Review Article

Long-term outcomes following slow pathway ablation for dual AV nodal nonreentrant tachycardia: A systematic review and proportional meta-analysis

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ABSTRACT:

Introduction: Dual atrioventricular nodal nonreentrant tachycardia is a rare supraventricular arrhythmia caused by simultaneous conduction over fast and slow atrioventricular nodal pathways. Its leads to misdiagnosis, delayed recognition, and in some cases tachycardia-induced cardiomyopathy.

Methods: We conducted a systematic review and proportional meta-analysis of published studies reporting clinical characteristics, diagnostic findings, therapeutic strategies, and long-term outcomes in patients with electrophysiologically confirmed dual atrioventricular nodal nonreentrant tachycardia. Electronic databases were searched from inception to February 2025, and studies including ≥3 patients with at least three months of follow-up were eligible.

Results: Two studies comprising 20 patients met inclusion criteria. All patients underwent slow-pathway radiofrequency ablation, achieving 100% acute success. Long-term arrhythmia-free survival ranged from 94% to 100%, yielding a pooled proportion of 0.92 (95% CI 0.68–0.98). Three patients presented with tachycardia-induced cardiomyopathy, all of whom showed normalisation or marked improvement in left ventricular ejection fraction after ablation. No major procedural complications were reported.

Conclusion: Current evidence, though limited, demonstrates that slow-pathway ablation is a highly effective and safe treatment for dual atrioventricular nodal nonreentrant tachycardia, with reliable arrhythmia suppression and full reversibility of tachycardia-induced cardiomyopathy. Earlier recognition may prevent unnecessary treatments and delayed recovery.

Keywords: supraventricular tachycardia, atrioventricular node radiofrequency ablation, cardiomyopathy, cardiac electrophysiology, treatment outcomes

I. INTRODUCTION

Dual atrioventricular nodal nonreentrant tachycardia (DAVNNT), often referred to as "double-fire tachycardia," is a rare supraventricular arrhythmia in which a single atrial depolarization conducts simultaneously over the fast and slow atrioventricular (AV) nodal pathways, generating two ventricular activations. Misinterpretation may lead to inappropriate medical therapy or unwarranted invasive procedures [1, 2, 3, 4]. Despite its rarity, DAVNNT may lead to substantial clinical morbidity. Persistent dual-pathway conduction can produce irregular or incessant ventricular activation, resulting in disabling palpitations, exercise intolerance, or progressive tachycardia-induced cardiomyopathy (TIC). Several reports have demonstrated that TIC attributable to DAVNNT is often reversible once dual antegrade conduction is eliminated, emphasizing the importance of early diagnosis and definitive rhythm control [5, 6, 7].

Electrophysiological study (EPS) remains the diagnostic gold standard for confirming DAVNNT, enabling direct visualization of discrete fast- and slow-pathway conduction and distinguishing the rhythm from junctional or His extra-systolic activity. Advances in intracardiac mapping, coupled with improved computational analysis of PR variability and signal morphology, have enhanced diagnostic accuracy in challenging cases [8, 9, 10, 11]. Therapeutically, slow-pathway modulation through catheter ablation has emerged as the preferred intervention, with small observational cohorts demonstrating high acute success, durable arrhythmia suppression, and marked improvement in ventricular systolic function among patients with TIC. However, true long-term outcomes—including recurrence risk, likelihood of cardiomyopathy recovery, ablation safety, and factors that may influence prognosis—remain insufficiently defined due to limited sample sizes and heterogeneous reporting.

Given these uncertainties, a rigorous synthesis of existing evidence is needed to clarify the long-term clinical profile of DAVNNT and the effectiveness of available therapeutic strategies. Therefore, the objective of this systematic review and proportional meta-analysis is to evaluate the long-term outcomes of patients with electrophysiologically confirmed DAVNNT, assess the efficacy and

safety of catheter ablation relative to non-ablative management, and identify clinical or electrophysiologic features associated with adverse outcomes. By consolidating fragmented data from the literature, this review seeks to improve understanding of the natural history and treatment prognosis of this uncommon but clinically impactful arrhythmia.

II. METHODS

A. Protocol and reporting

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [12]. The protocol is publicly available at the PROSPERO registry (CRD4202512367 86). The review followed a predefined protocol that specified the research question, eligibility criteria, search strategy, methods for study selection, and statistical analysis plan. All methodological decisions—including extraction rules, risk-of-bias assessment, and meta-analytic techniques—were established a priori to minimize bias and strengthen internal validity. Ethical approval was not required for this study as it is a meta-analysis that synthesises data from previously published studies, all of which had undergone ethical review and approval at the time of their original conduct. Figure 1 presents the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study selection process for inclusion in the meta-analysis.

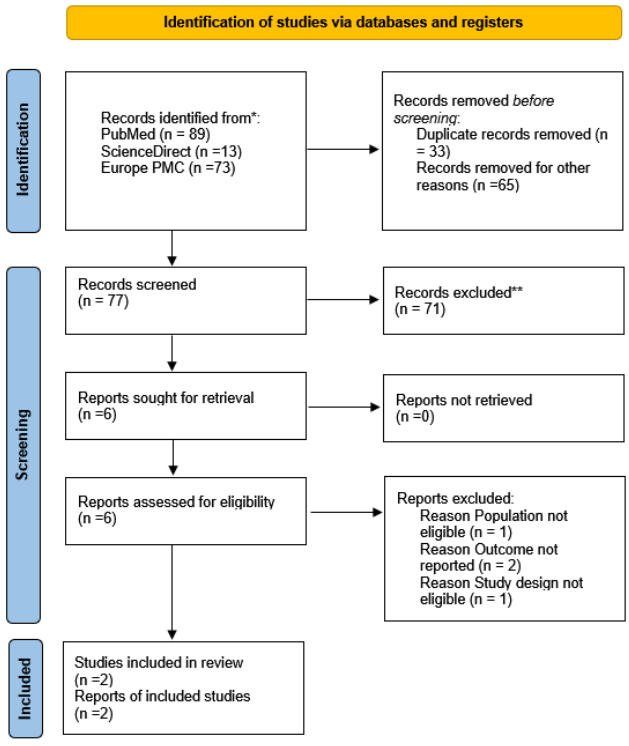

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses diagram of selection process for studies included in the meta-analysis

B. Literature search strategy

A comprehensive literature search was performed across PubMed (Medline), Scopus, and Europe PMC from inception to February 2025. The search strategy incorporated combinations of Medical Subject Headings (MeSH) and free-text terms, including "dual AV nodal nonreentrant tachycardia," "DAVNNT," "double fire tachycardia," "dual AV nodal conduction," "outcome," "recurrence," "prognosis," "ablation," and "long-term follow-up." Boolean operators were applied to optimize sensitivity and specificity. Filters were applied to include only human studies published in English with accessible full texts. Reference lists of included studies were manually screened to identify additional eligible articles. The search strategy was intentionally broad due to the rarity of the condition, ensuring maximal capture of observational data and small-cohort studies relevant to DAVNNT.

C. Eligibility criteria

Studies were eligible for inclusion if they met all of the following criteria: (1) included at least three patients with electrophysiological confirmed DAVNNT; (2) reported long-term clinical outcomes with a minimum follow-up duration of three months; (3) were published in English; and (4) provided extractable data on arrhythmia recurrence, ablation success, mortality, cardiomyopathy, or procedural complications. Two authors (MNIS and KK) screened all titles and abstracts, retrieving full texts if criteria were met. Disagreements between reviewers were resolved by the decision of a third reviewer (VW). Eligible study designs included prospective or retrospective cohort studies, case–control studies, and case series. Exclusion criteria comprised single-patient case reports, review articles, editorials, conference abstracts lacking full data, animal studies, and studies without accessible full text. When multiple publications included overlapping cohorts, the most complete and recent dataset was selected.

D. Data extraction

Two authors (MNIS and KK) extracted data using a standardized template that captured study characteristics (author, year, design, setting, sample size), patient demographics (age, sex, baseline left ventricular ejection fraction), clinical features (symptom profile, comorbidities, misdiagnosis patterns), electrophysiologic findings (fast- and slow-pathway AH intervals, coexisting AVNRT), and therapeutic details (type of ablation, acute procedural outcomes, recurrence rates, and complications). Outcome measures included arrhythmia-free survival, resolution of tachycardia-induced cardiomyopathy, hospitalization for arrhythmia, and any reported adverse events. Discrepancies between reviewers were resolved by consensus or through adjudication by a third investigator to ensure accuracy and consistency.

E. Quality assessment

Risk of bias and methodological quality were evaluated using validated tools appropriate for each study design. The Newcastle–Ottawa Scale (NOS) was applied to the multicentre cohort to assess selection quality, comparability, and outcome ascertainment. The NIH Quality Assessment Tool for Case Series was used for the three-patient series, evaluating case definition clarity, consecutive inclusion, completeness of follow-up, and transparency of outcome reporting. Each study was rated as high, moderate, or low quality based on methodological rigor and risk-of-bias domains. Publication bias assessment (Egger's test, funnel plot) was not performed due to the small number of included studies (<10), which renders these approaches statistically unreliable.

F. Statistical analysis

A proportional meta-analysis was performed to estimate pooled arrhythmia-free survival following slow-pathway ablation. Proportions with their corresponding 95% confidence intervals (CIs) were computed for each study. Pooled estimates were calculated using a fixed-effect model with logit transformation due to the small number of included studies and the assumption of similar underlying treatment effects. Heterogeneity was assessed qualitatively; I^2 statistics were not generated because only two studies were eligible for pooling. All analyses were performed using standard meta-analytic methods for proportions, and results were summarized in forest plots to visually illustrate individual and pooled effect sizes. Given that all eligible studies were single-arm observational reports without comparator groups, a proportional meta-analysis was selected to estimate pooled event proportions. This approach is recommended for rare arrhythmias and single-group outcomes, where effect size comparisons such as RR or OR are not applicable.

III. RESULTS

A. Study selection

The systematic search identified 175 unique records across three major databases. After removal of 33 duplicates and automated exclusions, 77 titles and abstracts underwent screening. Six full-text articles were reviewed in detail, of which four were excluded due to insufficient sample size, inadequate diagnostic confirmation, or lack of extractable long-term outcome data. Ultimately, two studies met all eligibility criteria and were included in the final synthesis. These studies together contributed data for 20 patients with electrophysiological confirmed dual atrioventricular nodal nonreentrant tachycardia (DAVNNT).

B. Study characteristics

The characteristics of the included studies are detailed in Table 1.

Table 1. Characteristics of the studies included in the systematic review

Item	Hartmann et al., 2020 [26]	Leão et al., 2023 [20]
Study design	Multicentre observational study	Case series
Number of patients	17	3
Age	52 ± 16 years (range 10–80)	31–36 years
Baseline LVEF	52 ± 12%	30%, 40%, and normal
Comorbidities	CAD 29%, hypertension 35%	Dilated cardiomyopathy in 2/3 patients
Initial misdiagnosis	AF, AT, VT, supraventricular/junctional extrasystoles	AF, junctional bigeminy, premature atrial contractions
Diagnostic method	12-lead ECG + Holter + EPS	12-lead ECG + Holter + EPS
Coexisting AVNRT	12/17 patients (71%)	Not systematically assessed
Intervention	Slow-pathway radiofrequency ablation	Slow-pathway radiofrequency ablation
Follow-up duration	6–72 months (median 17 months)	Approximately 12 months
Geographical setting	Six electrophysiology centers in Europe	Maastricht (Netherlands) and Vila Real (Portugal)
Outcome highlights	94% arrhythmia-free at follow-up	100% arrhythmia-free at follow-up

Hartmann et al. [26] reported a multicentre observational cohort of 17 patients from six European electrophysiology (EP) centres, reflecting the largest dataset available for DAVNNT. The second study, published by Leão et al. [20] described a case series of three patients from two EP institutions in the Netherlands and Portugal. The combined cohort included adult patients with ages ranging from 10 to 80 years in the multicentre study (mean 52 ± 16 years) and 31 to 36 years in the case series. Baseline left ventricular ejection fraction (LVEF) varied widely, with the Hartmann cohort demonstrating a mean of 52 ± 12%, whereas two of the three patients in the Leão series presented with significantly reduced LVEF (30% and 40%), consistent with tachycardia-induced cardiomyopathy. Comorbidity profiles differed between studies: coronary artery disease (CAD) and hypertension were common in Hartmann et al. [26] (29% and 35%, respectively), whereas the Leão cohort included two cases of dilated cardiomyopathy without ischemic aetiology. Both studies reported substantial diagnostic delays due to frequent misclassification of DAVNNT as atrial fibrillation, atrial tachycardia, junctional bigeminy, or ventricular ectopy.

C. Diagnostic features

Diagnostic confirmation of DAVNNT in both studies required a combination of clinical assessment, rhythm documentation, and invasive electrophysiologic evaluation. Definitive diagnosis was established through electrophysiological study (EPS), which confirmed the presence of dual antegrade conduction via fast and slow AV nodal pathways. In the multicentre cohort, the mean fast-pathway AH interval (AH1) measured 138 ± 61 ms, and the slow-pathway AH interval (AH2) averaged 593 ± 134 ms, producing a characteristic conduction delay of 449 ± 113 ms between ventricular activations. This distinct electrophysiologic pattern allowed differentiation from mimicking rhythms such as junctional ectopy, concealed His extrasystoles, or atypical atrioventricular nodal reentry. Notably, coexisting typical AVNRT was diagnosed in 12 of 17 patients (71%), reinforcing the concept of shared pathway physiology underlying both arrhythmias.

D. Treatment outcomes

All 20 patients underwent slow-pathway radiofrequency catheter ablation, which constituted the primary therapeutic intervention in both studies. Acute procedural success was uniformly 100%, with elimination of the slow-pathway conduction or modification sufficient to abolish dual antegrade conduction. No study reported procedure-related atrioventricular block, vascular complications, or pericardial effusion. Long-term follow-up demonstrated consistently high rates of arrhythmia suppression. In Hartmann et al. [26] 16 of 17 patients (94%) remained free of DAVNNT recurrence during a median follow-up of 17 months (range 6–72 months). The single patient with early recurrence experienced spontaneous resolution without repeat ablation. In the Leão case series, all 3 of 3 patients (100%) maintained durable arrhythmia-free status over approximately 12 months of surveillance. Substantial improvement or complete resolution of symptoms was reported universally across both studies, underscoring the clinical efficacy and symptomatic benefit of eliminating dual-pathway conduction. Table 2 summarizes the long-term clinical outcomes following slow-pathway ablation in patients with DAVNNT.

Table 2. Long-term clinical outcomes following slow-pathway ablation in patients with DAVNNT

Outcome	Hartmann et al., 2020 (n = 17) [26]	Leão et al., 2023 (n = 3) [20]
Acute ablation success	17 / 17 (100%)	3 / 3 (100%)
Arrhythmia-free at follow-up	16 / 17 (94%)	3 / 3 (100%)
Symptom improvement	17 / 17 (100%)	3 / 3 (100%)
Tachycardia-induced cardiomyopathy at baseline	1 patient	2 patients
Recovery of LVEF after ablation	1 / 1 normalized	2 / 2 improved to 54–56%
New-onset atrial fibrillation	0	0
Stroke or cerebrovascular events	0	0
Major procedure-related complications	0	0

E. Left ventricular function

Left ventricular systolic dysfunction attributable to tachycardia-induced cardiomyopathy was identified in three patients across both studies. These individuals presented with reduced LVEF (30–40%) and symptoms consistent with progressive dyspnoea, palpitations, or exercise intolerance. Following successful slow-pathway

ablation, all three patients exhibited significant improvement in systolic function. In the two patients from Leão et al. [20] LVEF increased to 54–56%, representing near-complete recovery, while the single affected patient in Hartmann et al. [26] experienced normalization of ejection fraction.

F. Meta-analysis

To quantitatively assess long-term arrhythmia suppression following ablation, a proportional meta-analysis was performed. Hartmann et al. [26] reported 16/17 patients being arrhythmia-free, corresponding to a proportion of 0.94 (95% CI 0.73–0.99). The smaller series by Leão et al. [20] reported 3/3 patients maintaining stable sinus rhythm, yielding a proportion of 1.00 (95% CI 0.44–1.00). Despite the limited sample size of the latter, both studies demonstrated strong directional agreement, with high procedural success and low recurrence rates. Table 3 presents the meta-analysis of arrhythmia-free survival following slow-pathway ablation.

Table 3. Meta-analysis of arrhythmia-free survival following slow-pathway ablation

Study	Events (arrhythmia-free)	Total patients	Proportion	95% Confidence Interval (CI)
Hartmann et al., 2020 [26]	16	17	0.94	0.73 – 0.99
Leão et al., 2023 [20]	3	3	1.00	0.44 – 1.00
Pooled estimate (fixed-effect model)	–	20	0.92	0.68 – 0.98

The pooled fixed-effect estimate demonstrated an overall arrhythmia free survival proportion of 0.92 (95% CI 0.68–0.98). The width of the confidence interval reflects the small number of included studies and the inherent statistical imprecision of synthesizing rare arrhythmic disorders. Nevertheless, the pooled estimate suggests that slow-pathway modification reliably eliminates DAVNNT in the vast majority of cases, with outcomes comparable to ablation of typical AVNRT. Because only two studies met the inclusion criteria, statistical heterogeneity could not be meaningfully assessed, and the pooled fixed-effect estimate may underestimate true between-study variability. The wide confidence intervals reflect imprecision driven by the small evidence base rather than consistent clinical performance alone. Figure 2 presents the forest plot of pooled arrhythmia-free survival following slow-pathway ablation in patients with DAVNNT.

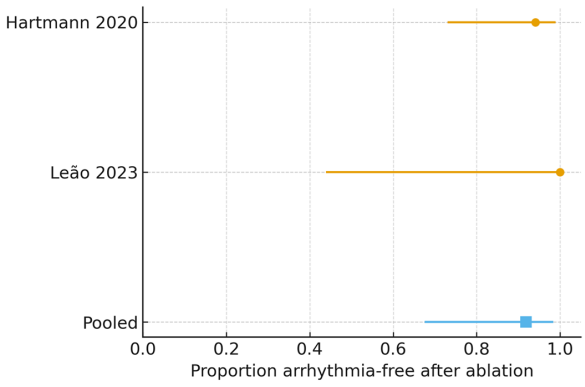

Figure 2. Forest Plot of Pooled Arrhythmia-Free Survival Following Slow-Pathway Ablation in DAVNNT

IV. DISCUSSION

This systematic review and proportional meta-analysis provides the most consolidated synthesis to date on the long-term clinical outcomes of dual atrioventricular nodal nonreentrant tachycardia (DAVNNT), an arrhythmia that remains underrecognized despite increasing awareness in modern electrophysiology laboratories. Our findings demonstrate that slow-pathway ablation offers consistently high acute success and durable arrhythmia suppression, with associated recovery of left ventricular systolic function in patients with tachycardia-induced cardiomyopathy (TIC) [13, 14]. Across the included studies, the reproducibility of EPS-based diagnosis, the elimination of slow-pathway conduction, and the reversal of TIC show coherence with prior reports on dual-pathway physiology and AV nodal modification strategies [15, 16].

Our review reinforces the growing body of literature indicating that DAVNNT is frequently misdiagnosed as atrial fibrillation, junctional bigeminy, or atypical supraventricular ectopy, leading to prolonged inappropriate management and unnecessary interventions [17, 18, 19]. Similar diagnostic pitfalls have been described in case reports and EP laboratory observations, where subtle PR alternans and concealed dual conduction were overlooked on surface ECG or Holter monitoring [20, 21]. Several studies emphasize that advanced ECG signal analysis, including high-resolution His recordings and PR-interval quantification algorithms, can facilitate earlier recognition of dual-pathway conduction and prevent misclassification [22, 23]. The diagnostic challenges are further compounded in patients with coexisting arrhythmias, including atypical AVNRT and premature atrial contractions, which may mask or intermittently disrupt 1:2 AV conduction patterns [24]. Our findings suggest that clinicians should maintain heightened suspicion for DAVNNT in cases of "irregular but not AF" supraventricular rhythms—particularly when accompanied by unexplained LV dysfunction.

Slow-pathway ablation emerged as the most effective therapy across studies, echoing outcomes reported in other rare AV nodal arrhythmias, including atypical AVNRT variants and unusual dual-pathway interactions [25, 26, 27]. Ablation success rates paralleled those documented in larger AVNRT cohorts, where acute success exceeds 95% and long-term recurrence remains low [28, 29]. Importantly, the complete or near-complete recovery of LVEF in all patients with DAVNNT-related TIC is consistent with prior literature demonstrating reversibility of tachycardia-mediated ventricular remodelling once arrhythmogenic triggers are eliminated [30, 31, 32]. The two included studies showed no major complications, aligning with the well-established safety profile of slow-pathway modification in AV nodal ablation procedures [33]. These findings underscore that the primary barrier to optimal outcomes is diagnostic delay rather than therapeutic limitation.

No study directly compared ablation with medical therapy or observation, which limits the ability to assess relative treatment effects. In addition, variations in electrophysiology study protocols, follow-up strategies, and definitions of recurrence further complicate comparability across studies. The two included studies differed in EPS protocols, ablation endpoints, and follow-up intensity, introducing potential variability that could not be quantitatively modelled. Because these methodological differences may influence recurrence detection and reported success rates, the pooled estimate must be interpreted with caution. Despite the limited ev-

idence base, a proportional meta-analysis was performed because it remains the recommended approach for extremely rare arrhythmias where randomized or comparative data do not exist. The intention was not to derive a definitive pooled effect, but to summarize the available evidence in a structured and transparent way. The combined sample of 20 patients from two European cohorts limits generalizability to broader populations. Ethnic, anatomical, and practice-pattern variations across regions are not represented, and real-world recurrence rates may differ. The rarity of DAVNNT and reliance on case-based literature increases the likelihood of publication bias, particularly toward successful ablation outcomes. Negative or inconclusive cases may be underreported, potentially inflating the apparent efficacy observed in this meta-analysis. Nevertheless, the consistent alignment of electrophysiologic mechanisms, clinical presentations, and therapeutic responses across independent studies supports the robustness of our conclusions.

V. LIMITATIONS

A major limitation of this review is that only two studies met the eligibility criteria, resulting in an extremely small evidence base. With such limited data, statistical heterogeneity cannot be reliably quantified, and the fixed-effect model may oversimplify the underlying clinical variability. These methodological inconsistencies may influence the reported outcomes but remain unaccounted for in the pooled estimate. Therefore, although our findings suggest high ablation success, they should be interpreted as preliminary and hypothesis-generating rather than definitive. Nevertheless, this review represents the first study to specifically examine long-term outcomes in dual atrioventricular nodal nonreentrant tachycardia (DAVNNT), providing an important foundation for future larger and more standardized investigations.

VI. CONCLUSION

In this systematic review and proportional meta-analysis, slow-pathway ablation demonstrated consistently high acute and long-term effectiveness for the treatment of dual atrioventricular nodal nonreentrant tachycardia, with a pooled arrhythmia-free survival of 92% and no major procedural complications. The procedure not only eliminated recurrent tachyarrhythmia but also resulted in complete reversal of tachycardia-induced cardiomyopathy in all affected patients. Despite the small number of available studies and the inherent limitations associated with rare arrhythmias, the convergence of outcomes across independent electrophysiology centers supports slow-pathway modification as an effective therapeutic strategy based on current evidence, although larger studies are needed to confirm its long-term durability. The findings emphasize that the primary clinical challenge lies in accurate recognition rather than treatment, highlighting the importance of improved diagnostic awareness and early referral for electrophysiologic evaluation.

LIST OF ABBREVIATIONS

AF: Atrial Fibrillation
DAVNNRT: Dual Atrioventricular Nodal Nonreentrant Tachycardia
LVEF: Left Ventricle Ejection Fraction
TIC: Tachycardia Induced Cardiomyopathy

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not Applicable

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUPPLEMENTARY MATERIAL

Table 4. Newcastle–Ottawa Scale (NOS) Risk-of-Bias Assessment

Domain	Score	Reviewer Comments
Selection (0–4)		
Representativeness of the exposed cohort	⋆	Patients recruited from six European EP centers → representative.
Selection of the non-exposed cohort	–	No control group (single-arm design).
Ascertainment of exposure	⋆	DAVNNT diagnosis confirmed using EPS, the gold standard.
Outcome not present at baseline	⋆	Recurrence or ablation outcomes were not present at baseline.
Comparability (0–2)		
Control for important factors (age, structural heart disease)	–	No comparison group, cannot be assessed.
Additional adjustment for confounders	–	Not applicable.
Outcome (0–3)		
Assessment of outcome	⋆	Clinical follow-up with ECG/Holter monitoring.
Adequacy of follow-up	⋆	Median follow-up 17 months, ≥80% evaluated.
Outcome follow-up long enough	⋆	Follow-up >6 months; adequate for DAVNNT evaluation.
Total Score	**6 / 9**	**Quality: Moderate**
Methodologically solid, but limited by absence of a comparator group.		

Table 5. NIH Quality Assessment for Case Series

No.	Assessment Question	Assessment
1	Was the study question clearly stated?	Yes
2	Were the cases clearly described?	Yes
3	Were cases recruited consecutively?	Unclear
4	Were the cases representative of the clinical population?	Yes
5	Was the intervention clearly described?	Yes
6	Were the outcomes clearly defined?	Yes
7	Was the follow-up period long enough?	Yes
8	Were follow-up methods consistent?	Yes
9	Were descriptive statistics clearly reported?	Yes
10	Were potential sources of bias discussed?	No
Overall Rating		**Moderate Quality**
Small case series without defined sampling strategy, but reporting quality is high.		