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Catheter ablation for fascicular ventricular tachycardia: A systematic review☆

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ABSTRACT

Introduction: Catheter ablation has been evaluated as treatment for fascicular ventricular tachycardia (FVT) in several single-centre cohort studies, with variable results regarding efficacy and outcomes.
Methods: A systematic search was performed on PubMed, EMBASE and Cochrane database (from inception to November 2017) that included studies on FVT catheter ablation.
Results: Thirty-eight observational non-controlled case series comprising 953 patients with FVT undergoing catheter ablation were identified. Three studies were prospective and only 5 were multi-centre. Eight-hundred and eighty-four patients (94.2%) had left posterior FVT, 25 (3.4%) left anterior FVT and 30 (2.4%) other forms. In 331 patients (41%), ablation was performed in sinus rhythm (SR). The mean follow-up period was 41.4 ± 10.7 months. Relapse of FVT occurred in 100 patients (10.7%). Among the 79 patients (8.3%) requiring a further procedure after the index ablation, 19 (2%) had further FVT relapses. Studies in which ablation was performed in FVT had similar success rate after multiple procedures compared to ablation in SR only (95.1%, $CI_{95\%}$ 92.2–97%, $I^2 = 0\%$ versus 94.8%, $CI_{95\%}$ 87.6–97.9%, $I^2 = 0\%$, respectively). Success rate was numerically lower in paediatric-only series compared to non-paediatric cases (90.0%, $CI_{95\%}$ 82.1–94.6%, $I^2 = 0\%$ versus 94.3%, $CI_{95\%}$ 92.2–95.9%, $I^2 = 0\%$, respectively).
Conclusion: Data derived from observational non-controlled case series, with low-methodological quality, suggest that catheter ablation is a safe and effective treatment for FVT, with a 93.5% success rate after multiple procedures. Ablation during FVT represents the first-line and most commonly used approach; however, a strategy of mapping and ablation during SR displayed comparable procedural results to actively mapping patients in FVT and should therefore be considered in selected cases where FVT is not inducible.

1. Introduction

Fascicular ventricular tachycardia (FVT) was first described by Zipes et al. in 1979 [1]. Belhassen et al. demonstrated in 1981 that FVT can be terminated by verapamil [2]. FVT represents 10–15% of idiopathic ventricular tachycardia and is the most common form of idiopathic left ventricular (LV) tachycardia [3]. It has a male preponderance (60–80% of reported cases occur in men) and usually presents in young adults (15–40 years) with structurally normal hearts [4–6]. Its prevalence is higher in Asian populations [7]. Three subtypes have been described: (1) left posterior FVT (90% of cases), with a right-bundle brunch block (RBBB) pattern and left axis deviation (Fig. 1); (2) left anterior FVT (5–10% of cases), with RBBB and right axis deviation; and (3) upper septal FVT (<1% of cases), with usually narrow QRS and normal frontal axis.

FVT is a re-entry tachycardia involving abnormal Purkinje tissue with decremental properties, left ventricular myocardium and the left anterior or posterior fascicles [8], though the entire components of the reentry circuit remain incompletely defined and understood [9].

☆ All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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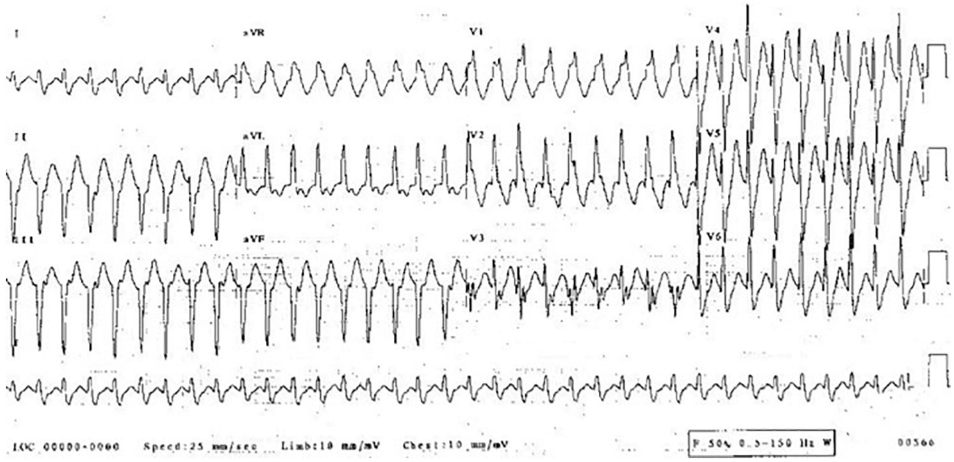


Fig. 1. Twelve-lead electrocardiogram of left-posterior fascicular ventricular tachycardia.

In this report, we aim systematically to review the available data in the literature and assess the efficacy and rates of periprocedural complications following catheter ablation for FVT.

2. Methods

2.1. Study selection

A systematic electronic search was performed on PubMed, EMBASE and Cochrane database (from inception to November 2017) with no language limitations, using the following search string: "fascicular ventricular tachycardia" OR "idiopathic left ventricular tachycardia" OR "verapamil-sensitive tachycardia" AND ("ablation" OR "catheter ablation").

The population, intervention, comparison and outcome (PICO) approach was used [10]. The population of interest was patients with FVT, and the intervention was catheter ablation of FVT. In the absence of a control group, a non-controlled observational analysis was performed. The primary outcome measure was freedom of FVT at the end of follow-up. The other outcome considered was mortality. Procedural complications were assessed on a study-by-study basis.

Eligibility criteria required studies to provide patient demographics and the FVT morphology. Observational non-controlled case series required a minimum of 6 patients to be considered eligible.

Review articles, editorials and case reports were not considered eligible for the purpose of this review.

Reference lists of all accessed full-text articles were further searched for sources of potentially relevant information.

Two independent reviewers (AC and RP) screened all abstracts and titles to identify potentially eligible studies, and the full text of was subsequently interrogated. Agreement of the two reviewers was required for studies to be considered eligible for analysis. Study quality was formally evaluated using the *National Heart, Lung, and Blood Institute Quality Assessment Tool for Case Series Studies* [11] by two reviewers (AC, RP). An agreement between the two reviewers was mandatory for the final classification of studies. A third author (AWC) intervened to resolve disputes whenever the two reviewers were in disagreement regarding the inclusion or classification of a study.

Data extraction and presentation for the preparation of this manuscript followed the recommendations of the PRISMA group [12]. Where available the following data were extracted from the selected studies: study design, study population characteristics (age and sex), FVT morphology and cycle length, follow-up duration, ablation procedure, definition of relapse, post-procedural monitoring, and use of anti-arrhythmic agents. Patient-level data were obtained whenever these were available in the manuscripts, or provided by authors after contact.

2.2. Statistical analysis

Statistical heterogeneity on each outcome of interest was quantified using the I^2 statistic, which describes the percentage of total variation across studies due to heterogeneity rather than chance. Values of <25%, 25% to 50%, and >50% are by convention classified as low, moderate, and high degrees of heterogeneity, respectively.

If no heterogeneity was found ($I^2 \leq 40\%$) OR were calculated using a fixed-effect model. If heterogeneity between studies was observed ($I^2 > 40\%$), ORs were calculated using random-effects model. Comprehensive Meta-Analysis software (Version 2) was used for the analyses. Overall incidences and 95% confidence interval were estimated.

Sub-group analyses were performed for mapping strategy (mapping sinus rhythm vs. mapping in VT), use or not of mapping systems, paediatric vs. non-paediatric cohorts, and use of irrigated versus non-irrigated ablation catheter.

3. Results

3.1. Study selection and patient characteristics

A total of 38 studies meeting the inclusion criteria were identified. The selection process is illustrated in Fig. 2 (PRISMA) and a total population of 953 patients with FVT undergoing catheter ablation were included. Twenty-eight patients from 7 studies [7,13–18] did not receive catheter ablation and therefore were not considered for the present analysis. Non-inducibility of FVT was the most common reason for deferring ablation. The mean age of the patients was 29.5 ± 12.4 years; 82% were male. Eight-hundred and eighty-four patients (94.2%) had left posterior FVT, 25 (3.4%) left anterior FVT and 20 (2.1%) had upper septal FVT. The sub-type of FVT was not specified in the remaining 24 patients. The mean cycle length was 364 ± 66 ms. Eighty-nine patients (9.3%) had a previous failed or attempted FVT ablation before the index procedure considered in the present study. Data regarding antiarrhythmic treatment before catheter ablation were available for 18 studies (equating to 399 patients) and verapamil was used in the majority. Among the 363 patients with previous long-term antiarrhythmic drug treatment, 305 (84%) had symptomatic FVT relapses despite medical therapy.

There was a perfect agreement between investigators on the inclusion of the selected studies. Baseline data and the design of selected trials are summarized in Table 1.

The 38 studies used for the analysis were all case series. Three studies were prospective [7,19,20]. All the studies were observational, with no control group and all but 5 [15,17,21–23] were single-centre. According to the *National Heart, Lung, and Blood Institute Quality Assessment Tool for Case Series Studies* [11] a maximum of 9 criteria apply for case series as shown in Table 1 in Ref [55]. Twenty-one studies fulfilled 8 criteria [7,8,13,17–20,24–37], 12 studies fulfilled 7 criteria [15,21,23,38–46] and 5 studies fulfilled 6 criteria [14,16,24,47,48]. Both authors (AC and RP) were in agreement regarding study classification.

3.2. Procedural data

During the index procedure, FVT was inducible or incessant in 871 patients (91%). Of the 38 studies included in our analysis, only 11 studies reported on the duration of the procedure as well as the mean fluoroscopy time (Table 2). A tridimensional (3-D) mapping system was used in 416 cases (Biosense Webster CARTO system in 224 cases and Abbott-St. Jude Ensite NavX or Velocity in 149 cases, unknown in the remaining), while no 3-D mapping system was used in 531 patients. No data were reported regarding use of mapping system in one study (6 patients) [48]. Irrigated or non-irrigated 3.5 or 4 mm tip catheters were

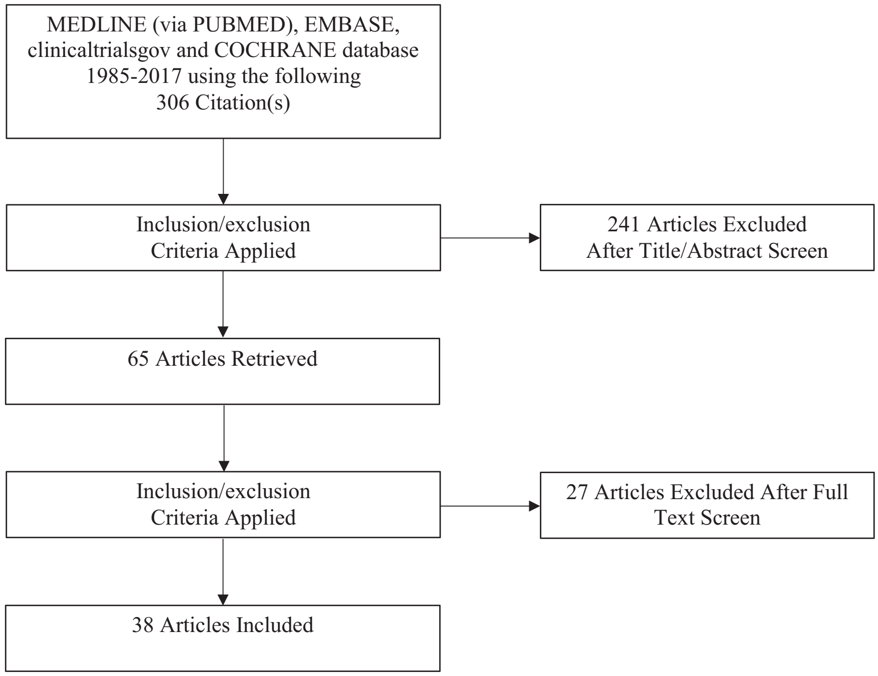


Fig. 2. Flowchart diagram illustrating study selection methodology.

used for mapping and ablation (Table 2). A combination of radiofrequency and cryo-ablation was used in 3 cases [15]. Thirty-three studies (equating to 816 patients) described whether the catheter ablation was performed during sinus rhythm (SR) or during tachycardia. In 331 patients (41%), the ablation was performed during SR. The targets of ablation varied among the studies. Fascicular block was induced in 196 patients (20.6%). For most of the studies, termination and/or non-inducibility of FVT was the acute procedural outcome. Detailed procedural data are presented in Table 2 on this paper and in Table 2 in Ref [55].

3.3. Efficacy of catheter ablation

The mean follow-up period was 41.4 ± 10.7 months. During the follow-up period, a total of 20 patients were lost in one study. Among those with follow-up, relapse of FVT occurred in 100 of 933 patients (10.7%). Among the 79 patients (8.3%) requiring a further procedure after the index ablation, 19 (2.0%) had further FVT relapses. These data are summarized in Table 3.

In 17 studies freedom from FVT relapse was 100% after the index ablation procedure [8,13,17,20,22,25–31,33,34,40,43–45]. Suzuky et al. reported the highest rate of relapse (50%) after catheter ablation [48].

Overall, the pooling of our data (Fig. 3a–b) shows that catheter ablation is effective to abolish FVT, with a success rate of 93.5% after multiple procedures. Interestingly, data regarding antiarrhythmic therapy was available for 18 studies included in the present analysis, and the overall long-term success rate of medical therapy was only 16%.

3.4. Sub-group analyses

Similar results were found between ablation during FVT only versus SR only, with a success rate after multiple procedures of 95.1% ($CI_{95\%}$ 92.2–97%, $P < 0.001$, $I^2 = 0\%$) and 94.8% ($CI_{95\%}$ 87.6–97.9%, $P < 0.001$, $I^2 = 0\%$), respectively. In the 9 studies in which catheter ablation was performed in either FVT or SR, the success rate was 86.7% ($CI_{95\%}$ 82.1–90.2%, $P < 0.001$, $I^2 = 0\%$) after the index procedure and 93.2% ($CI_{95\%}$ 85.7–96.9%, $P < 0.001$, $I^2 = 38\%$) after multiple procedures.

Use of 3-D mapping did improve numerically the success rate compared to fluoroscopy-only procedures, especially after the index procedure (92%, $CI_{95\%}$ 87.8–94.9%, $P < 0.001$ $I^2 = 0\%$ versus 89.5%, $CI_{95\%}$ 83.7–93.4%, $P < 0.001$, $I^2 = 0\%$, respectively).

Success rate was numerically lower in paediatric-only series compared to non-paediatric cases (success rate after multiple procedures 90.0%, $CI_{95\%}$ 82.1–94.6%, $P < 0.001$, $I^2 = 0\%$ versus 94.3%, $CI_{95\%}$ 92.2–95.9%, $P < 0.001$, $I^2 = 0\%$, respectively) .

No significant differences were found between use of irrigated versus non-irrigated ablation catheter, with a success rate after the index procedure of 88.8% ($CI_{95\%}$ 69.9–96.5%, $P < 0.001$, $I^2 = 1\%$) and 87.7% ($CI_{95\%}$ 84.4–90.4%, $P < 0.001$, $I^2 = 0\%$), respectively (Table 4). No data were available regarding patients treated with irrigated catheters having repeated procedures, and therefore comparison of success rates after multiple procedures was not possible.

3.5. Procedural complications

Procedural complications occurred in 13 patients (1.4%). Suzuky et al. [48] reported that one patient (17%) developed complete left bundle branch block (LBBB) and that another patient (17%) developed complete heart block requiring permanent pacemaker implant. Collins et al. [15] reported complications in 6 patients (7%), including 2 (2%) VF arrest, 3 (3%) polymorphic VT and one (1%) transient atrio-ventricular block; also, one patient developed LBBB which did not fit with the complication definition of the study and therefore has not been included in the present analysis. Topilski et al. [18] and Shin et al. [21] reported iatrogenic VF arrest requiring direct-current shock in one patient each. Guo et al. [13] reported one femoral pseudo-aneurysm, while Arya et al. reported one haematoma at the femoral access site. In addition, Nagakawa et al. [37] reported a mitral valve damage not requiring surgery. Thirty-one studies reported absence of any procedural complication. In the remaining 7 studies, the rate of procedural complications varied between 5.9% and 33%. No cardiac tamponades or procedural deaths were reported. Overall, 0.2% ($n = 2$) of patients developed either persistent or transient complete atrio-ventricular block, 0.2% ($n = 2$) developed LBBB, 0.5% ($n = 4$) had VF arrest, 0.1% ($n = 1$) required permanent pacemaker implant and only 0.3% ($n = 3$) was reported to have groin complications. No complications occurred in the remaining 98.6% of patients.

Table 1
Baseline characteristics of studies.

Study	Date of procedures/country	Centres (N)	Design	Prospective/retrospective	Total pts enrolled N (pts who underwent CA)	Age (years)	Female gender N (%)	Mean LVEF (%)	Type of FVT N (%)[a]	Pts refractory to AADs % (N) [mean N of AADs]
Ma [38]	2012–2016 China	1	Case series	Retrospective	41	28 ± 10 (8) 37 ± 15 (15) 36 ± 11 (18)	N/A	58.7 ± 5.5	LPFT - 41 (100%)	N/A
Luo [24]	2000–2013 China	1	Case series	Retrospective	195	29.7	32 (16.4%)	65	LPFT - 195 (100%)	N/A
Guo [13]	2003–2015 China	1	Case series	Retrospective	11 (10)[b]	27	2 (18%)	N/A[c]	LUSFT – 10 (100%)	N/A
Zhan [25]	2013–2014 China	1	Case series	Retrospective	24	41 ± 22	6 (25%)	N/A[c]	LPFT - 24 (100%)	100% (24) [2 ± 1]
Liu Q [8]	2015–2016 China	1	Case series	Retrospective	14	36	3 (21.4%)	N/A[c]	LPFT - 14 (100%)	N/A
Chen [19]	2012–2015 China	1	Case series	Prospective	21	32	5 (24%)	65	LPFT - 17 (81%) LAFT - 4 (19%)	100% (21) [N/A]
Liu Y [7]	2008–2012 China	1	Case series	Prospective	120 (117)[d]	29.3	22 (28.3%)	65	LPFT - 115 (98.3%) LAFT - 2 (1.7%)	100% (117) [1.3 ± 0.9]
Letsas [39]	N/A Greece	1	Case series	Retrospective	10	37.2	2 (20%)	N/A[c]	LPFT – 8 (80%) LAFT - 2 (20%)	N/A
Gopi [14]	2009–2012 India	1	Case series	Retrospective	68 (64)[e]	34.6	21 (31%)	N/A[c]	LPFT - 64 (100%)	N/A
Fishberger [22]	N/A US	2	Case series	Retrospective	6	13.2	1 (17%)	60–70%	LPFT – 5 (83%) LAFT – 1 (17%)	100% (6) [1.2 ± 0.4]
Talib [17]	2006–2014 Japan	N/A (multicentre)	Case series	Retrospective	12 (10)[f]	41 ± 22	5 (50%)	N/A[c]	LUSFT - 10 (100%)	N/A
Liu XY [26]	2009–2011 China	1	Case series	Retrospective	20	37 ± 7	4 (20%)	58 ± 5	LPFT - 20 (100%)[g]	100% (20) [1.3 ± 1.3]
Suzuki [48]	2006–2012 Japan	1	Case series	Retrospective	6	8.8	2 (33%)	N/A[c]	LAFT – 4 (77%) LAFT + LPFT – 2 (33%)	100% (6) [N/A]
Collins [15]	1998–2010	22	Case series	Retrospective	102 (88)[h]	12.5	N/A	N/A[c]	LPFT – 84 (95.6%) NON LPFT – 4 (4.4%)	21% (13)[i] [N/A]
Kataria [20]	2008–2010 India	1	Case series	Prospective	15	32	2 (13%)	62.5	LPFT – 15 (100%)	40% (6) [N/A]
Park [40]	N/A Korea	1	Case series	Retrospective	14	34.6 ± 13.3	3 (21%)	N/A	N/A[q]	N/A
Wissner [41]	2000–2005 Germany	1	Case series	Retrospective	24	26	8 (30%)	N/A[c]	LPFT – 24 (100%)	58% (14) [N/A]
Chu [27]	2008–2009 China	1	Case series	Retrospective	10	N/A (range 25–54)	2 (20%)	N/A[c]	LPFT – 10 (100%)	100% (10) [3 ± 1]
He [28]	N/A China	1	Case series	Retrospective	30	40 ± 11.6	7 (23%)	N/A	LPFT – 30 (100%)	N/A
Shin [21]	2004–2007 Korea	3	Case series	Retrospective	11	31.6 ± 8.3	1 (9%)	N/A[c]	LPFT – 11 (100%)	N/A
Ma [42]	N/A China	1	Case series	Retrospective	39	29	9 (23%)	N/A[c]	LPFT – 39 (100%)	N/A
Magalhaes [16]	1998–2003 Portugal	1	Case series	Retrospective	12 (9)[d]	30	2 (17%)	N/A[c]	LPFT −7 (70%) LAFT −2 (28.6%)	N/A
Lin [43]	1999–2003 US	1	Case series	Retrospective	6	N/A (range 17–46)	1 (17%)	N/A[c]	LPFT – 6 (100%)	N/A
Arya [29]	2002–2004 Iran	1	Case series	Retrospective	15	28 ± 11	3 (20%)	N/A[j]	LPFT – 14 (94%)[g] LAFT – 1 (6%)	N/A

(continued on next page)

Table 1 (*continued*)

Study	Date of procedures/country	Centres (N)	Design	Prospective/retrospective	Total pts enrolled N (pts who underwent CA)	Age (years)	Female gender N (%)	Mean LVEF (%)	Type of FVT N (%)[a]	Pts refractory to AADs % (N) [mean N of AADs]
Topilski [18]	1992–2003 Israel	1	Case series	Retrospective	18 (17)[k]	32 ± 11	2 (12%)	N/A[c]	LPFT – 17 (100%)	N/A
Gupta [44]	N/A US	1	Case series	Retrospective	7	21	1 (14%)	46	LPFT – 7 (100%)	100% (7) [2.3 ± 1.7]
Ouyang [30]	2000–2001 Germany	1	Case series	Retrospective	10	N/A (range 12–36)	3 (30%)	N/A[c]	LPFT – 10 (100%)	100% (10) [3 ± 1]
Aiba [31]	N/A Japan	1	Case series	Retrospective	10	29 ± 10	3 (30%)	N/A[c]	LPFT – 10 (100%)	100% (10) [N/A]
Miyauchi [32]	N/A Japan	1	Case series	Retrospective	9	28 ± 10	0 (0%)	N/A[c]	LPFT – 9 (100%)	100% (9) [N/A]
Nogami [33]	1994–1999 Japan	1	Case series	Retrospective	20	32 ± 13	3 (15%)	N/A	LPFT – 20 (100%)	N/A
Tsuchiya [34]	N/A Japan	1	Case series	Retrospective/prospective	16	32	4 (25%)	N/A	LPFT – 16 (100%)	N/A
Nogami [35]	1994–1996 Japan	1	Case series	Retrospective	6	54	1 (17%)	54	LAFT – 6 (100%)	N/A
Bennett [47]	1993–1996 UK	1	Case series	Retrospective	9	N/A (range 21–48)	3 (33%)	N/A[l]	LPFT – 7 (78%) LAFT – 2 (22%)	100% (9) [1.5 ± 0.8]
Wen [45]	1993–1997 China	1	Case series	Retrospective	7[m]	28 ± 12	0 (0%)	N/A[c]	LPFT – 7 (100%)	N/A
Katristis [23]	1990–1994 UK	2	Case series	Retrospective	7	29	3 (43%)	N/A[c]	LPFT – 7 (100%)	100% (7) [N/A]
Zardini [36]	1990–1993 Canada	1	Case series	Retrospective	8	32 ± 13	2 (25%)	N/A[c]	LPFT – 8 (100%)	100% (8) [2.3 ± 1.3]
Wen [46]	1991–1993 China	1	Case series	Retrospective	20	28 ± 8	3 (15%)	N/A[c]	LPFT – 13 (65%) LAFT – 1 (5%) Unknown – 6 (30%)[n]	N/A
Nagakawa [37]	N/A US	1	Case series	Retrospective	8	26	2 (25%)	N/A[c]	LPFT – 8 (100%)	100% (8) [N/A]
Mean/total (38)	–	–	–	–	981 (953)[o]	29.5 ± 12.4	175 (18%)	–	LPFT – 884 (94.2%) LAFT – 25 (3.4%) OTHER – 30 (2.4%) N/A – 14	84% (305)[p]

Abbreviations: CA – catheter ablation; pts. – patients; LPFT – left posterior fascicular tachycardia; LAFT – left anterior fascicular tachycardia; LUSFT – left upper septal fascicular tachycardia; US – United States of America; UK – United Kingdom; N: number; N/A: not available; AADs: anti-arrhythmic drugs.

[a] Only pts. who underwent CA considered.
[b] One patient declined CA.
[c] Structurally normal heart in all patients.
[d] Three patients did not have CA because of lack of inducibility.
[e] Four patients did not have CA because of lack of inducibility.
[f] Two patients did not have CA for unknown reasons.
[g] In one patient both LPFT and LAPFT were induced.
[h] Nine patients did not have CA because of lack of inducibility, one for impossibility to localise fascicular signal and 4 for unknown reasons.
[i] 62 patients had AADs.
[j] Structurally normal heart in all but one patient who had tachycardia-induced cardiomyopathy.
[k] One patient did not have CA because of inaccurate pace-mapping data and lack of recording Purkinje spikes.
[l] Structurally normal heart in all but one patient who had severe LV systolic dysfunction.
[m] 27 patients enrolled, but procedure details and results described for 7 patients only.
[n] Undetermined axis.
[o] In 28/981 patients CA was not performed.
[p] Data available for 18 studies, equating to 399 patients, 363 of whom received AADs.
[q] LPFVT in most of the patients.

Table 2
Procedural characteristics.

Study	Procedure duration (min)	Fluoroscopy time (min)	Mapping system % (N)	Catheters, energy source, temperature, power, time (N)	Inducible VT % (N)	Cycle length of FVT (mean - ms)	Ablation during SR % (N)	Target of ablation % (N)	Ablation end-point	Number of RFCA lesions (mean)
Ma [38]	N/A	N/A	Ensite-Velociy 100% (14)	Non-irrigated tip, RFCA, 50–60 °C, 35 W, 60–120 s	100% (41)	346 ± 42 (8) 340 ± 63 (15) 330 ± 47 (18)	0% (0)	Earliest PP	Termination during ablation and non-inducibility after 30 min	N/A[a]
Luo [24]	N/A	N/A	CARTO 23% (44), fluoroscopy only for the remainder (151)	4-mm non-irrigated tip 71% (138) or 3.5-mm irrigated tip 29% (57), RFCA, 65 °C/43 °C, 20–35 W, 30–60 s	72.8% (142)	378	90.3% (176)	In VT: earliest PP 6.34% (19) In SR: high-frequency sharp PP 93.66% (123) No pace-mapping used	Non-inducibility (for CA during FVT) or LPF block (for CA during SR)	7
Guo [13]	N/A	N/A	CARTO 100% (10)	3.5-mm irrigated tip, RFCA, max 25 W, 60 s	100% (11)[b]	384	0% (0)	Earliest PP 90% (9) Diastolic potentials 10% (1)	Non-inducibility of FVT 30 min after ablation	N/A
Zhan [25]	N/A	N/A	CARTO 100% (24)	4-mm non-irrigated tip, RFCA, 50–55 °C, 30–40 W, 30–60 s	100% (24)	389 ± 46	100% (24)	Abnormal wide, low-frequency fragmented antegrade Purkinje potential at the posterior septum of left posterior fascicle	Non-inducibility after 30 min	2–3
Liu Q [8]	N/A	N/A	Ensite-Velociy 100% (14)	4-mm irrigated tip, RFCA, 30–35 W	100% (11)	346	0% (0)	Distal P1 64% (9) Earliest PP 36% (5)	Non-inducibility	2.5
Chen [19]	N/A	N/A	Ensite-Velocity or CART O 100% (21)	Non-irrigated tip, RFCA, 50–60 °C, 35 W, 60–120 s	100% (21)[c]	343.7 ± 75.8 (LPFT) N/A for LAFT	N/A	Earliest PP during FT or predicted PP site during SR	Termination during ablation and non-inducibility after 30 min	N/A
Liu Y [7]	138.4 ± 54.8 (90 pts. with axis change after ablation) 122.4 ± 57.3 (25 pts. with axis unchanged after ablation)	12.9 ± 5.5–23 pts. 15.9 ± 8.3–67 pts. 11 ± 4.5–25 pts.	Ensite-NavX 71.6% (84), fluoroscopy only for the remainder (33)	4-mm non-irrigated tip, RFCA, 40–60 °C, 35 W, ≤120 s	97.5% (117)	362.1 ± 79.4 (LPFT) 364.0 ± 26.9 (LAFT)	0% (0)	Earliest PP 100% (117)	Termination during ablation and non-inducibility after 30 min	N/A
Letsas [39]	N/A	N/A	CARTO 100% (10)	3.5 mm irrigated tip, RFCA, 43 °C, 35 W	80% (8)	355.8 ± 39.7	20% (2)	P1–60% (6) Earliest PP – 40% (4), isolated diastolic potentials recorded during SR coincided with successful ablation sites	Non-inducibility	N/A
Gopi [14]	N/A	N/A	CARTO 100% (64)	Non-irrigated tip, RFCA, 43 °C, 30 W	94% (64)	N/A	0 (0%)	Earliest PP, pace-mapping	Termination during ablation and non-inducibility	N/A
Fishberger [22]	N/A	N/A	Ensite-NavX 100% (6)	4-mm non-irrigated tip, RFCA, 65 °C, 50 W, up to 60 s	33% (2)	N/A	100% (6)	Most apical site in which a PP could be recorded	QRS axis shift (creation of partial fascicular block), non-indubicility and persistence of QRS axis shift after 25 min	11.3
Talib [17]	N/A	N/A	CARTO or Ensite-NavX 75% (9/12)	Irrigated tip (80%), RFCA, 50 W, 30–120 s	100% (10)	349 ± 53	N/A[d]	Site where P1 recorded during VT (at the left upper-middle ventricular septum)	Non-inducibility	N/A
Liu XY [26]	N/A	N/A	CARTO 100% (20)	4-mm non-irrigated tip, RFCA, 50–60 °C, 20–40 W, 60–120 s	100% (20)	330 ± 51	100% (20)	Junction area with Purkinje potential and diastolic potential	Non-inducibility	N/A
Suzuky [48]	N/A	44	N/A	N/A	76% (5)	N/A	34% (2)	Earliest ventricular activation or DP during VT or isolated diastolic potentials during SR or best pace-mapping	N/A	29.3
Collins [15]	N/A	24	14% 3-D mapping system (14)[e]	RFCA ablation 97% (86) RFCA + cryo-ablation 3% (3)	84% (86)[f]	N/A	N/A	Activation mapping, identification of diastolic potentials in tachycardia and in SR, mapping of PP and pace-mapping	N/A	8
Kataria [20]	N/A	N/A	Ensite-Velocity 100% (15)	4-mm non-irrigated tip, RFCA, 60 °C, 60 W, 60 s	100% (15)	320 ± 28	0 (0%)	Sites showing fascicular potentials just before the ventricular activation potential. If ablation did not terminate tachycardia, then it	Termination during ablation and/or myocardium-posterior fascicle conduction block	6.56 ± 1.1

(continued on next page)

Table 2 (*continued*)

Study	Procedure duration (min)	Fluoroscopy time (min)	Mapping system % (N)	Catheters, energy source, temperature, power, time (N)	Inducible VT % (N)	Cycle length of FVT (mean - ms)	Ablation during SR % (N)	Target of ablation % (N)	Ablation end-point	Number of RFCA lesions (mean)
								was extended progressively distal linearly		
Park [40]	197.5 ± 63.5	61.3 ± 31	Ensite-Navx 100% (14)	5-mm non-irrigated tip, RFCA, 60 °C, 50 W, 60 s	100% (14)	357 ± 40.2	100% (14)	Earliest activation site (defined as origin of the activation wave-front with high −dV/dt at the slow conduction zone)	Non-inducibility	4.1 ± 1.4
Wissner [41]	240	7	CARTO 100% (24)	4-mm non-irrigated tip, RFCA, 55 °C, 40 W, maximum 120 s	75% (18)	407 ± 94	17% (3)	DPs along the posterior mid-septal LV (during FT) or the earliest sharp, high-frequency, low-amplitude retro-PP in the posterior mid-septal LV (during SR)	Non-inducibility and elimination of the earliest retro-PP during SR	4
Chu [27]	104 ± 23	16.6 ± 5.6	CARTO 100% (10)	4-mm non-irrigated tip, RFCA, 50–60 °C, 40 W, 60–120 s	100% (10)	406 ± 83	100% (10)	Slow conduction zone (crossover junction area with both PP and diastolic potentials)	Non-inducibility	1.5 ± 0.7
He [28]	42.8 ± 6.9	9.7 ± 1.9	Fluoroscopy only 100% (30)	4-mm non-irrigated tip, RFCA, 60 °C, 30–60 W, 100–130 s	100% (30)	381 ± 73	0 (0%)	Earliest PP	Non-inducibility	4.1 ± 0.8
Shin [21]	N/A	N/A	Fluoroscopy only 100% (11)	4-mm non-irrigated tip, RFCA, 60 °C, 60 s	100% (11)	N/A	100% (11)	Area of mechanical termination and/or PP	Non-inducibility	11.1 ± 6.5
Ma [42]	N/A	N/A	Fluoroscopy only 100% (39)	4-mm non-irrigated tip, RFCA, initial power 20–25 W, 60–90 s	87% (34)	361 ± 66	95% (37)	Earliest PP during FVT or sharp PP in the LV midseptum during SR	Left posterior fascicular block and non-inducibility	1.7 ± 0.9
Magalhaes [16]	N/A	N/A	CARTO 11% (1), fluoroscopy only for the remainder (8)	4-mm or 3.5-mm non-irrigated tip, RFCA, median temperature 56 ± 5.8 °C	100% (9)	366 ± 60	N/A	Earliest PP 78% (7) Site near the slow conduction pathway (with simultaneous recording of DP and PP) 22% (2)	Non-inducibility	7 ± 4.6
Lin [43]	75	39.6	CARTO 100% (6)	4-mm non-irrigated tip, RFCA, 52 °C, 50 W, 60–90 s	100% (6)[g]	N/A	100% (6)	Ablation in the region of the mid to mid-inferior apical septum of the LV, and further guided by the presence of PP + plus pace-mapping	Non-inducibility of any VT or premature ventricular complexes (PVCs)	9
Arya [29]	N/A	N/A	Fluoroscopy only % (13) Non-contact mapping (Ensite 3000) 13% (2)	Non-irrigated tip, RFCA, 70 °C, 50–60 W, 60 s	100% (15)	356 ± 53	0% (0)	Earliest PP or late diastolic potentials	Non-inducibility	7.2 ± 4.3
Topilski [18]	N/A	N/A	Fluoroscopy only 100% (17)	Non-irrigated tip, RFCA, 72 °C, 30–60 s	88% (15)[h]	337	41% (7)	Pace-mapping ± earliest PP ± earliest ventricular activation ±site of diastolic potentials	Non-inducibility	4.1 ± 2.2
Gupta [44]	74	14	Fluoroscopy only 100% (7)	4-mm, RFCA	100% (7)	351 ± 31	0 (0%)	Earliest PP	Abolition of inducible and spontaneous VT	1.6
Ouyang [30]	262 ± 45	5.4 ± 1.4	CARTO 100% (10)	4-mm non-irrigated tip, RFCA, 60 °C, 20–40 W, 120 s	100% (10)	406 ± 83	3 (33.3%)	During FVT: site of mechanical termination or site with diastolic potentials. During SR: earliest retro-PP	Non-inducibility	N/A
Aiba [31]	N/A	N/A	Fluoroscopy only 100% (10)	Non-irrigated tip, RFCA, 60 s	100% (10)	358 ± 64	0 (0%)	Pre-PP (defined as dull potential preceding the PP)	Non-inducibility	1.3 ± 0.6
Miyauchi [32]	N/A	N/A	Fluoroscopy only 100% (9)	4-mm non-irrigated tip, RFCA, 10–20 W (power controlled) or 50–60 °C (temperature controlled), 60–120 s	100% (7)	336 ± 23	0 (0%)	Pace-mapping or site of pre-QRS fractionated potentials	Termination during ablation and non-inducibility	N/A
Nogami [33]	N/A	N/A	Fluoroscopy only 100% (20)	4-mm non-irrigated tip, RFCA, 20–25 W, 75–125 s	100% (20)	355 ± 59	0 (0%)	Diastolic potential (P1) (double potential group) or exit site showing a single fused P2 (single potential group)	Termination during ablation and non-inducibility	2 ± 2.1

Tsuchiya [34]	N/A	N/A	Fluoroscopy only 100% (16)	Non-irrigated tip, RFCA, 20–30 W, 30 s	100% (16)	350 ± 56	0 (0%)	Earliest ventricular activation (5), or earliest PP (2) or late diastolic potentials (9)	Non-inducibility	3.8 ± 3.1
Nogami [35]	N/A	N/A	Fluoroscopy only 100% (6)	4-mm non-irrigated tip, RFCA, initial power 20–25 W, 60–120 s	83% (5)[i]	390 ± 62	17% (1)	VT exit site 50% (3), zone of slow conduction with early diastolic PP 33% (2), both 17% (1)	Termination during ablation and non-inducibility	N/A
Bennett [47]	N/A	N/A	Fluoroscopy only 100% (9)	4-mm non-irrigated tip, RFCA	100% (9)[j]	N/A	N/A	Earliest onset of ventricular activation or pace-mapping	Non-inducibility	N/A
Wen [45]	N/A	N/A	Fluoroscopy only 100% (7)	4-mm or 5-mm non-irrigated tip, RFCA, 25–35 W, 70–130 s	100% (7)	349 ± 63	0% (0)	Site (at least 2 cm away from the exit site) where FVT could be terminated transiently by application of mechanical pressure to the catheter tip without the induction of ventricular ectopic beats (PP potential noted at the ablation site)	Non-inducibility	N/A
Katristis [23]	110 (median)	23	Fluoroscopy only 100% (7)	4-mm non-irrigated tip, RFCA, 30–50 W and/or low energy shocks at 5–25 J	100% (7)	307 ± 67	100% (7)	Earliest onset of ventricular activation and pace-mapping	Non-inducibility	N/A
Zardini [36]	282 ± 51	40 ± 15	Fluoroscopy only 100% (8)	RFCA (25–35 W for 10–60 s) and/or DC shocks (150 J via standard defibrillator or 10–50 J with a short pulse-width defibrillator)	100% (8)	361 ± 61	2 (25%)	Earliest endocardial activation, presence of a high frequency presystolic potential and/or pace-mapping	Non-inducibility	2.75 ± 1.9
Wen [46]	173 ± 41	48 ± 18	Fluoroscopy only 100% (20)	4-mm non-irrigated tip, RFCA, 20–25 W, 10–20 s	90% (18)[k]	355 ± 55	0% (0)	Earliest onset of ventricular activation and pace-mapping	Non-inducibility	6 ± 5
Nagakawa [37]	N/A	N/A	Fluoroscopy only 100% (8)	4-mm non-irrigated tip, RFCA, 45–67 V, 60 s or longer	100% (8)[l]	346 ± 59	0% (0)	Earliest PP potential, pace-mapping during FVT	Termination during ablation and non-inducibility	2 ± 1.2
Mean/total	–	–	3-D mapping system: 43.7% (416)[e] Fluoroscopy only – 55.7% (531) Unknown - 0.6% (6)	–	91% (871)	364 ± 66	41% (331)[m]	–	–	–

Abbreviations: N/A: non-available; W: Watt; VT: ventricular tachycardia; SR: sinus rhythm; ms: milliseconds; LV: left ventricle; N: number; PP: Purkinje potential; DD: diastolic potential; RFCA: radio-frequency catheter ablation.

[a] 1 to 2 applications in 73% of patients, 3 to 4 in the remaining.
[b] Incessant or spontaneous in 6 patients.
[c] Incessant in one patient.
[d] Ablation during SR "in the majority of the cases".
[e] This includes 14 patients with unattempted catheter ablation.
[f] Spontaneous in 11 patients.
[g] Non-sustained during the procedure in 5 patients (83%), no longer inducible after initial induction in one patient (17%).
[h] Incessant in one patient.
[i] In 1 patient FVT was initially incessant, but then terminated and was non-inducible.
[j] Spontaneous in 3 patients.
[k] Incessant in 2 patients, spontaneous but non-sustained in 2 patients.
[l] Incessant in 2 patients.
[m] Data not available for 137 procedures.

Table 3
Procedural complications and outcomes post-FVT ablation.

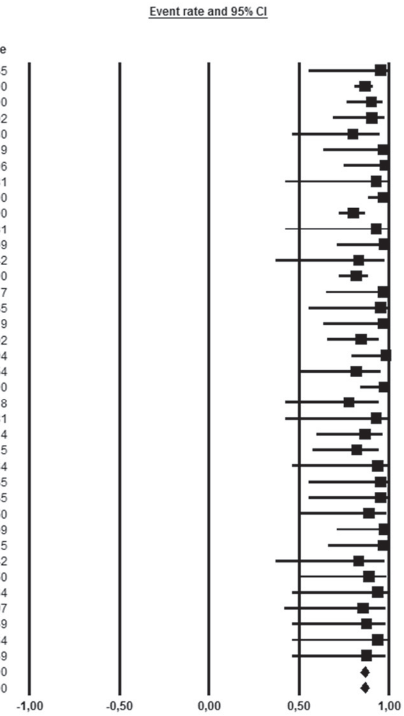
Study	Procedural complications % (N)	Procedural mortality % (N)	FUP duration (months)	Mortality during FUP % (N)	Success rate after index procedure without AADs % (N)	Previous CA % (N)	Redo procedures (after index procedure) % (N)	Success rate after multiple procedures without AADs % (N)	Predictors of FVT relapse
Ma [38]	0% (0)	0% (0)	24 ± 3	0% (0)	90% (37)	N/A	0% (0)	–	N/A
Luo [24]	0% (0)	0% (0)	85[a]	0.5% (1)[b]	86.86% (152)[b]	25.6% (50)	10.8% (21)	100% (173)	Recovery of LPF block after index procedure and the non-earliest PP-QRS interval
Guo [13]	10% (1): femoral pseudoaneurism	0% (0)	34[a]	0% (0)	100% (10)	60% (6)	0% (0)	–	N/A
Zhan [25]	0% (0)	0% (0)	16.3 ± 7.2	0% (0)	100% (24)	0% (0)	0% (0)	–	N/A
Liu Q [8]	0% (0)	0% (0)	4.5[a]	0% (0)	100% (14)	21.4% (3)	0% (0)	–	N/A
Chen [19]	0% (0)	0% (0)	14 ± 8.6	0% (0)	89.5% (19)	0% (0)	0% (0)	–	N/A
Liu Y [7]	0% (0)	0% (0)	55.7[a]	0% (0)	80.3% (94)	1.7% (2)	16.7% (20)	97.4% (114)	Faster FVT cycle lengths
Letsas [39]	0% (0)	0% (0)	25.2 ± 13.1	0% (0)	80% (8)	N/A	20% (2)	N/A	N/A
Gopi [14]	0% (0)	0% (0)	29 ± 13	0% (0)	97% (62)	N/A	0% (0)	–	N/A
Fishberger [22]	0% (0)	0% (0)	27[a]	0% (0)	100% (6)	N/A	0% (0)	–	N/A
Talib [17]	0% (0)	0% (0)	58 ± 35	0% (0)	100% (6)	50% (5)	0% (0)	–	N/A
Liu XY [26]	0% (0)	0% (0)	20.6 ± 10.5	0% (0)	100% (20)	15% (3)	0% (0)	–	N/A
Suzuky [48]	33% (2): 17% (1) LBBB and 17% (1) complete AVB requiring PPM implant	0% (0)	33[a]	0% (0)	50% (5)	17% (1)	50% (3)[d]	N/A	N/A
Collins [15]	7% (6): 2% (2) VF arrest, 3% (3) polymorphic VT and 1% (1) transient AVB	0% (0)	24[a]	1% (1)[c]	81% (72)	N/A	21% (21)	77% (79)	N/A
Kataria [20]	0% (0)	0% (0)	20.8 ± 8.5	0% (0)	100% (15)	0% (0)	0% (0)	–	N/A
Park [40]	0% (0)	0% (0)	23.3 ± 7.5	0% (0)	100% (14)	N/A	0% (0)	–	N/A
Wissner [41]	0% (0)	0% (0)	105[a]	0% (0)	92% (22)	21% (5)	8% (2)	100% (24)	N/A
Chu [27]	0% (0)	0% (0)	22.4 ± 5.1	0% (0)	100% (10)	30% (3)	0% (0)	–	N/A
He [28]	0% (0)	0% (0)	12.3 ± 6.1	0% (0)	100% (30)	N/A	0% (0)	–	N/A
Shin [21]	9% (1): VF	0% (0)	36.2 ± 12.8	0% (0)	82% (9)	N/A	18% (2)	100% (11)	N/A
Ma [42]	0% (0)	0% (0)	17[a]	0% (0)	97% (38)	13% (5)	3% (1)	100% (39)	N/A
Magalhaes [16]	0% (0)	0% (0)	44.5 ± 12.4	0% (0)	78% (7)	N/A	8% (1)	89% (8)	N/A
Lin [43]	0% (0)	0% (0)	16 ± 8	0% (0)	100% (6)	33% (2)	0% (0)	–	N/A
Arya [29]	7% (1): groin haematoma	0% (0)	12 ± 7	0% (0)	87% (13)	0% (0)	13% (2)	100% (15)	N/A
Topilski [18]	5.9% (1): iatrogenic VF requiring DC shock	0% (0)	41.3 ± 35.2	0 (0%)	82% (14)	0% (0)	12% (2)	94% (16)	N/A
Gupta [44]	0% (0)	0% (0)	22 ± 7	0% (0)	100% (7)	N/A	0% (0)	–	N/A
Ouyang [30]	0% (0)	0% (0)	9.1 ± 5.1	0 (0%)	100% (10)	33.3% (3)	0% (0)	–	N/A
Aiba [31]	0% (0)	0% (0)	16 ± 11	0 (0%)	100% (10)	0% (0)	0% (0)	–	N/A
Miyauchi [32]	0% (0)	0% (0)	32 ± 12	0% (0)	89% (8)	0% (0)	0% (0)	–	N/A
Nogami [33]	0% (0)	0% (0)	38 ± 19	0% (0)	100% (20)	N/A	0% (0)	–	N/A
Tsuchiya [34]	0% (0)	0% (0)	17.6 ± 10.5	0% (0)	100% (16)	N/A	0% (0)	–	N/A
Nogami [35]	0% (0)	0% (0)	32 ± 9	0% (0)	83% (5)	N/A	0% (0)	–	N/A
Bennett [47]	0% (0)	0% (0)	N/A	0% (0)	89% (8)	0% (0)	0% (0)	–	N/A
Wen [45]	0% (0)	0% (0)	26 ± 11	0% (0)	100% (7)	0% (0)	0% (0)	–	N/A
Katristis [23]	0% (0)	0% (0)	11 ± 4	0% (0)	86% (6)	14% (1)	0% (0)	–	N/A
Zardini [36]	0% (0)	0% (0)	17 ± 13	0% (0)	87% (7)	0% (0)	0% (0)	–	N/A
Wen [46]	0% (0)	0% (0)	7 ± 8	0 (0%)	75% (15)	0% (0)	10% (2)	85% (17)	N/A
Nagakawa [37]	12% (1): mitral regurgitation due to mitral valve damage	0% (0)	10.5[a]	0% (0)	88% (7)	0% (0)	0% (0)	–	N/A
Total/mean	1.4% (13)	0% (0)	41.4 ± 10.7	0.2% (2)	89.3% (833)	9.3% (89)[e]	8.3% (79)	95.7% (893)	–

Abbreviations: N/A: non-available; FVT: fascicular ventricular tachycardia; VF: ventricular fibrillation; VT: ventricular tachycardia; LBBB: left bundle branch block; AVB: atrio-ventricular block; PPM: permanent pacemaker; FU: follow-up; LPF: left posterior fascicule; CA: catheter ablation.

[a] Median.
[b] 20 patients lost during FU.
[c] Non-cardiovascular death.
[d] 38% (2) required a second procedure, 17% (1) required a third procedure.
[e] Data not available for 322 patients.

a. Success rate after index procedure

Model	Study name	Outcome	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	Guo 2017	Success index procedure	0,955	0,552	0,997	2,103	0,035
	Luo 2017	Success index procedure	0,869	0,810	0,911	8,440	0,000
	Ma 2017	Success index procedure	0,902	0,767	0,963	4,227	0,000
	Chen 2016	Success index procedure	0,905	0,689	0,976	3,028	0,002
	Letsas 2016	Success index procedure	0,800	0,459	0,950	1,754	0,080
	Liu Q 2016	Success index procedure	0,967	0,634	0,998	2,341	0,019
	Zan 2016	Success index procedure	0,980	0,749	0,999	2,724	0,006
	Fishberger 2015	Success index procedure	0,929	0,423	0,996	1,748	0,081
	Gopi 2015	Success index procedure	0,969	0,883	0,992	4,780	0,000
	Liu Y 2015	Success index procedure	0,803	0,721	0,866	6,052	0,000
	Talib 2015	Success index procedure	0,929	0,423	0,996	1,748	0,081
	Liu XY 2014	Success index procedure	0,976	0,713	0,999	2,594	0,009
	Suzuki 2014	Success index procedure	0,833	0,369	0,977	1,469	0,142
	Collins 2013	Success index procedure	0,818	0,724	0,886	5,442	0,000
	Kataria 2013	Success index procedure	0,969	0,650	0,998	2,390	0,017
	Chu 2012	Success index procedure	0,955	0,552	0,997	2,103	0,035
	Park 2012	Success index procedure	0,967	0,634	0,998	2,341	0,019
	Wissner 2012	Success index procedure	0,846	0,655	0,941	3,136	0,002
	He 2011	Success index procedure	0,984	0,789	0,999	2,883	0,004
	Shin 2010	Success index procedure	0,818	0,493	0,954	1,924	0,054
	Ma 2006	Success index procedure	0,974	0,839	0,996	3,591	0,000
	Magalhaes 2006	Success index procedure	0,778	0,421	0,944	1,562	0,118
	Lin 2005	Success index procedure	0,929	0,423	0,996	1,748	0,081
	Arya 2004	Success index procedure	0,867	0,595	0,966	2,464	0,014
	Topilski 2004	Success index procedure	0,824	0,573	0,942	2,421	0,015
	Gupta 2002	Success index procedure	0,938	0,461	0,996	1,854	0,064
	Ouyang 2002	Success index procedure	0,955	0,552	0,997	2,103	0,035
	Aiba 2001	Success index procedure	0,955	0,552	0,997	2,103	0,035
	Miyauchi 2000	Success index procedure	0,889	0,500	0,985	1,961	0,050
	Nogami 2000	Success index procedure	0,976	0,713	0,999	2,594	0,009
	Tsuchiya 1999	Success index procedure	0,971	0,664	0,998	2,436	0,015
	Nogami 1998	Success index procedure	0,833	0,369	0,977	1,469	0,142
	Bennett 1997	Success index procedure	0,889	0,500	0,985	1,961	0,050
	Wen 1997	Success index procedure	0,938	0,461	0,996	1,854	0,064
	Katristis 1996	Success index procedure	0,857	0,419	0,980	1,659	0,097
	Zardini 1995	Success index procedure	0,875	0,463	0,983	1,820	0,069
	Wen 1994	Success index procedure	0,938	0,461	0,996	1,854	0,064
	Nakagawa 1993	Success index procedure	0,875	0,463	0,983	1,820	0,069
Fixed			0,868	0,842	0,890	17,577	0,000
Random			0,868	0,842	0,890	17,577	0,000



b. Success rate after multiple procedures

Model	Study name	Outcome	Event rate	Lower limit	Upper limit	Z-Value	p-Value
	Guo 2017	Success after multiple procedures	0,955	0,552	0,997	2,103	0,035
	Luo 2017	Success after multiple procedures	0,989	0,955	0,997	6,271	0,000
	Ma 2017	Success after multiple procedures	0,902	0,767	0,963	4,227	0,000
	Chen 2016	Success after multiple procedures	0,905	0,689	0,976	3,028	0,002
	Letsas 2016	Success after multiple procedures	0,800	0,459	0,950	1,754	0,080
	Liu Q 2016	Success after multiple procedures	0,967	0,634	0,998	2,341	0,019
	Zan 2016	Success after multiple procedures	0,980	0,749	0,999	2,724	0,006
	Fishberger 2015	Success after multiple procedures	0,929	0,423	0,996	1,748	0,081
	Gopi 2015	Success after multiple procedures	0,969	0,883	0,992	4,780	0,000
	Liu Y 2015	Success after multiple procedures	0,974	0,924	0,992	6,219	0,000
	Talib 2015	Success after multiple procedures	0,929	0,423	0,996	1,748	0,081
	Liu XY 2014	Success after multiple procedures	0,976	0,713	0,999	2,594	0,009
	Suzuki 2014	Success after multiple procedures	0,833	0,369	0,977	1,469	0,142
	Collins 2013	Success after multiple procedures	0,898	0,815	0,946	6,174	0,000
	Kataria 2013	Success after multiple procedures	0,969	0,650	0,998	2,390	0,017
	Chu 2012	Success after multiple procedures	0,955	0,552	0,997	2,103	0,035
	Park 2012	Success after multiple procedures	0,967	0,634	0,998	2,341	0,019
	Wissner 2012	Success after multiple procedures	0,923	0,739	0,981	3,376	0,001
	He 2011	Success after multiple procedures	0,984	0,789	0,999	2,883	0,004
	Shin 2010	Success after multiple procedures	0,958	0,575	0,997	2,170	0,030
	Ma 2006	Success after multiple procedures	0,988	0,829	0,999	3,070	0,002
	Magalhaes 2006	Success after multiple procedures	0,889	0,500	0,985	1,961	0,050
	Lin 2005	Success after multiple procedures	0,929	0,423	0,996	1,748	0,081
	Arya 2004	Success after multiple procedures	0,969	0,650	0,998	2,390	0,017
	Topilski 2004	Success after multiple procedures	0,941	0,680	0,992	2,690	0,007
	Gupta 2002	Success after multiple procedures	0,938	0,461	0,996	1,854	0,064
	Ouyang 2002	Success after multiple procedures	0,955	0,552	0,997	2,103	0,035
	Aiba 2001	Success after multiple procedures	0,955	0,552	0,997	2,103	0,035
	Miyauchi 2000	Success after multiple procedures	0,889	0,500	0,985	1,961	0,050
	Nogami 2000	Success after multiple procedures	0,976	0,713	0,999	2,594	0,009
	Tsuchiya 1999	Success after multiple procedures	0,971	0,664	0,998	2,436	0,015
	Nogami 1998	Success after multiple procedures	0,833	0,369	0,977	1,469	0,142
	Bennett 1997	Success after multiple procedures	0,889	0,500	0,985	1,961	0,050
	Wen 1997	Success after multiple procedures	0,938	0,461	0,996	1,854	0,064
	Katristis 1996	Success after multiple procedures	0,857	0,419	0,980	1,659	0,097
	Zardini 1995	Success after multiple procedures	0,875	0,463	0,983	1,820	0,069
	Wen 1994	Success after multiple procedures	0,938	0,461	0,996	1,854	0,064
	Nakagawa 1993	Success after multiple procedures	0,875	0,463	0,983	1,820	0,069
Fixed			0,935	0,914	0,951	17,189	0,000
Random			0,935	0,914	0,951	17,189	0,000

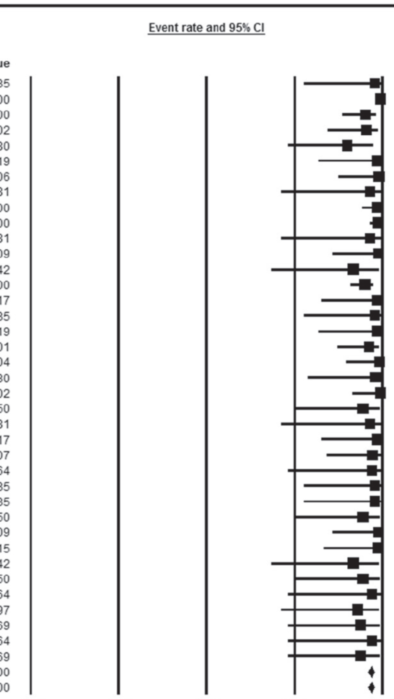


Fig. 3. Forest plots assessing success rate a) after index procedure, b) after multiple procedures.

4. Discussion

Our review confirms the high success rate for catheter ablation of FVT (93.5% freedom of FVT after multiple procedures) with a low complication rate (observed incidence of complications was 1.4%), with no procedural deaths or need of urgent cardiac surgery. The success rate after the index procedure was 87%. As much as 9.3% of patients in this review had had a previous attempt or failed catheter ablation for FVT prior to the index procedure. Unfortunately, none of the studies included in this review reported specifically the procedural outcome in subjects with

Table 4
Sub-group analyses.

	Success rate (%) after index procedure	Success rate (%) after multiple procedures
A)		
Tridimensional mapping	92%, $CI_{95\%}$ 87.8–94.9%, $P < 0.001$; $I^2 = 0\%$	93.2%, $CI_{95\%}$ 89.2–95.7%, $P < 0.001$ $I^2 = 0\%$
Fluoroscopy only	89.5%, $CI_{95\%}$ 83.7–93.4%, $P < 0.001$, $I^2 = 0\%$	92.7%, $CI_{95\%}$ 87.6–95.8%, $P < 0.001$, $I^2 = 0\%$
B)		
Paediatric only cases	82.4%, $CI_{95\%}$ 73.6–88.7%, $P < 0.001$; $I^2 = 0\%$	90.0%, $CI_{95\%}$ 82.1–94.6%, $P < 0.001$; $I^2 = 0\%$
Non-paediatric cases	87.6%, $CI_{95\%}$ 84.8–89.9%, $P < 0.001$; $I^2 = 0\%$	94.3%, $CI_{95\%}$ 92.2–95.9%, $P < 0.001$; $I^2 = 0\%$
C)		
Ablation during SR only	92.1%, $CI_{95\%}$ 83.4–96.5%, $P < 0.001$, $I^2 = 0\%$	94.8%, $CI_{95\%}$ 87.6–97.9%, $P < 0.001$, $I^2 = 0\%$
Ablation during VT only	91.4%, $CI_{95\%}$ 86.5–94.6%, $P < 0.001$, $I^2 = 21\%$	95.1%, $CI_{95\%}$ 92.2–97%, $P < 0.001$, $I^2 = 0\%$
Ablation during either SR or VT	86.7%, $CI_{95\%}$ 82.1–90.2%, $P < 0.001$, $I^2 = 0\%$	93.2%, $CI_{95\%}$ 85.7–96.9%, $P < 0.001$, $I^2 = 38\%$
D)		
Irrigated ablation catheter	88.8% ($CI_{95\%}$ 69.9–96.5%, $P < 0.001$, $I^2 = 1\%$)	N/A
Non-irrigated ablation catheter	87.7% ($CI_{95\%}$ 84.4–90.4%, $P < 0.001$, $I^2 = 0\%$)	94.0 ($CI_{95\%}$ 91.5–95.8, $P < 0.001$, $I^2 = 0\%$)

N/A: not available.

previous FVT ablation compared to naïve patients. These results support the overall efficacy and safety of catheter ablation in a FVT patient population where arrhythmia relapse had occurred in 84% of those treated with anti-arrhythmic agents. To the best of our knowledge, this is the first systematic review analysing the available literature and data on this topic.

Catheter ablation is a well-established treatment for FVT. However, evidence supporting its efficacy is limited to small non-randomised observational studies. This is likely due to the low prevalence as well as good prognosis of FVT. Medical treatment (i.e. verapamil) has been shown to be efficacious for the termination of acute episodes and prevention of recurrence in small case-series [49–52].

We have identified no studies comparing long-term medical therapy versus catheter ablation for preventing FVT relapses. However, most patients in this analysis had previously relapsed while on anti-arrhythmic drugs. According to American Heart Association/American College of Cardiology/Heart Rhythm Society guidelines, catheter ablation is useful in patients with verapamil-sensitive, idiopathic left VT related to interfascicular reentry for whom antiarrhythmic medications are ineffective, not tolerated, or not the patient's preference (class of recommendation I, level of evidence B-NR) [53]. Current guidelines from European Society of Cardiology recommend catheter ablation by experienced operators as a first-line treatment in symptomatic patients with idiopathic LV tachycardia (class of recommendation I, level of evidence B) [54].

Non-inducibility of FVT during electrophysiological study is often considered a pitfall of catheter ablation strategy and, in the studies included in this analysis, this represented the most common reason for deferring ablation. Earlier reports did show difficulty in induction of FVT in approximately 25–40% of the patients [14]. Our analysis suggests that FVT was inducible or incessant in 91% of cases, although occasionally VT was not sustained for long enough to enable mapping during tachycardia (often because of contact inhibition). Interestingly, ablation was performed during SR in almost half of the patients included in our analysis, usually targeting Purkinje-potentials (PP) in the interventricular septum region [19,21,22,24,25,41–43], though delayed diastolic potentials or areas with best pace-mapping have been used as alternative targets [18,23,26,27,39,43,48]. A sub-analysis of our data did not demonstrate a difference in the long-term efficacy of ablation during SR vs FVT. Non-inducibility or lack of sustained inducibility of FVT during the procedure therefore should not be a contraindication for performing catheter ablation.

Interestingly, studies that included paediatric-only populations did demonstrate a trend for poorer procedural results compared to those enrolling adults only. A possible explanation could be a less aggressive ablation approach likely to have been adopted in children.

Tridimensional mapping system was used in all the series published in the last 11 years. Our data suggest that availability of 3-D mapping system led to an improvement in procedural success compared to fluoroscopy-only procedures, especially after the index procedure.

5. Limitations

The main limitation of this study was the inability to analyse data from case-control design due to the absence of control groups in all studies. However, given the low efficacy of medical therapy and the high success rate and safety of catheter ablation, randomised controlled trials comparing these different treatment options might not be ethically appropriate. The efficacy of antiarrhythmic therapy reported in the present study could be underestimated, given that only selected patients were included (i.e., only patients undergone to catheter ablation). Most of the studies included were retrospective, single-centre and based on small cohorts. No studies provided comparative data on outcomes using different mapping and ablation strategies (e.g., mapping and ablating in FVT versus SR, or mapping earliest PP versus mechanical termination, or use of irrigated versus non-irrigated catheters). Data regarding procedure duration and fluoroscopy time are missing in several studies and therefore no comparison between ablation using irrigated versus non-irrigated catheters or 3-D mapping versus fluoroscopy only was possible.

6. Conclusions

Data derived from observational non-controlled case series, with low-methodological quality, suggest that catheter ablation is a safe and effective treatment for FVT, with a 93.5% success rate after multiple procedures in patients with previously failed anti-arrhythmic therapy. Ablation during FVT represents the first-line and most commonly used approach; however, a strategy of mapping and ablation during SR displayed comparable procedural results to actively mapping patients in FVT and should therefore be considered in selected cases where FVT is not inducible.

Conflict of interest

All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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