Noninducibility in Postinfarction Ventricular Tachycardia as an End Point for Ventricular Tachycardia Ablation and Its Effects on Outcomes
A Meta-Analysis

Hamid Ghanbari, MD, MPH; Kazim Baser, MD; Miki Yokokawa, MD; William Stevenson, MD; Paolo Della Bella, MD; Pasquale Vergara, MD; Thomas Deneke, MD; Karl-Heinz Kuck, MD; Hans Kottkamp, MD; She Fei, MD, PhD; Fred Morady, MD; Frank Bogun, MD

Background—Although ventricular tachycardia (VT) ablation is a widely used therapy for patients with VT, the ideal end points for this procedure are not well defined. We performed a meta-analysis of the published literature to assess the predictive value of noninducibility of postinfarction VT for long-term outcomes after VT ablation.

Methods and Results—We performed a systematic review of MEDLINE (1950–2013), EMBASE (1988–2013), the Cochrane Controlled Trials Register (Fourth Quarter, 2012), and reports presented at scientific meetings (1994–2013). Randomized controlled trials, case–control, and cohort studies of VT ablation were included. Outcomes reported in eligible studies were freedom from VT/ventricular fibrillation and all-cause mortality. Of the 3895 studies evaluated, we identified 8 cohort studies enrolling 928 patients for the meta-analysis. Noninducibility after VT ablation was associated with a significant increase in arrhythmia-free survival compared with partial success (odds ratio, 0.49; 95% confidence interval, 0.29–0.84; P=0.009) or failed ablation procedure (odds ratio, 0.10; 95% confidence interval, 0.06–0.18; P<0.001). There was also a significant reduction in all-cause mortality if patients were noninducible after VT ablation compared with patients with partial success (odds ratio, 0.59; 95% confidence interval, 0.36–0.98; P=0.04) or failed ablation (odds ratio, 0.32; 95% confidence interval, 0.10–0.99; P=0.049).

Conclusions—Noninducibility of VT after VT ablation is associated with improved arrhythmia-free survival and all-cause mortality. (Circ Arrhythm Electrophysiol. 2014;7:677-683.)

Key Words: meta-analysis • tachycardia, ventricular

Several studies have demonstrated the efficacy of radiofrequency catheter ablation as adjunctive therapy in selected patients with recurrent, drug-resistant ventricular tachycardia (VT). Despite major advances in the field, this therapy remains technically challenging and time-consuming. Different ablation strategies have been proposed, and their outcomes have been different across clinical trials. Several studies have demonstrated that patients in whom VT cannot be induced at the conclusion of an ablation have a favorable outcome. However, these studies have been limited because of the small number of patients, heterogeneous population, and lack of long-term follow-up. Therefore, the ideal end point of VT ablation in patients with prior infarction is unclear. To answer this important clinical question, we evaluated the outcomes of patients with prior myocardial infarction who were noninducible after VT ablation compared with those who remained inducible at the end of the procedure through a meta-analysis of studies published in the literature.

Received August 5, 2013; accepted May 1, 2014.

The meta-analysis was an analysis of prior published studies, an institutional review board approval is not applicable.

**Study Selection**
Randomized controlled trials, case–control, or cohort studies evaluating ablation for treatment of VT were eligible. Case–control and cohort studies were defined according to the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) statement. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Studies were included if the outcome was reported depending on inducibility of VT after completion of the ablation procedure. The outcomes of interest were recurrence of VT/ventricular fibrillation (VF) and all-cause mortality. Authors of relevant studies were contacted to obtain these data if not reported in the original article. Additional information from 4 studies was provided by the authors and included in the article. We included only studies with a postablation programmed ventricular stimulation protocol. A limitation of programmed stimulation is the lack of a universally agreed protocol for VT induction. This analysis, therefore, was limited to studies using a generally accepted stimulation protocol with ≥2 basic drive cycle lengths with ≤3 extrastimuli at 2 ventricular sites. The length and adequacy of follow-up in all the included trials were thought to be sufficient to allow the outcomes of interest to occur within the follow-up period.

**Data Abstraction**
Two independent reviewers (H.G. and S.F.) evaluated the studies for inclusion into the meta-analysis. A third blinded reviewer (F.B.) resolved disagreements between reviewers. Abstracted data included eligibility criteria, baseline characteristics, duration of follow-up, cause of heart failure, procedural complications, and number of patients in the trial.

**Definitions**
Complete success was defined as elimination of all inducible VTs at the conclusion of the procedure. Partial success was defined as elimination of all clinical VTs with ≥1 nonclinical VT inducible at the end of the procedure. The procedure was labeled as unsuccessful if any clinical VT still was inducible at the end of the procedure.

**Quality Assessment**
We used the Newcastle-Ottawa Scale to describe the quality of the studies included in the meta-analysis. The items assessed for cohort studies were as follows: (1) representativeness of the exposed cohort, (2) selection of the nonexposed cohort, (3) ascertainment of exposure, (4) outcome of interest not present at the onset of the study, (5) comparability of cohorts on the basis of the design or the analysis, (6) assessment of outcome, (7) length of follow-up long enough for outcomes to occur, and (8) adequacy of follow-up of cohorts. One or 2 stars were assigned and are displayed in Table I in the Data Supplement summarizing risk of bias.

We used the Grades of Recommendations, Assessment, Development, and Evaluation system to evaluate the quality of the evidence for outcomes reported in this review. Because only observational studies were available, the body of evidence was assigned according to the Grades of Recommendations, Assessment, Development, and Evaluation system as low quality in the first place. For most outcomes, the quality of evidence was further downgraded to very low quality. The summary of findings and evidence profile were created using the Grades of Recommendations, Assessment, Development, and Evaluation software.

**Statistical Analysis**
Odds ratio (OR) was chosen as the principal measure of effect. The ORs from each included study were pooled using fixed- and random-effects models that used weighting based on inverse variance calculated according to DerSimonian and Laird. The Q test and F index were used to check for quantitative heterogeneity, with P<0.05 deemed statistically significant. Where no significant statistical heterogeneity was identified, the fixed-effects estimate was used preferentially as the summary measure. Sensitivity analyses were performed to assess the contribution of each study to the pooled estimate by excluding individual trials one at a time and recalculating the pooled OR estimates for the remaining studies. Publication bias was assessed graphically using a funnel plot and mathematically using an adjusted rank correlation test, according to the method of Begg and Mazumdar.

Sensitivity analyses were performed to assess the importance of different statistical models. There were no differences in the general direction of outcomes when using the fixed- and random-effects models. All statistical analyses were performed with Comprehensive Meta-Analysis 2.0.

**Results**

**Quantitative Analysis**
All the trials included in this analysis were observational cohort studies. Baseline characteristics of the patients enrolled in these trials, types of cardiomyopathy, and follow-up and ablation strategies are summarized in the Table. There were sufficient similarities in these trials warranting their inclusion in this analysis. We have summarized the qualitative differences between groups using the Newcastle-Ottawa Scale in Table I in the Data Supplement. We assessed the overall quality of evidence using the Grades of Recommendations, Assessment, Development, and Evaluation criteria, and the results are provided in Figures I to III in the Data Supplement.

**Efficacy of VT ablation**
Noninducibility of VT was achieved in the majority of the patients (event rate, 0.59; 95% confidence interval [Cl], 0.49–0.67). Partial success was achieved in a higher number of
patients (event rate, 0.27; 95% CI, 0.20–0.36) compared with failed ablation (event rate, 0.10; 95% CI, 0.06–0.17).

**Noninducibility and Recurrence of VT/VF**
There were a significant number of patients who had recurrence of VT after the ablation procedure, despite being noninducible at the conclusion of the procedure (range, 11%–37%). However a larger number of patients who had a failed ablation had recurrence of VT (range, 76%–100%). There were also a significant number of patients with partial success who had recurrence of VT after ablation (range, 27%–61%). Patients who were rendered noninducible at the conclusion of the index VT ablation procedure were less likely to have recurrence of VT/VF during follow-up compared with patients with a partially successful (OR, 0.49; 95% CI, 0.29–0.84; P=0.009; Figure 1) or a failed ablation procedure (OR, 0.10; 95% CI, 0.06–0.18; P<0.001; Figure 2). Patients with partial success were less likely to have recurrence of VT/VF compared with those with failed ablation (OR, 0.24; 95% CI, 0.13–0.45; P<0.001; Figure 3).

**Table. Characteristics of the Included Studies**

<table>
<thead>
<tr>
<th>Study</th>
<th>Age, y</th>
<th>No. of Patients, n</th>
<th>Follow-Up Time, mo</th>
<th>Patients Lost to Follow-Up, n</th>
<th>Ejection Fraction</th>
<th>Sex (Male)</th>
<th>No. of VT/VF Episodes Before Ablation</th>
<th>No. of Patients With No EPS at the End of Ablation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deneke et al20</td>
<td>66±9</td>
<td>115</td>
<td>Median: 16±10 mo</td>
<td>0</td>
<td>34±13%</td>
<td>NA</td>
<td>21.5±40 VT episodes in 3 mo</td>
<td>Range: 4–220 mo</td>
</tr>
<tr>
<td>Reddy et al21</td>
<td>66±7.9</td>
<td>11</td>
<td>Mean: 13±1.9 mo</td>
<td>0</td>
<td>31±8%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Kim et al22</td>
<td>67±8</td>
<td>21</td>
<td>Mean: 13±5.0 mo</td>
<td>None</td>
<td>31±7.5</td>
<td>20/21</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Stevenson et al23</td>
<td>Median: 68</td>
<td>231</td>
<td>6 mo for the assessment of recurrent arrhythmias, 12 mo for death</td>
<td>206/231</td>
<td></td>
<td>Median of 11 episodes of VT in the preceding 6 months 25th to 75th percentile: 5–32 mo</td>
<td>19 (8%)</td>
<td></td>
</tr>
<tr>
<td>Della Bella et al24</td>
<td>67±6</td>
<td>137</td>
<td>Median: 36 mo Interquartile range: 18–60 mo</td>
<td>None</td>
<td>36.3±7.6% (complete success) 34.6±7.1% (partial or no success)</td>
<td>91/137</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Deneke et al25</td>
<td>62±10</td>
<td>25</td>
<td>10±4 mo</td>
<td>None</td>
<td>37±12</td>
<td>NA</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>Yokokawa et al26</td>
<td>67±10</td>
<td>98</td>
<td>Mean: 35±23 mo Range: 1–89 mo</td>
<td>0</td>
<td>Mean: 27±13%</td>
<td>88/98</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Della Bella et al27</td>
<td>62.1±14</td>
<td>Total: 528 Ischemic: 290</td>
<td>Median: 26 mo Interquartile range: 13–46 mo</td>
<td>47</td>
<td>38.5±13</td>
<td>473/528</td>
<td>151 (28.6%) with electric storm Overall: 46/528 (8.7%) Ischemic: 22/290 (7.5%)</td>
<td>0</td>
</tr>
</tbody>
</table>

EPS indicates programmed ventricular stimulation; VF, ventricular fibrillation; and VT, ventricular tachycardia.

**Figure 1.** Noninducible vs partial success and ventricular tachycardia (VT) recurrence. The 95% confidence intervals (CIs; error bars), overall effect (diamonds), and effect for each study (squares) are displayed; overall effect and effect for each study represent the width of the CI. Two studies23 did not report VT/ventricular fibrillation (VF) events, and 1 study26 reported VT/VF events in every patient; therefore, they were not included in the overall analysis.
Noninducibility and Mortality
Patients who were noninducible at the end of the ablation procedure had a lower risk of mortality compared with those with a partially successful procedure (OR, 0.59; 95% CI, 0.36–0.98; \(P=0.04\); Figure 4) or failed ablation (OR, 0.32; 95% CI, 0.10–0.99; \(P=0.049\); Figure 5). There was no difference in mortality in patients in whom only the clinical VT could be eliminated compared with the patient group in whom the ablation failed (OR, 0.37; 95% CI, 0.11–1.22; \(P=0.10\); Figure 6).

\section*{Discussion}

\subsection*{Main Findings}
This meta-analysis demonstrates that lack of inducibility of any VT after ablation of postinfarction VT is associated with longer longevity and lower VT/VF recurrence and, therefore, is a reasonable end point for VT ablation.

\subsection*{Lack of VT Inducibility as an End point for VT Ablation}
The traditional end point of VT ablation has been noninducibility of VT using programmed ventricular stimulation.\(^4\) The use of this end point in determining the success of VT ablation has been called into question because of its many limitations.\(^28\) Several studies have attempted to clarify the value of programmed stimulation to predict outcome after an ablation procedure, but they have been limited by a small number of patients with short-term follow-up. A randomized clinical trial would be the most appropriate way to answer this question.

However, in the absence such a trial, a meta-analysis is an important tool in helping clinicians determine the value of noninducibility on the outcomes of VT ablation procedures. This meta-analysis demonstrated that noninducibility of VT was associated with a significant reduction in both mortality and recurrence of VT/VF events. It is possible, though, that the patients who remain noninducible after VT ablation may represent a healthier population with a more favorable outcome. Therefore, lack of inducibility may represent a healthier substrate rather than an ideal outcome after VT ablation.

\subsection*{Limitations of Programmed Stimulation as an End Point for VT Ablation}
There are several limitations when performing programmed stimulation after VT ablation procedures. The lack of inducibility of VTs up-front and the potential suppression of VTs with antiarrhythmics such as amiodarone make it difficult to be certain that all of the VTs in a given patient have been targeted and eliminated during the ablation procedure. Not all VTs are reproducibly inducible, and the lack of reproducibility of VT inducibility may limit the predictive value of noninducibility at the end of the ablation procedure. Furthermore, programmed stimulation at the conclusion of a long ablation procedure may not be safe in an unstable patient and, therefore, may need to be deferred.

The substrate responsible for initiation and maintenance of VT in patients with ischemic heart disease is prone to changes over time. A changing substrate may curtail the prediction of future events based on programmed stimulation at one point in time.

Despite these limitations, the predictive value of programmed stimulation cannot be ignored, and to assure the best possible...
outcome of a VT ablation procedure, programmed stimulation should strongly be considered at the conclusion of the ablation procedure. A recent report in which ablation of the entire scar was performed supports this consideration. A strategy targeting and ablating the entire low-voltage area demonstrated a significantly improved outcome compared with patients in whom arrhythmias were specifically targeted, provided that the patients were rendered completely noninducible.29 The former study confirms the value of programmed stimulation as an end point when different ablation strategies are compared.

In patients in whom no VT can be induced at baseline, a different ablation strategy needs to be pursued. The predictive value of abolition of late potentials as a procedural end point has been evaluated and found to be beneficial especially in patients without inducible VTs at baseline.30

**Ablation of the Clinical VT and Outcomes**

Our analysis demonstrated only a trend toward reduced mortality in patients in whom VT remained inducible after ablation if at least the clinical VTs could be eliminated. There was, however, a significant reduction of VT recurrence if this end point was achieved. This information is important because common practice considers targeting the clinical VT as an acceptable strategy,4 and based on this analysis complete elimination of VT was associated with significantly lower mortality and VT recurrence compared with partial success and may, therefore, be considered a preferred end point when feasible.

A smaller study including both ischemic and nonischemic patients also demonstrated similar results.30 However, inducibility of multiple VTs before the procedure and failure to eliminate all VTs may just identify a sicker patient population with larger scar burden. Therefore, failure to eliminate VTs may identify a more diseased patient population with a worse prognosis and higher likelihood of future VT/VF recurrence. However, failure to eliminate VT after ablation in high-risk patients has been associated with an increase in cardiac mortality compared with high-risk patients in whom VT could be eliminated.27 Therefore, it is possible that effective ablation alone confers a more favorable impact on outcomes, particularly in high-risk patients.

**Search for an Optimal Ablation End Point**

Despite the predictive value of programmed stimulation on outcomes, patients still have VT recurrences even if they are completely noninducible at the end of the ablation procedure. The use of noninvasive programmed stimulation a few days after VT ablation has been described to help improve assessment of outcomes after VT ablation.5,31 Edema formation may prohibit VT inducibility immediately after ablation as opposed to inducibility several days later after some of the edema has resolved. This strategy may not affect intraprocedural end points during the ablation procedure but may help to increase the predictive value of noninducible patients. Elimination of abnormal electrograms has been demonstrated to be beneficial in reducing recurrences and may be used in situations where not all VTs can be induced to prevent recurrences.32

**Limitations**

This meta-analysis is limited by the studies included in the analysis. All of the studies were observational studies, and

---

**Table 1.**

<table>
<thead>
<tr>
<th>Study name</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>p-Value</th>
<th>Non inducible</th>
<th>Partial success</th>
<th>Odds ratio and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deneke29</td>
<td>0.37</td>
<td>(0.08-1.17)</td>
<td>0.576</td>
<td>2/71</td>
<td>2/7</td>
<td></td>
</tr>
<tr>
<td>Kim21</td>
<td>6.27</td>
<td>(10.29-3.82)</td>
<td>0.284</td>
<td>0/11</td>
<td>6/28</td>
<td></td>
</tr>
<tr>
<td>Stevenson27</td>
<td>0.72</td>
<td>(0.21-3.01)</td>
<td>0.477</td>
<td>12/112</td>
<td>9/63</td>
<td></td>
</tr>
<tr>
<td>Della Bella24</td>
<td>1.08</td>
<td>(0.21-5.71)</td>
<td>0.955</td>
<td>5/60</td>
<td>7/35</td>
<td></td>
</tr>
<tr>
<td>Yokokawa28</td>
<td>0.36</td>
<td>(1-1.25)</td>
<td>0.108</td>
<td>31/217</td>
<td>9/34</td>
<td></td>
</tr>
<tr>
<td>Della Bella27</td>
<td>0.46</td>
<td>(0.20-1.08)</td>
<td>0.076</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.59</td>
<td>(0.36-0.98)</td>
<td>0.041</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.** Noninducible vs partial success and mortality. Two studies21,25 did not report mortality events; therefore, they were not included in the overall analysis. CI indicates confidence interval.

**Figure 5.** Noninducible vs failed ablation and mortality. Three studies21,25,26 did not report mortality events; therefore, they were not included in the overall analysis. CI indicates confidence interval.
therefore they are susceptible to selection bias. There were significant differences in the patients included and the strategy used when performing VT ablations. Although the overall strategy was to target all inducible VTs, only 1 study indicated ablation of all clinically relevant VTs as a predetermined end point.23 Table II in the Data Supplement indicates the specific protocols and catheters used in the analyzed studies.

Another important limitation is the definition of the clinical VT. The definition used in the selected studies is not uniform and is not based on the 12-lead ECG in all studies. Because 12-lead ECGs are not available for all patients, VT electrogram morphology from implantable cardioverter defibrillators can be used instead with similar accuracy and have been found to be helpful in identifying the clinical VT.5 This definition was used by only one, but not all studies.26

Although the stimulation protocol was not uniform, all studies included used stimulation from ≥2 ventricular sites with ≤3 extrastimuli. The details are indicated in Table II in the Data Supplement. Left ventricular stimulation was not uniformly used, yet the incremental benefit of left ventricular stimulation compared with stimulation from 2 right ventricular sites is rather small.14

None of the included studies accounted for baseline differences when comparing the results of patients who remained inducible compared with those without inducible VT at the end of the ablation procedure. These differences may influence the short-term and long-term outcomes of the index VT ablation procedure. The ideal way to overcome the differences in baseline characteristics and follow-up would be to conduct a meta-analysis using individual patient data for time-to-event analysis. However, in the absence of such data, our analysis represents the best available evaluation of effects of noninducibility on outcomes after VT ablation. Unfortunately, because individual patient data were not available for analysis, we were not able to analyze data separately from a minority of patients in whom programmed stimulation was not performed at the conclusion of the ablation procedure. Furthermore, 1 study27 included a minority of noninducible patients at the onset of the procedure, and a separate analysis excluding these patients could not be performed. Exclusion of this study, however, did not change the overall results of this analysis.

Conclusions
Noninducibility of any VT may be a preferred end point of VT ablation in patients with postinfarction VT. However, although this may be the most preferred end point, this should not compromise patient stability, which may be a concern in some patients with advanced disease. Whether noninducibility is an independent marker for improved long-term outcome remains to be determined. Additional studies are needed to evaluate the effect of different ablation strategies and end points to optimize the outcomes of patients undergoing VT ablation.

Sources of Funding
Dr Bogun has received a grant from the Leducq foundation. Dr Ghanbari has received a grant from the Birkhill foundation.

Disclosures
Dr Bogun participated in a catheter study by Biosense Webster. Dr Stevenson is coholder of a patent for needle ablation that is consigned to Brigham and Women’s Hospital. Dr Della Bella has received consulting fees from St Jude Medical and Biosense Webster and research funding from Biosense Webster, St Jude Medical, and Biotronik. Dr Kuck has research contracts and grants from Biosense Webster, Medtronic, St. Jude Medical, and Boston Scientific and has consulted for St. Jude Medical, Stereotaxis, and Edwards Lifesciences. Dr Ghanbari has received research funding from Biotronik and St Jude Medical and has received lecturing honoraria from Biotronik. The other authors report no conflicts.

References
4. Aklot EM, Stevenson WG, Almemrad-Garrote JM, Bogan F, Calkins CH, Delacretaz E, Della Bella P, Hindricks G, Jais P, Josephson ME, Kautzner J, Kay GN, Kuck KH, Lerman BB, Marchlinski F, Reddy V, Schlatl MJ, Schilling R, Soejima K, Wilber D; European Heart Rhythm Association (EHRA); Registered Branch of the European Society of Cardiology (ESC); Heart Rhythm Society (HRS); American College of Cardiology (ACC); American Heart Association (AHA). EHRA/HRS Expert Consensus on Catheter Ablation of Ventricular Arrhythmias: developed in a partnership with the European Heart Rhythm Association (EHRA), a Registered Branch of the European Society of Cardiology (ESC), and the Heart Rhythm Society (HRS); in collaboration with the American College of Cardiology (ACC) and the American Heart Association (AHA). Heart Rhythm. 2009;6:886–933.
Noninducibility in Postinfarction Ventricular Tachycardia as an End Point for Ventricular Tachycardia Ablation and Its Effects on Outcomes: A Meta-Analysis
Hamid Ghanbari, Kazim Baser, Miki Yokokawa, William Stevenson, Paolo Della Bella, Pasquale Vergara, Thomas Deneke, Karl-Heinz Kuck, Hans Kottkamp, She Fei, Fred Morady and Frank Bogun

_Circ Arrhythm Electrophysiol._ 2014;7:677-683; originally published online May 30, 2014; doi: 10.1161/CIRCEP.113.001404

_Circulation: Arrhythmia and Electrophysiology_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2014 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-3149. Online ISSN: 1941-3084

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circep.ahajournals.org/content/7/4/677

Data Supplement (unedited) at:
http://circep.ahajournals.org/content/suppl/2014/05/30/CIRCEP.113.001404.DC1

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation: Arrhythmia and Electrophysiology_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to _Circulation: Arrhythmia and Electrophysiology_ is online at:
http://circep.ahajournals.org//subscriptions/
## Supplemental Table 1: Risk of Bias

<table>
<thead>
<tr>
<th>Category</th>
<th>Deneke(^{26})</th>
<th>Yokokawa(^{20})</th>
<th>Reddy(^{21})</th>
<th>Della Bella(^{24})</th>
<th>Deneke(^{26})</th>
<th>Kim(^{22})</th>
<th>Stevenson(^{27})</th>
<th>Della Bella(^{23})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representativeness of the exposed cohort(^a)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Selection of the non-exposed cohort(^b)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Ascertainment of exposure(^c)</td>
<td>*</td>
<td>0</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Demonstration that the outcome of interest was not present at start of study(^d)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Comparability of cohorts on the basis of the design or analysis(^e)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Assessment of outcome(^f)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Long enough follow up for outcomes to occur(^g)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Adequacy of follow-up of the cohorts(^h)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Stars were assigned according to the following for each category:

- \(^a\) Truly representative of the average population
- \(^b\) Drawn from the same community as the exposed cohort
- \(^c\) Programmed stimulation at the end of ablation
- \(^d\) Programmed stimulation at the start of the procedure demonstrated clinical and non clinical VT
- \(^e\) Study controls for the most important risk factors, additional star was given for controlling other risk factors
- \(^f\) Independent blind assessment or through medical records
- \(^g\) Follow-up was long enough for outcomes to occur
- \(^h\) Complete follow-up of all subjects accounted or subjects lost to follow up unlikely to introduce
### Supplemental Table 2. Ablation and Programmed Stimulation Protocols in the Included Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>EPS protocol</th>
<th>Mapping strategy</th>
<th>Ablation technology</th>
<th>Clinical VT documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deneke26</td>
<td>Up to three extra stimuli. LV programmed stimulation (n=3)</td>
<td>Voltage mapping, pace mapping</td>
<td>3.5 mm irrigated-tip ablation catheter</td>
<td>12 lead ECG: 38 patients ICD VTCL: 77 patients</td>
</tr>
<tr>
<td>Reddy21</td>
<td>Up to three extra stimuli.</td>
<td>Voltage mapping, pace mapping</td>
<td>3.5 mm irrigated-tip ablation catheter</td>
<td>Not reported</td>
</tr>
<tr>
<td>Kim22</td>
<td>Up to three extrastimuli, 2 drive cycle lengths, 2 RV sites, LV stimulation if clinical VT not inducible from the right ventricle</td>
<td>Pace mapping, activation mapping, entrainment mapping</td>
<td>4 mm tip temperature controlled ablation catheter</td>
<td>12 lead ECG</td>
</tr>
<tr>
<td>Stevenson27</td>
<td>Up to three extrastimuli, 2 drive cycle lengths, 2 RV sites</td>
<td>Pace mapping, Double potentials, Late potential mapping, entrainment mapping, voltage mapping</td>
<td>3.5 mm irrigated-tip ablation catheter</td>
<td>All sustained VTs with a cycle length within ≤ 20 ms of a documented spontaneous VT.</td>
</tr>
<tr>
<td>Della Bella24</td>
<td>Up to three extrastimuli, 3 drive cycle lengths, RV and LV stimulation</td>
<td>Voltage mapping, non contact mapping, entrainment mapping, activation mapping</td>
<td>4 mm tip temperature controlled ablation catheter</td>
<td>Not reported</td>
</tr>
<tr>
<td>Deneke25</td>
<td>Up to three extrastimuli, 2 drive cycle lengths, 2 RV sites</td>
<td>Voltage mapping, Pace mapping</td>
<td>8 mm tip temperature controlled ablation catheter</td>
<td>12 lead ECG: 9 patients ICD VTCL 15 patients</td>
</tr>
<tr>
<td>Yokokowa20</td>
<td>Up to four extrastimuli, 2 drive cycle lengths, 2 RV sites</td>
<td>Pace mapping, late potential mapping, voltage mapping, entrainment mapping</td>
<td>3.5 mm irrigated-tip ablation catheter 4 and 8 mm tip temperature controlled ablation catheter</td>
<td>ICD electrogram morphology</td>
</tr>
<tr>
<td>Della Bella23</td>
<td>Up to four extrastimuli, 3 drive cycle lengths, RV and LV stimulation</td>
<td>Late potential mapping, voltage mapping, activation mapping</td>
<td>3.5 mm irrigated-tip ablation catheter</td>
<td>12 lead ECGs, ICD VTCL</td>
</tr>
</tbody>
</table>

Abbreviations: ICD VTCL: Ventricular tachycardia cycle length based on recordings from the implanted cardioverter defibrillator, RV: right ventricular, LV: left ventricular
Supplemental Figure 1. GRADE evidence profile table for recurrence of VT/VF in patients with partial success compared with failed ablation

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Illustrative comparative risks* (95% CI)</th>
<th>Relative effect (95% CI)</th>
<th>No of Participants (studies)</th>
<th>Quality of the evidence (GRADE)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT/VF recurrence</td>
<td>827 per 1000 (382 to 682)</td>
<td>OR 0.24 (0.13 to 0.45)</td>
<td>322 (8 studies)</td>
<td>⊕⊕⊕⊝ moderate</td>
<td></td>
</tr>
<tr>
<td>EP study at the conclusion of VT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ablation</td>
<td>533 per 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>245 per 1000 (34 to 284)</td>
<td>OR 0.37 (0.11 to 1.22)</td>
<td>319 (8 studies)</td>
<td>⊕⊕⊕⊝ moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>107 per 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: Confidence interval; OR: Odds ratio;

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.
**Supplemental Figure 2.** GRADE evidence profile table for recurrence of VT/VF in non-inducible compared with partial success

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Illustrative comparative risks* (95% CI)</th>
<th>Relative effect (95% CI)</th>
<th>No of Participants (studies)</th>
<th>Quality of the evidence (GRADE)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assumed risk</td>
<td>Corresponding risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VT/VF recurrence</td>
<td>457 per 1000</td>
<td>292 per 1000</td>
<td>OR 0.49 (0.29 to 0.84)</td>
<td>788 (8 studies)</td>
<td>⊕⊕⊕⊝ moderate¹</td>
</tr>
<tr>
<td>EP study</td>
<td>196 to 414</td>
<td>(196 to 414)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>131 per 1000</td>
<td>82 per 1000</td>
<td>OR 0.59 (0.36 to 0.98)</td>
<td>788 (8 studies)</td>
<td>⊕⊕⊕⊝ moderate¹</td>
</tr>
<tr>
<td></td>
<td>52 to 129</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

CI: Confidence interval; OR: Odds ratio;

GRADE Working Group grades of evidence

**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.

**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

**Very low quality:** We are very uncertain about the estimate.
**Supplemental Figure 3.** GRADE evidence profile table for recurrence of VT/VF in non-inducible compared with failed ablation

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Illustrative comparative risks* (95% CI)</th>
<th>Relative effect (95% CI)</th>
<th>No of Participants (studies)</th>
<th>Quality of the evidence (GRADE)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT/VF recurrence EP study</td>
<td>827 per 1000 (222 to 462)</td>
<td>OR 0.10 (0.06 to 0.18)</td>
<td>665 (8 studies)</td>
<td>☺☺☺☺ moderate</td>
<td>1</td>
</tr>
<tr>
<td>Mortality</td>
<td>245 per 1000 (31 to 243)</td>
<td>OR 0.32 (0.1 to 0.99)</td>
<td>665 (8 studies)</td>
<td>☺☺☺☺ moderate</td>
<td>1</td>
</tr>
</tbody>
</table>

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).*

CI: Confidence interval; OR: Odds ratio;

---

GRADE Working Group grades of evidence

- **High quality**: Further research is very unlikely to change our confidence in the estimate of effect.
- **Moderate quality**: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
- **Low quality**: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
- **Very low quality**: We are very uncertain about the estimate.

---

1 No explanation was provided
Supplemental Figure 4. QUOROM diagram of included studies

Potentially relevant articles identified: (n=3895)

Citations or abstracts screened for possible retrieval (n=204)

Studies excluded using search limitations (n=3691)

Potentially appropriate studies to be included in the analysis (n=11)

Studies excluded (n=703)
- Reviews (86)
- Case Reports (65)
- Non ischemic Cardiomyopathy (24)
- Outcome of interest not reported (18)

Outcomes of EP study post procedure not defined (2) EP protocol inadequate (1)

8 studies included in meta-analysis