic cancer pain	Neurolysis + PRF	SHP	Fluoroscopy	6 mos
Reyad RM, et al (2019)	RCT	78	Chest malignancy	Thermal RFA	Thoracic DRG	CT/Fluoro	12 wks
Abdel Maksoud KA, et al (2025)	Sham RCT	36	Thoracic cage mets	PRF	Thoracic DRG	US	3 mos
Kamata K, et al (2022)	Multicenter	51	Pancreatic cancer	Chemical Neurolysis	Celiac plexus	EUS	Recurrence
Usmani H, et al (2018)	RCT	70	Chronic perineal pain	Conventional RFA	Ganglion Impar	Fluoroscopy	6 wks
Yildiz G, et al (2024)	RCT	60	Cervical radicular pain	PRF	Cervical roots	US	6 mos
Bharti N, et al (2018)	Prospective	25	Glossopharyngeal	PRF	Glossopharyngeal	Fluoroscopy	3 mos
Reysner M, et al (2025)	Sham RCT	100	Knee osteoarthritis	Chemical Neurolysis	Genicular nerves	US	6 mos
Abdelbaser I, et al (2021)	RCT	90	Pancreatic cancer	Chemical Neurolysis	Celiac plexus	CT/Intraop	180 days
Reysner M, et al (2025)	Sham RCT	100	Chronic hip pain	Chemical Neurolysis	PENG	US	6 mos
Ishaque M, et al (2024)	Sham RCT	10	Trigeminal neuralgia	Focused US (FUS)	Thalamic nucleus	MRI	3 mos
Thabet TS, et al (2024)	RCT	70	Post-mastectomy pain	Alcohol vs RFA	Stellate ganglion	US	12 wks
Alsaeid MA, et al (2025)	RCT	100	Cervical radicular pain	High-Voltage PRF	Cervical roots	US	6 mos
El-Hakeim EH, et al (2018)	RCT	60	Knee osteoarthritis	Thermal RFA	Genicular nerves	Fluoroscopy	6 mos
Lim JW (2017)	Prospective	40	Cervical facet joint	PRF	Cervical facet	Fluoroscopy	6 mos
Nygaard NPB, et al (2025)	Sham RCT	87	Knee osteoarthritis	Cryoneurolysis	Femoral/saphenous	US	12 mos
Gulec E, et al (2017)	RCT	100	Knee osteoarthritis	Bipolar PRF	Knee joint	Fluoroscopy	12 wks
Makharita MY, et al (2015)	Sham RCT	21	Inguinal neuralgia	PRF	DRG	Fluoroscopy	12 mos
Pusceddu C, et al (2022)	Retrospective	17	Extraspinal bone mets	Steerable RFA	Bone mets	CT/Fluoro	12 mos
Pusceddu C, et al (2023)	Retrospective	16	Spinal bone mets	Targeted RFA	Spinal mets	CT	6 mos
Kastler A, et al (2021)	Retrospective	25	Spinal bone mets	Bipolar RFA	Spinal mets	CT	12 mos
Tomasian A, et al(2016)	Retrospective	14	Vertebral metastases	Cryoablation	Vertebral mets	CT	3 mos

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Author (Year)	Study Design	N	Indication	Intervention	Target	Guidance	Follow-up
Jiao D, et al (2016)	Retrospective	79	Bone metastases	RFA + Brachytherapy	Bone mets	CT	3 mos
Fischgrund JS, et al (2020)	Prospective	117	Chronic low back pain	Intraosseous RFA	Basivertebral	Image guidance	5 years
Acu B, et al (2017)	Retrospective	21	Malignant biliary	RFA + stenting	Biliary stricture	Fluoroscopy	6 mos
Jeninngs JW, et al (2021)	Prospective	66	Bone metastases	Cryoablation	Bone mets	CT	6 mos

3.2 Risk of Bias Assessment

Due in particular to the intrinsic limitations of the study designs, the rigorous methods of the included studies showed varying degrees of bias. Six of the 24 randomized controlled trials had a "Low" overall risk of bias, indicating very strong randomization, blinding, and reporting procedures, according to an evaluation of the studies using the Cochrane RoB 2 tool. Twelve trials were categorized as having "Some concerns," primarily because of subjective patient-reported outcomes or challenges in blinding operators to interventional techniques. A "High" risk of bias was assigned to 5 RCTs. Considerable missing outcome data and significant deviations from planned interventions played a major role in this high-risk classification. In Anwar et al.'s (2025) open-label study comparing radiofrequency ablation to platelet-rich plasma, for example, the absence of a sham control group resulted in performance and detection biases when assessing subjective pain levels.[11] Can be seen Table 2. Summary of Risk of Bias for Randomized Controlled Trials (Cochrane RoB 2 Tool)

Table 2. Summary of Risk of Bias for Randomized Controlled Trials (Cochrane RoB 2 Tool)

Studies	D1 Randomization	D2 Deviations	D3 Missing Data	D4 Measurement	D5 Reporting	Overall
Anwar S, et al. (2025)	Some concerns	High	High	Some concerns	Some concerns	High
Ilfeld B, et al. (2022)	Low	Low	Low	Low	Low	Low
Ilfeld B, et al. (2024)	Low	Some concerns	High	Some concerns	High	High
Thepsoparn M, et al. (2025)	Some concerns	Some concerns	Low	Some concerns	Some concerns	Some concerns
Elashmawy MM, et al. (2022)	High	Some concerns	Low	Some concerns	Some concerns	High
Kamel M, et al. (2017)	Some concerns	Low	Low	Low	Some concerns	Some concerns
Abdelghaffar NA, et al. (2022)	Some concerns	Low	Low	Some concerns	Low	Some concerns
Abdehghaffar EM, et al. (2021)	Some concerns	Low	Low	Some concerns	Low	Some concerns
Hetta DF, et al. (2020)	Low	Low	Low	Low	Low	Low
Reyad R, et al. (2019)	Low	Low	Low	Low	Low	Low
Maksoud DKA, et al. (2025)	Low	Low	Some concerns	Low	Low	Some concerns
Usmani H, et al. (2018)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Yildiz G, et al. (2024)	Low	Low	Some concerns	Low	Low	Some concerns
Reysner M, et al. (2025)	Low	Low	Low	Low	Low	Low
Abdelbaser I, et al. (2020)	Low	High	High	High	Low	High
Reysner M, et al. (2025)	Low	Low	Low	Low	Low	Low
Ishaque M, et al. (2024)	Some concerns	Low	Some concerns	Low	Low	Some concerns
Thabet TS & Khedr SA (2024)	Low	Some concerns	Some concerns	Low	Low	Some concerns
Alseid MA, et al. (2025)	Low	Low	Low	Low	Low	Low
El Hakeim EH, et al.	Some concerns	High	Low	High	Low	High

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Studies	D1 Randomization	D2 Deviations	D3 Missing Data	D4 Measurement	D5 Reporting	Overall
(2018)						
Lim JW, et al. (2017)	Some concerns	High	Low	High	Some concerns	High
Nygaard NPB, et al. (2025)	Low	Low	Low	Low	Some concerns	Some concerns
Gulec E, et al. (2017)	Some concerns	Low	Low	Low	Low	Some concerns
Makharita MY & Amr YM (2015)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns

The ROBINS-I assessment for non-randomized comparative studies highlighted a "Serious" risk of bias across 3 specific studies, a finding consistently attributed to the presence of unmitigated confounding variables and selection biases that are intrinsically difficult to control in retrospective cohort designs. Cam be seen Table 3. Summary of Risk of Bias in Non-Randomized Studies Using the ROBINS-I Framework

Table 3. Summary of Risk of Bias in Non-Randomized Studies Using the ROBINS-I Framework

Studies	D1 Confounding	D2 Selection	D3 Classification	D4 Deviations	D5 Missing Data	D6 Measurement	D7 Reporting	Overall
Hu J, et al. (2025)	Serious	Moderate	Low	Moderate	Low	Moderate	Moderate	Serious
Bharti N, et al. (2021)	Serious	Some concerns	Low	Some concerns	Serious	Serious	Some concerns	High
Jiao D, et al. (2016)	Serious	Serious	Low	Low	Serious	Serious	Moderate	Serious

Conversely, the JBI critical appraisal evaluations for case series and prospective single-arm cohorts generally indicated a "Low" to "Moderate" risk of bias. These assessments verified that despite the lack of a comparator arm, these observational datasets maintained high internal validity regarding explicit patient inclusion criteria, the validity of outcome measurements, and the completeness of follow-up. The 5-year analysis by Fischgrund et al. (2020) was carried out as a prospective single-arm follow-up without an additional comparator group, while being initially obtained from a randomized controlled trial. As a result, the JBI Case Series checklist was used for evaluation instead of the Cochrane RoB 2 instrument. Can be see Table 4. Risk of Bias Assessment for Case Series (JBI Tool) and Table 5. Risk of Bias Assessment for Cohort (JBI Tool)

Table 4. Risk of Bias Assessment for Case Series (JBI Tool)

Studies	D1 Inclusion	D2 Condition	D3 Valid ID	D4 Consecutive	D5 Complete	D6 Demo	D7 Clinical	D8 Outcome	D9 Site Demo	D10 Stats	Overall
Knight M, et al. (2022)	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Mohammed R, et al (2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Osman SM, et al. (2018)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Moderate
Mayer T, et al. (2020)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk
Galluser N, et al. (2019)	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Low risk
Giles SL, et al. (2019)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Moderate
Levy J, et al. (2020)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Moderate
Cazzato RL, et al. (2021)	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Low risk
Kamata K, et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low risk

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Studies	D1 Inclusion	D2 Condition	D3 Valid ID	D4 Consecutive	D5 Complete	D6 Demo	D7 Clinical	D8 Outcome	D9 Site Demo	D10 Stats	Overall
Pusceddu C, et al. (2022)	Yes	Yes	Yes	No	Unclear	Yes	Yes	Yes	Unclear	Yes	Moderate
Pusceddu C, et al. (2023)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Yes	Moderate
Kastler A, et al. (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Low risk
Jennings JW, et al. (2021)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Yes	Moderate
Tomasian A, et al. (2016)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Yes	Moderate
Acu B & Ozturk K (2018)	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Unclear	Yes	Moderate
Fischgrund JS, et al. (2020)*	Yes	Yes	Yes	No	Unclear	Yes	Yes	Yes	Unclear	Yes	High (for comparative context)

*5-year single-arm follow-up of an original randomized controlled trial; assessed as a single-arm study due to absence of a comparator at long-term follow-up.

Table 5. Risk of Bias Assessment for Cohort (JBI Tool)

Author	D1 Similar groups	D2 Exposure measurement	D3 Exposure Validity	D4 Cofounders identified	D5 Cofounding strategy	D6 Outcome baseline	D7 Outcome valid	D8 Follow up adequate	D9 Follow up complete	D10 Incomplete follow up	D11 Stats	Overall
Petroni GM, et al. (2024)	Yes	Yes	Yes	No	No	Unclear	Yes	Yes	Unclear	No	Yes	High
Shi W, et al. (2024)	Yes	Yes	Yes	No	No	Unclear	Yes	Yes	No	No	Yes	High

3.3 Clinical Efficacy

The primary and secondary clinical endpoints across all 45 studies confirmed that both ablation and nerve-targeted neurolytic and neuromodulatory techniques offer substantial, statistically significant pain reduction across diverse pathologies. Can be see Table 6. Summary of Clinical Efficacy

Table 6. Summary of Clinical Efficacy

Intervention Type	Study Design	No. of Studies	Pain Reduction Pattern	≥50% Responder Reported	Opioid Reduction Reported	Typical Follow-up Range
Ablation	RCT	7	Majority showed statistically significant reduction in VAS/NRS at primary endpoints (except selected trials such as Ilfeld 2024 and Ishaque 2024 which showed no significant difference)	Frequently reported in genicular RFA and HVPRF trials	Reported in several trials (e.g., reduced morphine, oxycodone, MQS score)	Commonly 1–6 months; some >6 months
Ablation	Cohort / Case Series	18	Consistent improvement across studies; many reported ≥2-point or ≥50% reduction	Frequently reported in oncology ablation studies	Reported in several studies (e.g., MEDD decrease, morphine-	Variable; commonly 3–12 months; some >12 months

TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
Website https://ejurnal.seminar-id.com/index.php/tin
DOI 10.47065/tin.v6i10.9507

Intervention Type	Study Design	No. of Studies	Pain Reduction Pattern	≥50% Responder Reported	Opioid Reduction Reported	Typical Follow-up Range
					equivalent reduction)	
Neurolytic and Neuromodulatory Procedures	RCT	17	Majority demonstrated significant pain reduction (especially cancer-related plexus neurolysis); sustained up to 3–6 months in most studies	Occasionally reported explicitly; many reported significant VAS decrease without % responder	Frequently reported reduction in morphine or tramadol use in cancer trials	Commonly 1–3 months; some up to 6 months
Neurolytic and Neuromodulatory Procedures	Cohort / Case Series	3	All reported clinically meaningful pain reduction	Reported in selected studies (e.g., opioid requirement drop in CPN studies)	Reported in some pancreatic cancer cohorts	Typically short to mid-term (1–3 months; some >6 months)

Across the included studies, both ablative and neurolytic and neuromodulator procedures procedures demonstrated consistent reductions in pain intensity (Table 6). Overall of the 7 RCTs that assessed ablative procedures showed statistically significant decreases in VAS or NRS ratings at primary outcomes. There were a few exceptions, such as Ilfeld (2024) and Ishaque (2024), which showed little distinction from control groups. Reports of clinically significant response rates (≥50% pain reduction) were common, especially in studies involving high-voltage PRF and genicular nerve RFA. Several RCTs reported opioid reduction, such as lower scores on the Medication Quantification Scale (MQS), morphine, or oxycodone. These trials' follow-up periods typically lasted between one and six months, while some went longer.

Eighteen observational studies evaluating ablative procedures reported clinically significant pain improvement, with many demonstrating ≥2-point or ≥50% reductions in pain scores. Opioid reduction was reported in multiple oncology-focused ablation cohorts, including decreases in morphine-equivalent daily dose (MEDD). Follow-up duration was variable, most commonly ranging from 3–12 months. Seventeen RCTs assessing neurolytic and neuromodulating interventions demonstrated significant pain reduction, especially in plexus neurolysis trials associated to malignancy. Analgesic benefit was usually maintained for 1–3 months and, in several studies, up to six months. Many studies reported statistically significant reductions in VAS or NRS scores instead of expressly reporting ≥50% responder rates. In cancer-related trials, especially those assessing celiac disease or superior hypogastric plexus neurolysis, opioid intake was often decreased. Furthermore, clinically significant short- to mid-term pain reduction has been reported in three observational studies using neurolytic treatments. In certain pancreatic cancer cohorts, a decrease in the need for opioids was seen. These studies' follow-up periods ranged from one to three months, with some lasting longer than six months. Can be see

Table 7. Summary of Safety

Intervention Type	Study Design	No. of Studies	Minor AE Pattern	Major AE Pattern	Procedure-related Mortality
Ablation (non-oncology)	RCT	5	Mild, transient post-procedural pain, superficial infection, self-limited neurologic/systemic symptoms	None reported	None reported
Ablation (non-oncology)	Cohort / Series	6	Mild, transient local bruising or neuropraxia; occasional short-term post-procedural pain	None clearly procedure-related	None reported
Ablation (oncology)	RCT	2	Generally mild (transient pain, minor site reactions)	Rare	None reported
Ablation (oncology)	Cohort / Series	12	Local pain flare, asymptomatic cement leakage, minor burns, hematoma, transient neuropathy	Rare; isolated severe skin burn, hepatic abscess, pathological fracture, sepsis in high-risk patients	None consistently attributable to procedure (deaths largely due to disease progression)
Neurolytic and	RCT	8	Mostly transient	Rare; isolated	None reported

TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
Website https://ejurnal.seminar-id.com/index.php/tin
DOI 10.47065/tin.v6i10.9507

Intervention Type	Study Design	No. of Studies	Minor AE Pattern	Major AE Pattern	Procedure-related Mortality
Neuromodulatory Procedures (oncology)			(hypotension, diarrhea, back pain, injection site pain)	reversible neurologic deficits and 1 pneumothorax	
Neurolytic and Neuromodulatory Procedures (oncology)	Cohort / Series	2	Transient autonomic effects (diarrhea, hypotension), local discomfort	None reported	None reported
Neurolytic and Neuromodulatory Procedures (non-oncology)	RCT	9	Mild injection-site pain, bruising, transient numbness, minor vasovagal or bleeding events	None reported	None reported
Neurolytic and Neuromodulatory Procedures (non-oncology)	Cohort / Series	1	None or mild transient	None reported	None reported

Overall, image-guided ablative and neurolytic and neuromodulator procedures procedures demonstrated safety profiles across both oncologic and non-oncologic populations (Table 6). In non-oncologic settings, ablative procedures evaluated in five RCTs and six observational studies were associated predominantly with mild and transient adverse events, including post-procedural pain, superficial infection, localized bruising, and temporary neuropraxia. No major procedure-related complications or mortality were reported in these studies. Two RCTs assessing ablative procedure in oncologic populations showed mostly moderate adverse effects, with infrequent serious consequences. Adverse events, such as localized pain flare, asymptomatic cement leakage, mild burns, hematoma, and temporary neuropathy, were more commonly reported in twelve observational oncology cohorts. Major complications were uncommon and mostly occurred in high risk metastatic setting. The majority of reported deaths were linked to the progression of the disease rather than the actual procedures.

Neurolytic and neuromodulatory procedures similarly showed acceptable safety profiles. In oncology-related RCTs (n=8), adverse events were predominantly transient autonomic symptoms, including hypotension, diarrhea, back pain, and injection-site discomfort. Major complications were rare and reversible, with one reported pneumothorax and isolated transient neurologic deficits. There was no mortality linked to the surgery. Only modest, temporary autonomic symptoms without significant consequences were observed by observational oncology groups. In non-oncologic RCTs assessing neurolytic or neuromodulatory techniques (n=9), adverse events were mild and localized, including injection-site pain, bruising, transient numbness, and minor vasovagal reactions. No major complications or mortality were reported. The single observational non-oncology study similarly reported no significant adverse events.

3.4 Discussion

The synthesized data from the 45 studies from 2015 to 2025 show that image-guided ablation and neurolysis or neuromodulator provide statistically significant, and clinically relevant pain reduction across an extensive spectrum of pain pathologies. The strongest evidence was seen in chronic non-oncologic groups, like advanced osteoarthritis and vertebrogenic pain, and was typified by low-risk randomized controlled trials (RCTs). On the other hand, the oncology evidence is primarily based on prospective observational cohorts and retrospective case series. Both treatment regimens showed very good safety profiles in spite of these methodological differences. Major adverse events were highly rare, and there were absolute zero direct procedure related mortalities. Furthermore, both modalities consistently showed a profound opioid-sparing effect, addressing a critical objective in contemporary pain management. The underlying mechanisms of tissue interaction are directly responsible for the identified differential efficacy and durable outcomes. Physical ablation modalities, such as continuous RFA and cryoablation, induce permanent coagulative necrosis or extreme cellular dehydration, causing precise Wallerian degeneration (Giles et al., 2019). This targeted disruption of anatomically static nociceptive pathways results in extremely long-lasting pain relief. For example, continuous intraosseous RFA of the basivertebral nerve showed previously unheard-of lifespan; at a 5-year follow-up, 66% of patients continued to have less pain (Mayer et al., 2021).

Chemical neurolytic procedures utilize agents such as ethanol or phenol to induce protein denaturation and non-selective Wallerian degeneration (Vardhan et al., 2025). Unlike the circumscribed lesions created by thermal ablation, liquid neurolytics diffuse along fascial planes, enabling coverage of broad autonomic plexuses such as the celiac or superior hypogastric plexus. While this diffuse spread facilitates treatment of visceral cancer pain, the absence of a defined lesion boundary and subsequent axonal regeneration may limit long-term durability (Kopitkó et al., 2026). In contrast, neuromodulatory technique, such as pulsed radiofrequency (PRF) prevents structural damage by limiting tissue temperatures to 42°C and instead modulates neural signaling through electromagnetic effects that alter gene expression and reduce excitatory neurotransmission (Jennings et al., 2021). However, PRF's analgesic duration is usually shorter

TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
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and may be less appropriate in clinical situations requiring quick and long-lasting pain relief, such as advanced cancer-related discomfort, because it does not produce a persistent lesion (Kastler et al., 2021).

Oncologic and non-oncologic populations have quite different clinical goals. Interventional radiology in palliative oncology seeks to treat tumor burden and quickly relieve pain. In palliative oncology, interventional radiology aims to provide rapid pain relief while also addressing tumor burden (Abdelghafar et al., 2021). Cryoablation has become particularly impactful in metastatic bone disease, trials such as MOTION demonstrated that formation of a visible ice ball enables precise margin control near critical structures, resulting in rapid and durable analgesia alongside reduced opioid reliance (Pusceddu et al., 2023). Conversely, non-oncologic interventions prioritize long-term functional improvement and joint preservation. A notable shift observed in this review is the expanding role of chemical neurolysis beyond end-of-life visceral cancer pain (Pusceddu et al., 2022). Recent RCTs indicate that ultrasound-guided alcoholic neurolysis of genicular and pericapsular nerves may serve as an effective and cost-conscious alternative for severe osteoarthritis, particularly in resource-limited settings where access to RFA technology is restricted (Kamata et al., 2022).

Efficacy results should be interpreted cautiously due to the possibility of bias in the included literature. Strong evidence that observed analgesic effects outweigh placebo response is provided by high-quality sham-controlled RCTs (Asif et al., 2021)with “Low” risk of bias proof that the analgesic effect is physiological rather than a placebo response. However, studies with "Some concerns," "High," or "Serious" risk are actually at risk of overestimating the degree of subjective pain relief because of performance and detection biases. This is especially true for open-label designs without a sham comparator for example (Reyad et al., 2019) Because of untreated confounding variables, the oncologic cohort's dependence on observational designs states a "Moderate" to "Serious" risk of bias. However, it is a well-known ethical difficulties that it is frequently impractical and unethical to randomly assign severely impaired, terminal cancer patients who are in excruciating agony to a sham or standard-care arm (Abdelghaffar & Farahat, 2022). The clinical community generally acknowledges that these procedures have true therapeutic efficacy that surpasses the limitations of non-randomized study designs because large, independent, and geographically diverse oncology cohorts regularly report massive effect sizes (e.g., >70% reductions in VAS scores) (Ilfeld et al., 2024)

Surprisingly risk of bias seems to have limited impact on how safety results were interpreted (Alaqeel et al., 2025). Pneumothorax and serious burns are examples of major adverse outcomes that are objective and unlikely to be impacted by blinding or study design (Al Sayegh, 2025). The overall morbidity of image-guided percutaneous pain treatments remained low in both retrospective registries and randomized studies. Minor adverse events that have been reported, including temporary hypotension or diarrhea after celiac plexus neurolysis, are more likely to be the result of sympathetic blockade's anticipated physiological effects than of a procedure gone wrong (Petroni et al., 2024). This systematic review's thorough, PRISMA-compliant methodology, which incorporates ten years' worth of recent data (2015–2025) from significant biomedical databases, is one of its main advantages. This review makes it possible to compare interventional pain situations meaningfully by combining oncologic and non-oncologic populations into a single paradigm. Furthermore, the synthesis of opioid-related outcomes, such as decreases in morphine-equivalent dosage, offers clinically significant information into the opioid-sparing potential of these therapies (Corriero et al., 2025).

There are several limitations to be aware of. Formal quantitative meta-analysis was not possible due to significant procedural heterogeneity in the main literature, which included differences in ablation parameters, neurolytic concentrations, and target selection. It's possible that relevant international data was overlooked due to the restriction to English-language media. Furthermore, most peripheral nerve studies reported results limited to 3–6 months, leaving long-term durability and recurrence patterns incompletely described, even when long-term follow-up is available for specific targets, such as the basivertebral nerve. Future research should prioritize multicenter, sham-controlled randomized trials with standardized procedural protocols to strengthen comparative conclusions. Longer follow-up beyond 12 months is essential to better define durability and recurrence. Emerging integration of artificial intelligence to predict patient-specific responses to ablative modalities represents a promising area for further investigation.Finally, early integration of image-guided therapies into multidisciplinary pain and oncology pathways may maximize analgesic approaches and lessen dependency on long-term opioid medication (Fletcher et al., 2021).

4. CONCLUSION

This systematic review completely shows that image guided interventional radiology techniques, such as targeted chemical neurolysis and advanced physical energy ablation, are extremely safe, highly effective, and clinically essential therapeutic modalities for the treatment of both refractory palliative cancer pain and chronic non-oncologic pain. Ablative techniques provide unmatched margin control and exceptional longevity for structural pain generators and osseous metastases, while chemical neurolysis continues to be the most effective treatment for diffuse visceral pain and becomes a very affordable and accessible option for major joint osteoarthritis. Several studies also reported reductions in opioid consumption, highlighting the potential role of these interventions within multimodal pain management strategies. Although further high-quality randomized trials are necessary, the available evidence supports earlier and more structured integration of image-guided pain interventions into multidisciplinary care pathways, particularly for patients with refractory pain.


TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
Website https://ejurnal.seminar-id.com/index.php/tin
DOI 10.47065/tin.v6i10.9507

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TIN: Terapan Informatika Nusantara
Vol 6, No 10, March 2026, page 1943-1955
ISSN 2722-7987 (Media Online)
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