# Procedural Success and Safety of Cryoablation Versus Radiofrequency Ablation in Atrioventricular Nodal Reentrant Tachycardia: A Systematic Review and Meta-Analysis

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## Abstract

**Background:** This meta-analysis compares cryoablation and radiofrequency ablation efficacy, safety, and procedural outcomes in atrioventricular nodal reentrant tachycardia (AVNRT). This meta-analysis aims to compare procedural success, long-term recurrence, and complication rates of cryoablation versus radiofrequency ablation in the treatment of AVNRT.

**Methods:** Following PRISMA 2020, PubMed, EMBASE, and Scopus were searched (25 September 2025). Eligible randomized or observational studies directly compared CRYO versus RFA for AVNRT and reported procedural success, recurrence, and/or complications. Risk of bias was assessed (ROBINS-I for non-randomized studies). Pooled effects were calculated in RevMan 5.4 using random-effects models; risk ratios (RR) were used for dichotomous outcomes and standardized mean differences (SMD) for continuous outcomes. Estimates used the Wald-type method with REML; heterogeneity was summarized with $I^2$.

**Result:** Sixteen studies were included. Acute procedural success was equivalent between CRYO and RFA (RR 1.00, 95% CI 0.99–1.02; p=0.47; $I^2$=0%). CRYO showed higher recurrence during follow-up (RR 2.29, 95% CI 1.49–3.53; p=0.0002; $I^2$=39%). Complications favored CRYO (RR 0.51, 95% CI 0.28–0.92; p=0.03; $I^2$=0%). Fluoroscopy time was shorter with CRYO (SMD −0.42, 95% CI −0.66 to −0.19; p=0.0004; $I^2$=87%), while overall procedure duration was similar (SMD 0.12, 95% CI −0.06 to 0.31; p=0.19; $I^2$=79%). Overall risk of bias was predominantly low.

**Conclusions:** CRYO and RFA achieve comparable acute success in AVNRT. CRYO confers fewer complications and lower fluoroscopy exposure but a higher recurrence risk, highlighting a safety–durability trade-off.

## Introduction

Atrioventricular nodal reentrant tachycardia (AVNRT) is the most common type of paroxysmal supraventricular tachycardia, accounting for approximately 50–60% of cases in adults and a significant proportion in adolescents and young adults.[1] Although AVNRT is typically not life-threatening, its recurrent, sudden episodes of palpitations, dizziness, or syncope can severely impair quality of life and frequently lead to emergency department visits.[1] Catheter ablation has

become the treatment of choice for symptomatic patients, as pharmacologic therapy often proves less effective and poorly tolerated in the long term.[1,2]

Radiofrequency ablation (RFA) has historically been the standard technique, achieving procedural success rates above 95% with low recurrence rates of 3–5%.[3–5] However, RFA carries a small but notable risk of atrioventricular (AV) block requiring permanent pacemaker implantation, reported in 0.5–2% of patients.[6] In contrast, cryoablation (CRYO) was introduced as a safer alternative, particularly valued for its ability to test lesion reversibility ("cryomapping"), which reduces the risk of permanent AV block. Nonetheless, CRYO is often criticized for lower long-term success and higher recurrence rates, with some studies reporting up to 15% recurrence compared to RFA.[7,8]

Given the evolving evidence and ongoing debate over whether the safety advantage of CRYO offsets its lower efficacy compared to RFA, a comprehensive synthesis of outcomes is warranted. This meta-analysis aims to compare procedural success, long-term recurrence, and complication rates of cryoablation versus radiofrequency ablation in the treatment of AVNRT, providing updated evidence to guide clinical decision-making and procedural strategy

## Material And Methods

*Search Strategy*

This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 guidelines.[9] The protocol was not registered on PROSPERO. A comprehensive search of PubMed, EMBASE, and Scopus was performed on 25 September 2025, without language restrictions, to identify relevant studies comparing CRYO and RFA in patients with AVNRT. The search strategy combined controlled vocabulary terms and free-text keywords related to "AVNRT," "cryoablation," and "radiofrequency ablation." Reference lists of included studies and relevant reviews were hand-searched to ensure completeness.

*Eligibility Criteria*

Studies were selected according to the PICO framework:

- Population (P): Patients of any age diagnosed with AVNRT.
- Intervention (I): CRYO.
- Comparator (C): RFA.
- Outcome (O): Primary outcome was procedural success, defined as the elimination of inducible AVNRT at the end of the ablation procedure. Secondary outcomes included recurrence rate during follow-up and procedure-related complications.

Inclusion criteria were randomized controlled trials (RCTs) or observational studies (prospective or retrospective cohort studies) that directly compared CRYO versus RFA in AVNRT. Exclusion criteria were case reports, conference abstracts without full data, reviews or meta-analyses, editorials, and studies without a comparator group.

*Study Selection and Data Extraction*

All titles and abstracts were screened independently by two reviewers, followed by full-text evaluation of potentially eligible articles. Disagreements were resolved through discussion until consensus was achieved. Data extraction was performed independently by all reviewers using a standardized Google Sheets template. Extracted information included study characteristics (author, year, country, design, sample size), patient demographics, ablation technique, follow-up duration, and outcomes of interest.

*Risk of Bias and Certainty of Evidence*

Risk of bias for non-randomized studies was assessed using the ROBINS-I tool, evaluating seven domains including confounding, selection, classification of interventions, and outcome measurement. For randomized controlled trials, corresponding risk-of-bias criteria were applied. Additionally, the overall certainty of evidence for each outcome was graded using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach, considering factors such as study limitations, inconsistency, indirectness, imprecision, and publication bias.

*Statistical Analysis*

Meta-analysis was performed using Review Manager (RevMan) version 5.4. For dichotomous outcomes, risk ratios (RR) with 95% confidence intervals (CI) were calculated, while for continuous outcomes, standardized mean differences (SMD) with 95% CI were used. A random-effects model was applied regardless of heterogeneity, and all estimates were computed using the Wald-type method with Restricted Maximum Likelihood (REML) estimation. Statistical significance was defined as a two-sided p-value < 0.05. Heterogeneity was assessed using the $I^2$ statistic, and funnel plots were generated to evaluate potential publication bias.

## Result

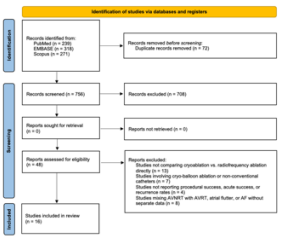


**Figure 1.** PRISMA Flow Diagram for Study Selection in the Meta-Analysis Comparing Cryoablation and Radiofrequency Ablation in Atrioventricular Nodal Reentrant Tachycardia

A total of 828 records were identified through database searches (PubMed = 239, EMBASE = 318, and Scopus = 271). After removing 72 duplicate records, 756 unique studies were screened based on titles and abstracts. Of these, 708 were excluded for not meeting the inclusion criteria, leaving 48 full-text articles assessed for eligibility. Following detailed evaluation, 32 studies were excluded for various reasons: not directly comparing cryoablation versus radiofrequency ablation (n = 13), involving cryo-balloon ablation or non-conventional catheters (n = 7), not reporting procedural success, acute success, or recurrence outcomes (n = 4), and mixing AVNRT with other arrhythmia types such as AVRT, atrial flutter, or atrial fibrillation without separate data (n = 8). Ultimately, 16 studies were included in the final qualitative and quantitative synthesis (figure 1).[10–25]

**Table 1.** Characteristics of Included Studies Evaluating Cryoablation versus Radiofrequency Ablation in AVNRT

| Study ID | | Type of study | Intervention | Population (n) | Age (mean ± SD) | Female n(%) | Follow-up (months) |
|---|---|---|---|---|---|---|---|
| Rivard et al. | 2008 | RC | 4-CRYO vs 6-CRYO | Total: 295; 4-CRYO: 152; 6-CRYO: 137 | 4-CRYO: 42.3 ± 15.2; 6-CRYO: 46.9 ± 16.1 | 4-CRYO: 116 (76); 6-CRYO: 106 (77) | 5.15 (3.65–7.61) |
| Berman et al. | 2017 | RC | NI-RFA vs IR-RFA vs 6/8-CRYO | Total: 183; NI-RFA: 60; IR-RFA: 67; 6/8-CRYO: 56 | NI-RFA: 51.2 ± 15.7; IR-RFA: 48.7 ± 19.2; 6/8-CRYO: 47.6 ± 18.6 | NI-RFA: 42 (70); IR-RFA: 43 (64); 6/8-CRYO: 43 (77) | 4.2 |
| Chaumont et al. | 2020 | RC | NI-RFA vs 6-CRYO | Total: 409; NI-RFA: 149; 6-CRYO: 260 | NI-RFA: 62 ± 14; 6-CRYO: 43 ± 18 | NI-RFA: 87 (58.4); 6-CRYO: 181 (71.9) | 39.6 ± 27.6 |
| Kimman et al. | 2004 | RCT | NI-RFA vs 4-CRYO | Total: 102; NI-RFA: 33; 4-CRYO: 30 | N/A | NI-RFA: 23 (69.7); 4-CRYO: 16 (53.3) | NI-RFA: 42.4 ± 27.6; 4-CRYO: 37.6 ± 26.8 |
| Rodriguez-Entem et al. | 2013 | RCT | NI-RFA vs 6-CRYO | Total: 119; NI-RFA: 59; 6-CRYO: 60 | NI-RFA: 49.8 ± 15; 6-CRYO: 47.7 ± 13 | NI-RFA: 28 (47.2); 6-CRYO: 24 (40) | 8.40 ± 1.47 |
| Opel et al. | 2009 | RC | NI-RFA vs 6-CRYO | Total: 272; NI-RFA: 149; 6-CRYO: 123 | Total: 53 ± 14; NI-RFA: 54 ± 14; 6-CRYO: 59 ± 15 | Total: 194 (68); NI-RFA: 100 (67.1); 6-CRYO: 84 (68.3) | NI-RFA: 2 (1–19); 6-CRYO: 3 (1–19) |
| Deisenhofer et al. | 2010 | RCT | NI-RFA vs 6-CRYO | Total: 509; NI-RFA: 258; 6-CRYO: 251 | NI-RFA: 51.5 ± 15.5; 6-CRYO: 50.1 ± 15.1 | NI-RFA: 171 (66.3); 6-CRYO: 163 (64.9) | 6 |
| Schwagten et al. | 2010 | RC | NI-RFA vs 4-CRYO | Total: 274; NI-RFA: 124; 4-CRYO: 150 | Total: 51 ± 17; NI-RFA: 52 ± 17; 4-CRYO: 50 ± 17 | N/A | N/A |
| Chan et al. | 2010 | RCT | RFA vs 6-CRYO | Total: 20; RFA: 9; 6-CRYO: 11 | Total: 46.5 ± 12.5; RFA: 47.6 ± 12.3; 6-CRYO: 45.6 ± 12.5 | Total: 12 (60); RFA: 44.4; 6-CRYO: 72.7 | 6 |
| Zrenner et al. | 2004 | RCT | NI-RFA vs 4-CRYO | Total: 200; NI-RFA: 100; 4-CRYO: 100 | NI-RFA: 51 ± 17; 4-CRYO: 51 ± 18 | NI-RFA: 68 (68); 4-CRYO: 58 (58) | NI-RFA: 9 (5.3–13); 4-CRYO: 7.5 (5.1–12.6) |
| Chan et al. | 2009 | CC | NI-RFA vs 6-CRYO | Total: 160; NI-RFA: 80; 6-CRYO: 80 | NI-RFA: 48.3 ± 14.8; 6-CRYO: 49.8 ± 14.8 | NI-RFA: 52 (65); 6-CRYO: 56 (70) | NI-RFA: 22.5 ± 20.1; 6-CRYO: 13.6 ± 12.7 |
| Kopelman et al. | 2003 | RCT | NI-RFA vs RFA | Total: 20; NI-RFA: 10; RFA: 10 | Total: 45.5 ± 17.4; NI-RFA: 47.8 ± 21.6; RFA: 43.1 ± 13.2 | NI-RFA: 7 (70); RFA: 8 (80) | 8.9 ± 2.2 |
| Chan et al. | 2012 | CC | NI-RFA vs 4-CRYO | Total: 40; NI-RFA: 20; 4-CRYO: 20 | NI-RFA: 44.8 ± 15.3; 4-CRYO: 49.4 ± 12.8 | NI-RFA: 7 (35); 4-CRYO: 5 (25) | NI-RFA: 10.4 (6–27.3); 4-CRYO: 8.4 (6.3–19.5) |
| Chan et al. | 2019 | RCT | NI-RFA vs 8-CRYO | Total: 158; NI-RFA: 78; 8-CRYO: 80 | Total: 48.9 ± 14.1; NI-RFA: 45.8 ± 14.2; 8-CRYO: 52.1 ± 13.4 | Total: 103 (65.2); NI-RFA: 54 (69.2); 8-CRYO: 49 (61.3) | 12 |
| Gupta et al. | 2006 | CC | NI-RFA vs 4-CRYO | Total: 142; NI-RFA: 71; 4-CRYO: 71 | NI-RFA: 52 ± 15; 4-CRYO: 52 ± 16 | NI-RFA: 55 (77.5); 4-CRYO: 55 (77.5) | NI-RFA: 1.9 ± 0.37; 4-CRYO: 2.2 ± 0.40 |
| Papagiannis et al. | 2010 | RC | RFA vs 6-CRYO | Total: 42; RFA: 20; 6-CRYO: 20 | RFA: 13.25 ± 2.59; 6-CRYO: 12.17 ± 3.07 | RFA: 12 (60); 6-CRYO: 11 (55) | RFA: 52.7 ± 19.5; 6-CRYO: 32.8 ± 11.9 |

CC = case control; RC = retrospective cohort; RCT = randomized controlled trial

The included studies (table 2) were conducted between 2003 and 2020, comparing various cryoablation protocols (4-, 6-, or 8-mm tip catheters) with conventional or irrigated RFA in patients diagnosed with AVNRT. The sample sizes across studies ranged from 20 to 509 participants, reflecting a broad range of

institutional experiences. Most trials included both non-irrigated (NI-RFA) and irrigated RFA (IR-RFA) groups, while some studies further differentiated between

cryoablation catheter sizes. The age of participants generally ranged from the early 40s to the mid-50s, with a relatively balanced sex distribution—female participants typically accounting for 60–75% of the total cohort.

Follow-up durations varied widely across studies, spanning from as short as 1 month to as long as nearly 40 months, with the majority of studies reporting follow-up between 6 and 12 months. The procedural comparisons consistently evaluated acute procedural success, recurrence rates, and major complications such as atrioventricular block. While methodological heterogeneity existed among studies, particularly regarding mapping systems, catheter technology, and definition of procedural success, all included trials provided quantitative data suitable for pooled analysis of procedural success and safety endpoints.

The meta-analysis demonstrated no significant difference in acute procedural success between cryoablation and RFA for AVNRT, with a pooled RR of 1.00 [95% CI, 0.99–1.02; p = 0.47], indicating equivalent efficacy between the two techniques (Figure 2). In contrast, cryoablation was associated with a significantly higher recurrence rate compared to RFA, with a pooled RR of 2.29 [95% CI, 1.49–3.53; p = 0.0002], suggesting roughly double the risk of recurrence following cryoablation (Figure 4). For procedural safety, the pooled analysis favored cryoablation, which demonstrated a significantly lower complication rate than RFA (RR = 0.51 [95% CI, 0.28–0.92; p = 0.03]), with no evidence of heterogeneity ($I^2$ = 0%) (Figure 2). Regarding procedural efficiency, cryoablation resulted in a significantly shorter fluoroscopy time (SMD = –0.42 [95% CI, –0.66 to –0.19; p = 0.0004], $I^2$ = 87%) (Figure 5), suggesting reduced radiation exposure. However, procedure duration did not differ significantly between the two approaches (SMD = 0.12 [95% CI, –0.06 to 0.31; p = 0.19], $I^2$ = 79%) (Figure 6). Collectively, these results indicate that both ablation techniques achieve comparable acute success, though cryoablation offers a superior safety profile and lower fluoroscopy exposure at the expense of a higher recurrence rate.

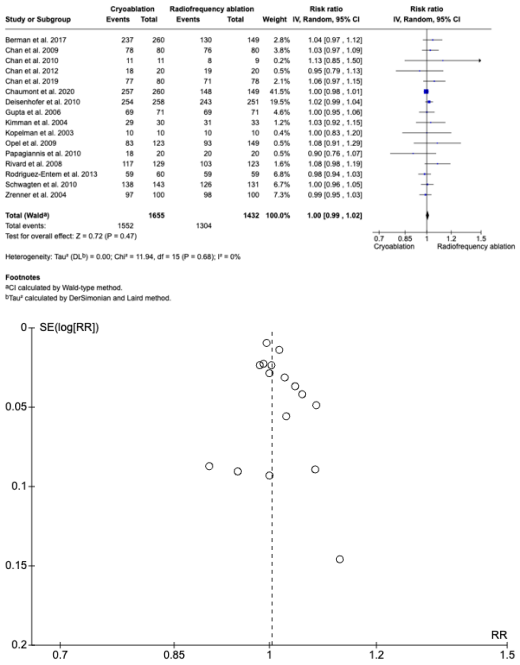


**Figure 2.** Meta-analysis of pooled acute success rate between cryoablation and radiofrequency ablation in AVNRT

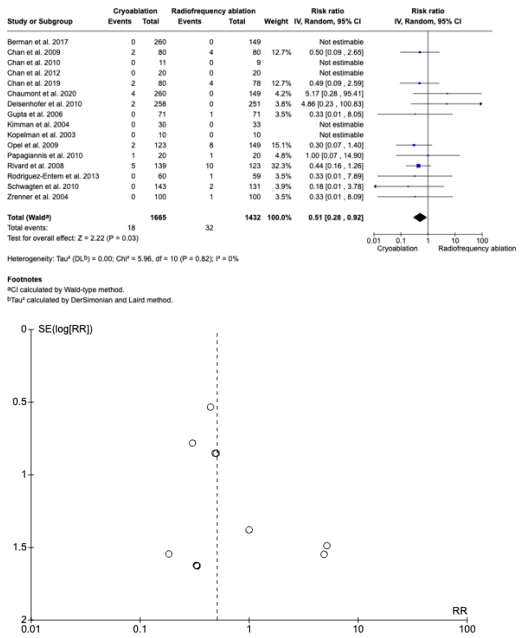


**Figure 3.** Meta-analysis of pooled complication rates between cryoablation and radiofrequency ablation in AVNRT

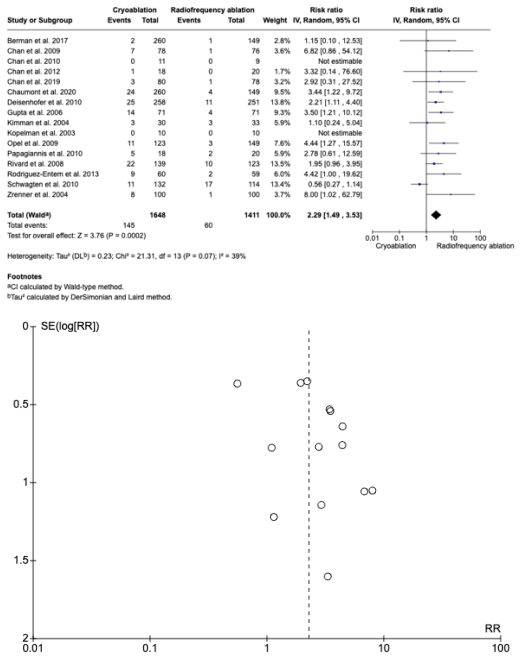


**Figure 4.** Meta-analysis of pooled recurrence rates following cryoablation and radiofrequency ablation in AVNRT

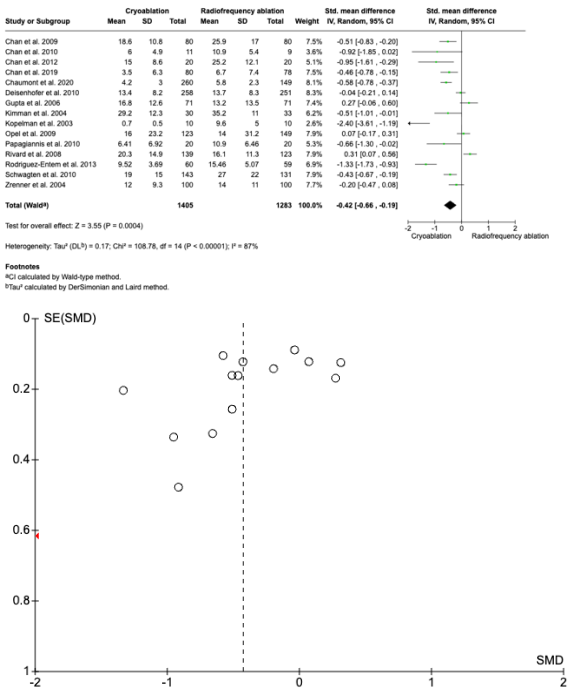


**Figure 5.** Meta-analysis of pooled fluoroscopy time between cryoablation and radiofrequency ablation in AVNRT

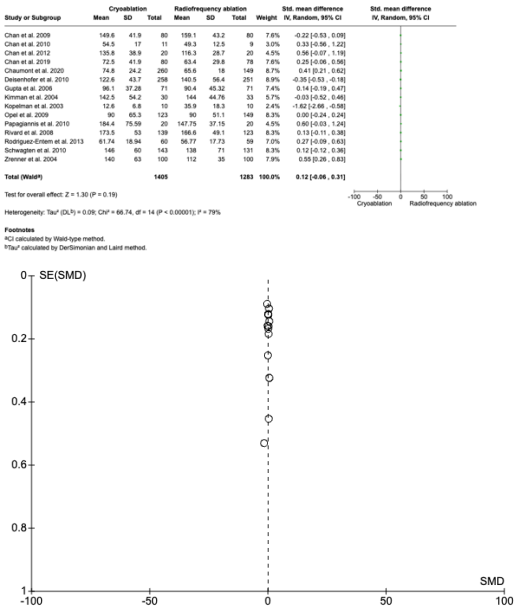


**Figure 6.** Meta-analysis of pooled procedure time between cryoablation and radiofrequency ablation in AVNRT

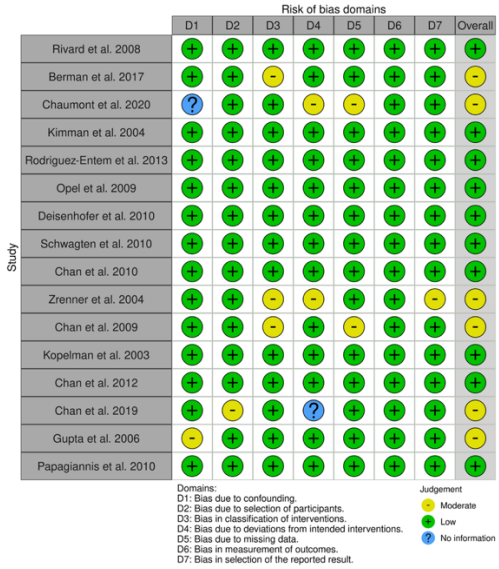


**Figure 7.** ROBINS-I risk of bias assessment.

The overall quality of the included non-randomized studies was rated as predominantly low risk of bias, with most domains demonstrating consistent methodological rigor across studies (Figure 7). A few studies exhibited moderate risk in domains related to classification of interventions, deviations from intended protocols, or selective reporting. Instances of unclear information were limited and mainly pertained to confounding or missing data, indicating generally reliable evidence quality for pooled analysis.

## Discussion

The present meta-analysis demonstrated that acute procedural success between cryoablation and RFA for AVNRT was statistically comparable. This finding aligns with previous trials reporting that both energy sources achieve immediate elimination of slow-pathway conduction in over 95% of patients.[26,27] Comparable success is likely due to the ability of both modalities to effectively interrupt the reentrant circuit at the slow pathway input. It is known that both cryothermal and radiofrequency energy create controlled tissue injury at the slow pathway region; however, cryoablation achieves this through reversible cellular freezing, allowing safe lesion titration.[28] The similar acute efficacy observed reflects that despite different biophysical mechanisms, both energies target the same nodal substrates with equivalent short-term success.

In contrast, the pooled recurrence rate was significantly higher following cryoablation compared to RFA. This result concurs with earlier studies such as Zrenner et al. and Deisenhofer et al., which demonstrated greater recurrence after cryothermal ablation, particularly when using 4-mm cryocatheters.[15,25] Literature suggests that recurrence stems from smaller lesion volumes and incomplete slow-pathway modification during cryoablation.[29] Physiologically, cryolesions are produced by intracellular ice formation and microvascular injury, processes that depend on temperature gradients and tissue contact stability. The resultant lesions are shallower and more reversible than the thermal coagulation necrosis created by RFA, potentially allowing late reconduction of the slow pathway. Hence, while cryoenergy preserves nodal function, its limited lesion depth may account for the higher recurrence observed in this analysis.

This study found that cryoablation was associated with significantly fewer complications compared to RFA. These results are consistent with extensive clinical data showing that permanent AV block is exceedingly rare with cryothermal energy but remains a risk with radiofrequency ablation.[30] Previous multicenter registries, such as those by Kugler et al. and Chan et al., have documented near-zero rates of complete AV block with cryoenergy, supporting its superior safety profile.[31] Anatomically, this advantage is explained by the cryoadhesion property, which stabilizes

catheter contact during freezing, and by the "cryomapping" capability that allows reversible testing near the AV node before permanent lesion formation.[32] These biophysical characteristics make cryoablation particularly suitable for pediatric or young adult populations where tissue preservation is paramount.

In terms of procedural efficiency, the pooled analysis showed that cryoablation resulted in a significantly shorter fluoroscopy time, but similar overall procedure duration. These findings are consistent with current evidence suggesting that cryothermal systems, aided by catheter adhesion and stable positioning, reduce the need for fluoroscopic repositioning and thus lower radiation exposure.[33] However, literature indicates that total procedure time can remain comparable because cryothermal applications require longer energy delivery (typically 240–300 seconds per lesion) compared with the brief thermal burns of RFA.[34,35] From a physiological perspective, the reduced fluoroscopy time reflects improved procedural stability due to ice-tip adhesion, while the similar overall duration reflects the time needed for progressive freezing and rewarming cycles intrinsic to the cryoablation process.

## Conclusion

In conclusion, this meta-analysis demonstrated that cryoablation and radiofrequency ablation (RFA) achieve comparable acute procedural success in the treatment of atrioventricular nodal reentrant tachycardia, confirming their equal efficacy in immediate slow-pathway modification. However, cryoablation was associated with a higher recurrence rate, reflecting its tendency to create smaller and more reversible lesions, while maintaining a markedly lower complication rate, particularly regarding atrioventricular block. These findings underscore a key clinical trade-off: cryoablation offers enhanced safety and reduced fluoroscopy exposure but at the cost of reduced long-term durability compared to RFA. Overall, both energy modalities remain highly effective, and the choice between them should be guided by patient-specific factors, procedural risk tolerance, and the operator's experience.

**Acknowledgment**
None

## References

1. Koulouris S, Ahmed I. Electrophysiology Study and Ablation of Atrioventricular Nodal Reentrant Tachycardia. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 [cited 2025 Oct 9]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK594260/.

2. Gupta D, Rienstra M, Van Gelder IC, Fauchier L. Atrial fibrillation: better symptom control with rate and rhythm management. The Lancet Regional Health - Europe. 2024;37:100801. doi: 10.1016/j.lanepe.2023.100801.

3. Ni Y, Mulier S, Miao Y, Michel L, Marchal G. A review of the general aspects of radiofrequency ablation. Abdom Imaging. 2005;30:381–400. doi: 10.1007/s00261-004-0253-9.

4. Mauri G, Sconfienza LM, Pescatori LC, Fedeli MP, Alì M, Di Leo G, Sardanelli F. Technical success, technique efficacy and complications of minimally-invasive imaging-guided percutaneous ablation procedures of breast cancer: A systematic review and meta-analysis. Eur Radiol. 2017;27:3199–3210. doi: 10.1007/s00330-016-4668-9.

5. Scaife CL, Curley SA. Complication, local recurrence, and survival rates after radiofrequency ablation for hepatic malignancies. Surgical Oncology Clinics of North America. 2003;12:243–255. doi: 10.1016/S1055-3207(02)00088-1.

6. Wasmer K, Dechering DG, Köbe J, Leitz P, Frommeyer G, Lange PS, Kochhäuser S, Reinke F, Pott C, Mönnig G, et al. Patients' and procedural characteristics of AV-block during slow pathway modulation for AVNRT-single center 10 year experience. International Journal of Cardiology. 2017;244:158–162. doi: 10.1016/j.ijcard.2017.06.043.

7. Gomes ILC, De Moura DTH, Ribeiro IB, Marques SB, De Sousa Carlos A, Nunes BCM, Hirsch BS, De Oliveira GHP, Trasolini RP, Bernardo WM, et al. Cryotherapy versus radiofrequency ablation in the treatment of dysplastic Barrett's esophagus with or without early esophageal neoplasia: a systematic review and meta-analysis. Clin Endosc. 2024;57:181–190. doi: 10.5946/ce.2023.065.

8. Jabarkhyl D, Marwat MKUK, Haider N, Farah A, Yusuf M, Ali N, Aziz W. Cryoablation Versus Radiofrequency Ablation in the Management of Pediatric Supraventricular Tachyarrhythmia: A Systematic Review and Meta-Analysis. Cureus [Internet]. 2025 [cited 2025 Oct 9]; doi: 10.7759/cureus.77812.

9. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;n71. doi: 10.1136/bmj.n71.

10. Berman AE, Rivner H, Chalkley R, Heboyan V. A comparative analysis of clinical outcomes and disposable costs of different catheter ablation methods for the treatment of atrioventricular nodal reentrant tachycardia. Clinicoecon Outcomes Res. 2017;9:677–683. doi: 10.2147/CEOR.S139861. Cited: in: : PMID: 29138585.

11. Chan NY, Choy CC, Lau CL, Lo YK, Chu PS, Yuen HC, Choi YC, Lau ST. Cryoablation versus Radiofrequency Ablation for Atrioventricular Nodal Reentrant Tachycardia: Patient Pain Perception and Operator Stress. Pacing Clinical Electrophis. 2011;34:2–7. doi: 10.1111/j.1540-8159.2010.02858.x.

12. Chan N-Y, Mok N-S, Choy C-C, Lau C-L, Chu P-S, Yuen H-C, Lau S-T. Treatment of atrioventricular nodal re-entrant tachycardia by cryoablation with an 8-mm-tip catheter

versus radiofrequency ablation. J Interv Card Electrophysiol. 2012;34:295–301. doi: 10.1007/s10840-012-9670-9. Cited: in: : PMID: 22403042.

13. Chan N-Y, Mok N-S, Yuen H-C, Lin L-Y, Yu C-C, Lin J-L. Cryoablation with an 8-mm tip catheter in the treatment of atrioventricular nodal re-entrant tachycardia: results from a randomized controlled trial (CRYOABLATE). Europace. 2019;21:662–669. doi: 10.1093/europace/euy225. Cited: in: : PMID: 30462198.

14. Chaumont C, Mirolo A, Savouré A, Godin B, Auquier N, Viart G, Hatrel A, Gillibert A, Eltchaninoff H, Anselme F. Very long-term outcomes after catheter ablation of atrioventricular nodal reentrant tachycardia: How does cryoenergy differ from radiofrequency? Cardiovasc electrophysiol. 2020;31:3215–3222. doi: 10.1111/jce.14784.

15. Deisenhofer I, Zrenner B, Yin Y-H, Pitschner H-F, Kuniss M, Grossmann G, Stiller S, Luik A, Veltmann C, Frank J, et al. Cryoablation versus radiofrequency energy for the ablation of atrioventricular nodal reentrant tachycardia (the CYRANO Study): results from a large multicenter prospective randomized trial. Circulation. 2010;122:2239–2245. doi: 10.1161/CIRCULATIONAHA.110.970350. Cited: in: : PMID: 21098435.

16. Gupta D, Al-Lamee RK, Earley MJ, Kistler P, Harris SJ, Nathan AW, Sporton SC, Schilling RJ. Cryoablation compared with radiofrequency ablation for atrioventricular nodal re-entrant tachycardia: analysis of factors contributing to acute and follow-up outcome. Europace. 2006;8:1022–1026. doi: 10.1093/europace/eul124. Cited: in: : PMID: 17101629.

17. Kimman GP, Jordaens LJ. Transvenous radiofrequency catheter ablation of atrioventricular nodal reentrant tachycardia and its pitfalls: a rationale for cryoablation? Int J Cardiol. 2006;108:6–11. doi: 10.1016/j.ijcard.2005.05.030. Cited: in: : PMID: 16455147.

18. Kopelman HA, Prater SP, Tondato F, Chronos N a. F, Peters NS. Slow pathway catheter ablation of atrioventricular nodal re-entrant tachycardia guided by electroanatomical mapping: a randomized comparison to the conventional approach. Europace. 2003;5:171–174. doi: 10.1053/eupc.2002.0296. Cited: in: : PMID: 12633642.

19. Opel A, Murray S, Kamath N, Dhinoja M, Abrams D, Sporton S, Schilling R, Earley M. Cryoablation versus radiofrequency ablation for treatment of atrioventricular nodal reentrant tachycardia: Cryoablation with 6-mm-tip catheters is still less effective than radiofrequency ablation. Heart Rhythm. 2010;7:340–343. doi: 10.1016/j.hrthm.2009.11.029.

20. Panday P, Holmes D, Park DS, Jankelson L, Bernstein SA, Knotts R, Kushnir A, Aizer A, Chinitz LA, Barbhaiya CR. Catheter ablation of atrioventricular nodal reentrant tachycardia with an irrigated contact-force sensing radiofrequency ablation catheter. J Cardiovasc Electrophysiol. 2023;34:942–946. doi: 10.1111/jce.15849. Cited: in: : PMID: 36738141.

21. Papagiannis J, Papadopoulou K, Rammos S, Katritsis D. Cryoablation versus radiofrequency ablation for atrioventricular nodal reentrant tachycardia in children: long-term results. Hellenic J Cardiol. 2010;51:122–126. Cited: in: : PMID: 20378513.

22. Rivard L, Dubuc M, Guerra PG, Novak P, Roy D, Macle L, Thibault B, Talajic M, Khairy P. Cryoablation outcomes for AV nodal reentrant tachycardia comparing 4-mm versus 6-mm electrode-tip catheters. Heart Rhythm. 2008;5:230–234. doi: 10.1016/j.hrthm.2007.10.013. Cited: in: : PMID: 18242545.

23. Rodriguez-Entem FJ, Expósito V, Gonzalez-Enriquez S, Olalla-Antolin JJ. Cryoablation versus radiofrequency ablation for the treatment of atrioventricular nodal reentrant tachycardia: results of a prospective randomized study. J Interv Card

Electrophysiol. 2013;36:41–45; discussion 45. doi: 10.1007/s10840-012-9732-z. Cited: in: : PMID: 23080326.

24. Schwagten B, Van Belle Y, Jordaens L. Cryoablation: how to improve results in atrioventricular nodal reentrant tachycardia ablation? Europace. 2010;12:1522–1525. doi: 10.1093/europace/euq294.

25. Zrenner B, Dong J, Schreieck J, Deisenhofer I, Estner H, Luani B, Karch M, Schmitt C. Transvenous cryoablation versus radiofrequency ablation of the slow pathway for the treatment of atrioventricular nodal re-entrant tachycardia: a prospective randomized pilot study. Eur Heart J. 2004;25:2226–2231. doi: 10.1016/j.ehj.2004.07.020. Cited: in: : PMID: 15589640.

26. Nakagawa H, Jackman WM. Catheter Ablation of Paroxysmal Supraventricular Tachycardia. Circulation. 2007;116:2465–2478. doi: 10.1161/CIRCULATIONAHA.106.655746.

27. Wang H, Li X. An observational study on efficacy of atrioventricular nodal slow pathway ablation in patients with atrioventricular nodal reentrant tachycardia and its influence on atrioventricular conduction function. Medicine (Baltimore). 2024;103:e40532. doi: 10.1097/MD.0000000000040532. Cited: in: : PMID: 39560545.

28. Skanes AC, Dubuc M, Klein GJ, Thibault B, Krahn AD, Yee R, Roy D, Guerra P, Talajic M. Cryothermal Ablation of the Slow Pathway for the Elimination of Atrioventricular Nodal Reentrant Tachycardia. Circulation. 2000;102:2856–2860. doi: 10.1161/01.CIR.102.23.2856.

29. Khairy P, Novak PG, Guerra PG, Greiss I, Macle L, Roy D, Talajic M, Thibault B, Dubuc M. Cryothermal slow pathway modification for atrioventricular nodal reentrant tachycardia. Europace. 2007;9:909–914. doi: 10.1093/europace/eum145. Cited: in: : PMID: 17675646.

30. Chan Y-W, Chuang C-M, Lee P-C, Tai I-H, Peng Y-H, Fan W-P, Lee Y-S, Lin M-C, Jan S-L, Fu Y-C, et al. Radiofrequency ablation vs. cryoablation for pediatric atrioventricular nodal reentrant tachycardia in the era of three-dimensional electroanatomical mapping. Front Cardiovasc Med. 2025;12:1527768. doi: 10.3389/fcvm.2025.1527768. Cited: in: : PMID: 39949589.

31. Miyamoto K, Kapa S, Mulpuru SK, Deshmukh AJ, Asirvatham SJ, Munger TM, Friedman PA, Packer DL. Safety and Efficacy of Cryoablation in Patients With Ventricular Arrhythmias Originating From the Para-Hisian Region. JACC: Clinical Electrophysiology. 2018;4:366–373. doi: 10.1016/j.jacep.2017.12.013.

32. Leila R, Raluca P, Yves DG, Dirk S, Bruno S. Cryoablation Versus Radiofrequency Ablation in AVNRT: Same Goal, Different Strategy. J Atr Fibrillation. 2015;8:1220. doi: 10.4022/jafib.1220. Cited: in: : PMID: 27957174.

33. Shekhar S, Ajay A, Agrawal A, Kumar A, Kaur M, Isogai T, Saad A, Abushouk AI, Abdelfattah O, Lak H, et al. Radiation reduction in a modern catheterization laboratory: A single-center experience. Catheter Cardiovasc Interv. 2022;100:575–584. doi: 10.1002/ccd.30396. Cited: in: : PMID: 36073017.

34. Andrade JG, Khairy P, Dubuc M. Catheter Cryoablation: Biology and Clinical Uses. Circ: Arrhythmia and Electrophysiology. 2013;6:218–227. doi: 10.1161/CIRCEP.112.973651.

35. Bastani H, Drca N, Insulander P, Schwieler J, Braunschweig F, Kennebäck G, Sadigh B, Tapanainen J, Jensen-Urstad M. Cryothermal vs. radiofrequency ablation as atrial

flutter therapy: a randomized comparison. EP Europace. 2013;15:420–428. doi: 10.1093/europace/eus261.

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