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Catheter ablation of scar-based ventricular tachycardia: Relationship of procedure duration to outcomes and hospital mortality

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Abstract

BACKGROUND—Ablation has become an important option for treatment of ventricular tachycardia (VT). The influence of procedure duration on outcomes remains unexamined.

OBJECTIVE—The purpose of this study was to determine the influence of procedure duration on outcomes and complications over an 8-year period

METHODS—Patients referred for scar-mediated VT ablation from 2004 to 2011 were retrospectively analyzed. Procedure duration was defined as the time from the insertion of catheters through the femoral vein to the time of their withdrawal. Procedure duration was analyzed in relationship with baseline and intraoperative covariates, acute procedural outcomes, complications, and 6-month clinical outcomes.

RESULTS—One hundred forty-eight patients underwent VT ablation with mean procedure duration of 5.7 ± 1.8 hours. VT recurrence and survival at 6 months were 46% and 82%, respectively, and were not associated with procedure duration. Hospital mortality increased with intraoperative intraaortic balloon pump insertion (adjusted odds ratio [OR] 13.7, 95% confidence interval [CI] 2.35–79.94, $P = .004$) and was improved with successful ablation of the clinical VT as a procedural end-point (adjusted OR 0.13, 95% CI 0.03–0.54, $P = .005$). The association between procedure duration and hospital mortality remained after adjusting for significant baseline variables (adjusted OR 1.75, 95% CI 1.14–2.68, $P = .0098$) and intraoperative variables (adjusted OR 1.6, 95% CI 1.12–2.29, $P = .0104$).

CONCLUSION—Hospital mortality was significantly increased by unsuccessful clinical VT ablation as a procedural end-point and intraoperative intraaortic balloon pump insertion. However, after adjusting for significant baseline and intraoperative covariates, procedure duration still was

associated with increased hospital mortality. Procedure duration had no impact on VT recurrence and survival at 6 months.

Keywords

Ventricular tachycardia; Ventricular tachycardia ablation; Procedure duration; Ventricular tachycardia ablation efficacy; Ventricular tachycardia recurrence; Hospital mortality

Introduction

Catheter ablation has become an important treatment option in the management of ventricular tachycardia (VT). Over the past 20 years, the procedure has evolved from endocardial-only ablation of stable VT to a substrate-based approach using both endocardial and selective epicardial access to target hemodynamically unstable arrhythmias. With the advent of electroanatomic mapping systems, cooled-tip ablation catheters, and percutaneous epicardial access, ablation now is implemented earlier in the course of VT management.^{1–3}

The relationship of VT ablation procedure duration with clinical efficacy and complication rate has not been systematically evaluated. With the increasing complexity of VT arrhythmogenic substrate and procedural techniques, the effect of procedure duration on outcomes is an important question. In this study, we examined the association between procedure duration and acute procedural outcomes, complications, hospital mortality, and 6-month clinical outcomes.

Methods

Patient population

All patients who underwent ablation for scar-mediated VT from January 2004 to July 2011 at our center were retrospectively analyzed. VT was scar-mediated if ejection fraction was $\geq 50\%$, scar was detected on electroanatomic mapping, and the origin of targeted VTs could be related to the scar by pace-mapping or entrainment. Procedure duration was defined as the time from insertion of catheters through the femoral vein to time of their withdrawal. All studies were performed with patients under general anesthesia. The institutional review board at UCLA Medical Center approved review of the retrospective data.

Electrophysiologic study and radiofrequency ablation

Mapping and ablation of scar-mediated VT at our center was performed as previously described.^{4–6} Percutaneous epicardial access was obtained using a technique previously described.⁷ In patients with prior cardiac surgery, pericardial access was obtained via a subxiphoid window or limited anterior thoracotomy.⁸ Radiofrequency ablation (60 seconds per site) was performed using a 3.5-mm open-irrigated catheter (ThermoCool, Biosense Webster, Diamond Bar, CA) at a 30-mL flow rate, or a closed-loop irrigated catheter (Chilli, Boston Scientific, Natick, MA) at 30–50 W, temperature limit at 45 °C for endocardial ablation and 50°C for epicardial ablation.

Acute outcomes, complications, and clinical follow-up

Acute procedural success was defined as noninducibility of any VT after ablation with up to triple extrastimulus testing. Partial success was defined as inducibility of only faster, nonclinical sustained VT(s). Complications were subdivided as either intraoperative or postoperative. Intraoperative complications were observed during the procedure, and postoperative complications were observed in the subsequent hospital course. Postoperative complications were categorized as either hospital deaths or nonlethal complications. Six-month follow-up for VT recurrence and survival were assessed from outpatient clinic notes and device interrogation.

Statistical analysis

All continuous data are given as mean $\pm$ SD when a Gaussian distribution was present. Multivariate logistic regression modeling was used to assess the simultaneous impact of procedure duration and other covariates on outcomes: hospital mortality, nonlethal postoperative complications, acute procedural outcomes, and 6-month clinical outcomes. Backward stepdown logistic regression using a liberal $P < .10$ variable retention criterion was performed to select final predictors from candidate predictors, except that procedure duration was retained.

The effect of procedure duration on outcomes was assessed with up to 13 baseline covariates considered: age, ischemic cardiomyopathy, ejection fraction, New York Heart Association class III or IV, VT storm, syncope, creatinine level, prior cardiac surgery, number of prior failed ablations, antiarrhythmic use, dialysis, pressor support (use of dopamine, norepinephrine, or vasopressin to support the blood pressure), and use of left ventricular assist device before ablation.

The effect of procedure duration on hospital mortality and nonlethal postoperative complications were assessed with up to 10 intraoperative covariates considered: surgical epicardial access, combined epicardial–endocardial mapping, combined epicardial–endocardial ablation, number of radio-frequency lesions delivered, number of VTs induced, number of cardioversions, intraoperative complications, intraaortic balloon pump (IABP) insertion for hemodynamic support, acute procedural success, and acute/partial procedural success. This analysis allowed evaluation of whether procedure duration per se affected these outcomes in addition to operative factors that themselves may increase procedure duration.

Finally, the effect of intraoperative variables on outcomes was also assessed after adjusting for baseline covariates listed earlier). $P < .05$ was considered significant.

Results

One hundred forty-eight patients underwent scar-mediated VT ablation over 8 years. Table 1A lists the baseline clinical characteristics of our cohort: mean age 63 ± 12 years, 51% ischemic cardiomyopathy (ICM)/49% nonischemic cardiomyopathy (NICM), and ejection fraction (EF) $30\% \pm 14\%$. Thirty-nine percent of patients presented with VT storm, and 4% required hemodynamic support with pressors before ablation. Mean procedure duration for

all cases was 5.7 ± 1.8 hours, with 47% of patients undergoing endocardial-only mapping, 7% epicardial-only mapping, and 46% combined epicardial–endocardial mapping (Figure 1). Compared to single-surface mapping, combined epicardial–endocardial mapping was associated with significantly longer procedure duration (6.3 ± 1.7 hours vs 5.1 ± 1.6 hours, $P < .0001$). Sixty-one percent of procedures ($n = 90$) were completed within 4 to 7 hours, 15% ($n = 22$) extended beyond 8 hours, and only 3% ($n = 4$) were completed within 3 hours.

Table 1B lists other procedure characteristics of our cohort: 67 patients (45%) underwent attempted percutaneous epicardial access, and 17 (11%) underwent surgical epicardial access. Thirteen patients (9%) required intraoperative intraaortic balloon pump insertion for hemodynamic support.

Procedural complications

Sixteen patients (11%) in our cohort had 18 intraoperative complications (Table 2A). Five intraoperative complications were related to percutaneous epicardial access and 4 were related to surgical epicardial access, representing a 7% complication rate among the 67 patients who underwent percutaneous epicardial access and a 24% complication rate among the 17 who underwent surgical epicardial access. Overall, 37 of cases (25%) had postoperative complications (Table 2B). Of these, 24 (65%) were nonlethal, and 13 (35%) resulted in hospital deaths.

Procedure outcomes and clinical follow-up

Table 3 lists the 6 outcomes that were analyzed and correlated with procedure duration, after adjusting for baseline covariates. The overall acute or partial procedural success rate was 87% (ICM 93% [70/75], NICM 81% [59/ 73]), and the acute procedural success rate (noninducibility of any VT after ablation) was 45% (ICM 49% [37/75], NICM 40% [29/73]). These success rates did not correlate significantly with increased procedure duration ($P = .24$ for acute procedural success, and $P = .95$ for combined acute/partial procedural success). At 6 months, 46% of patients had VT recurrence (ICM = 33% [24/72], NICM = 60% [42/70]), and 82% survived (ICM = 83% [60/72], NICM = 81% [57/70]). Neither VT recurrence ($P = .79$) nor survival rate at 6 months ($P = .93$) correlated with increased procedure duration. Overall hospital mortality was 9% (ICM = 7% [5/75], NICM = 11% [8/73]), and nonlethal postoperative complication rate was 16% (ICM = 21% [16/ 75], NICM = 11% [8/73]). After adjusting for significant baseline covariates, increased procedure duration correlated significantly with higher hospital mortality (adjusted odds ratio [OR] 1.75, 95% confidence interval [CI] 1.14–2.68, $P = .001$), with a trend toward increased nonlethal postoperative complications (adjusted OR 1.25, 95% CI 0.96–1.62, $P = .103$).

Impact of baseline covariates

Tables 4A and 4B list the significant baseline covariates for hospital mortality and nonlethal postoperative complications, respectively, based on multivariate logistic analysis. Baseline covariates associated with increased mortality included VT storm (OR 8.29, 95% CI 1.22–56.42, $P = .03$), use of pressors before ablation (OR 10.88, 95% CI 1.28–92.71, $P = .03$), age (OR 1.09 per year, $P = .03$), and prior cardiac surgery (OR 5.01, $P = .058$). Although EF did

not contribute additionally to hospital mortality after adjusting for the baseline covariates listed in Table 4A, patients who died had significantly lower baseline EFs compared to those who survived in the hospital ($23\% \pm 6\%$ vs $31\% \pm 14\%$, $P = .002$). Baseline covariates associated with increased nonlethal postoperative complications included reduced EF (OR for complication per 1% EF increase was 0.95, 95% CI 0.9–1.0, $P = .04$) and number of prior failed ablations (OR 1.4, $P = .07$). Patients with nonlethal complications had significantly lower baseline EF compared to patients without complications ($25\% \pm 10\%$ vs $31\% \pm 14\%$, $P = .0095$).

Effect of intraoperative variables

Table 5 displays the multivariate analysis for ten intraoperative variables, including acute procedural success and acute/partial success. The OR of each intraoperative variable for hospital mortality and nonlethal postoperative complication was adjusted for significant baseline covariates. Intraoperative variables associated with increased mortality were IABP insertion (adjusted OR 13.7, 95% CI 2.35–79.94, $P = .004$) and surgical epicardial access (adjusted OR 5.5, 95% CI 0.77–39.19, $P = .09$). Acute/partial procedural success (successful ablation of clinical VT) was associated with significantly reduced hospital mortality (adjusted OR 0.13, 95% CI 0.03–0.54, $P = .0050$), but acute success (non-inducibility of any VT after ablation) had no impact ($P = .65$). Intraoperative variables associated with increased non-lethal postoperative complications included surgical epicardial access (adjusted OR 6.38, 95% CI 1.73–23.5, $P = .0053$), number of VTs induced (adjusted OR 1.3 per VT, 95% CI 1.03–1.64, $P = .03$), and intraoperative complications (adjusted OR 3.12, 95% CI 0.98–9.89, $P = .054$). One hundred six patients (72%) had only unmappable VTs, and 27 (18%) had both mappable and unmappable VTs (Table 1B). Although the nonlethal postoperative complication rate correlated with the number of inducible VTs, it was not significantly associated with the number of intraoperative cardioversions for unstable VTs ($P = .39$).

Figure 2A shows increasing hospital mortality with longer procedure duration, stratified by each additional hour after 3 hours. Figures 2B and 2C estimate progressively increased risk of hospital mortality with longer procedure duration, after adjusting values for the most significant baseline and intraoperative covariates (acute/partial procedural success, IABP insertion), respectively. As previously discussed (Table 3), longer procedure duration correlated significantly with increased hospital mortality, after adjusting for baseline covariates. This relationship remained after adjusting for intraoperative covariates (adjusted OR 1.6, 95% CI 1.12–2.29, $P = .0104$).

Longer procedure duration was associated with a trend toward increased nonlethal postoperative complications, after adjusting for baseline covariates (Table 3). However, after adjusting for significant intraoperative covariates (surgical epicardial access, number of VTs induced, intraoperative complications), procedure duration had no relation with nonlethal postoperative complications (OR 1.03, 95% CI 0.78–1.36, $P = .84$).

Hospital deaths

Table 6 lists the characteristics of the 13 patients (9%) with hospital deaths in our cohort. Baseline characteristics were mean age 67 ± 10 years, 5 (38%) ICM/8 (62%) NICM, EF $23\% \pm 6\%$, and 11 (85%) with VT storm on presentation. Intraoperative characteristics were 5 (38%) required IABP insertion for hemodynamic support, 2 (15%) underwent surgical epicardial access, 2 (15%) had intraoperative complications, and 7 (54%) had acute/partial procedural success. Of the 13 deaths, 6 (46%) were due to recurrent VT, 3 (23%) heart failure, 2 (15%) respiratory complications, 1 (8%) hypoxic encephalopathy, and 1 (8%) voluntary withdrawal of support despite possibility of recovery.

Acute and partial procedural success were significantly associated with reduced risk of hospital mortality (Table 5). Of the 19 patients (13%) in our cohort who underwent a failed ablation in which clinical VT could not be eliminated, 6 (32%) died in the hospital (patients 2, 3, 6, 7, 10, 11). Three of these patients died of recurrent VT, resulting in hypoperfusion and multisystem organ failure. One patient required intubation for incessant VT, complicated by fatal aspiration pneumonia. Two other patients developed hypotension intraoperatively, requiring IABP support and procedural abortion. One of these patients died of lung collapse postoperatively, and the other because of voluntary withdrawal of support.

Intraoperative IABP insertion was significantly associated with increased hospital mortality (Table 5). Thirteen patients (9%) in our cohort required intraoperative IABP placement for hemodynamic support. Of these, 5 (38%) had hospital deaths (patients 2, 6, 7, 8, 11): 2 due to recurrent VT, 1 progressive heart failure, 1 lung collapse postoperatively, and 1 voluntary withdrawal of support despite possible full recovery. Both patients who died of recurrent VT (patients 2, 6) also had procedural failure to eliminate clinical VT. The patient who died of heart failure (patient 8) had baseline EF 22.5%, presented with VT storm, 6 implantable cardioverter-defibrillator (ICD) shocks in 1 day, and cardiac arrest before ablation.

Nonlethal postoperative complications

Surgical epicardial access was associated with significantly increased nonlethal postoperative complication (Table 5). Of the 17 patients (11%) in our cohort who underwent surgical epicardial access, 7 (41%) suffered nonlethal complications: 2 heart failure exacerbation (baseline EF 15% and 27.5%), 3 pneumonia (2 with VT storm), 1 sepsis, and 1 wound infection at the access site.

Sixteen patients (11%) in our cohort had intraoperative complications (Table 2A). Intraoperative complications were associated with increased nonlethal postoperative complications, with near statistical significance (Table 5). Of the patients with intraoperative complications, 6 (38%) developed nonlethal postoperative complications: 3 heart failure exacerbation, 2 aspiration pneumonia, and 1 pericarditis. All 3 patients with heart failure exacerbation had moderately to severely reduced baseline EF (27.5%, 15%, and 14%) and significant intraoperative bleeding (2 cases 4200 mL bleeding from surgical epicardial access, 1 with 1.3 L bleeding from right ventricular puncture with percutaneous epicardial access). Of the 2 cases of pneumonia, 1 lost 2 L blood intraoperatively (800 mL from surgical access and 1.2 L from retroperitoneal hematoma), requiring vasopressors and

intubation. The patient with pericarditis had 200 mL pericardial bleeding from percutaneous epicardial access, requiring pigtail catheter drainage for 2 days, and then developed pericarditis.

Discussion

The major findings from this study are as follows: 1) hospital mortality is significantly increased with acute procedural failure (to ablate clinical VT) and the need for intraoperative IABP insertion; (2) after adjusting for all significant baseline and intraoperative covariates, procedure duration still is associated with increased hospital mortality; and (3) at 6 months, procedure duration had no impact on VT recurrence and survival.

Hospital mortality

In our cohort, recurrent VT accounted for 46% of hospital deaths, and 85% of patients with hospital deaths presented with VT storm. Failure to eliminate clinical VT during ablation was significantly associated with hospital mortality. Similarly, in a cohort of 518 patients who underwent VT ablation, Tokuda et al⁹ reported 17 deaths within 30 days and found that uncontrollable VT/ventricular fibrillation accounted for 11 (65%) of the deaths. Among the 52 patients with acute procedural failure in their study, 4 of 4 deaths within 30 days were due to VT. The OR of mortality with failure to ablate VT was 1.9 in their study; in our study, OR was 7.7 (inverse of 0.13 for acute/partial procedural success). In a large European single-center experience with 227 patients, the hospital mortality rate was 4%, although procedural failure was only 7% in this cohort compared to 13% in our patient group.¹⁰ Although successful ablation of the clinical VT predicted decreased hospital mortality, our study did not show decreased hospital mortality in patients who achieved noninducibility of any VT after ablation. This procedural end-point has been associated with reduced long-term cardiovascular¹¹ and all-cause mortality.⁹

Intraoperative IABP insertion for hemodynamic support was also associated with hospital mortality, after controlling for significant baseline covariates. The exact mechanism by which IABP insertion was related to hospital mortality is unclear from our study. In a multicenter experience of patients requiring left ventricular assist devices in VT ablation, of which one-third (n = 22) received an IABP and two-thirds (n = 44) either an Impella or a Tandem Heart device, the overall hospital mortality was 17%, with no differences between the 2 groups.¹²

After controlling for significant baseline and intraoperative covariates, the association between procedure duration and hospital mortality remained. Possible explanations for this relationship in addition to the intraoperative variables we analyzed may be increased exposure to general anesthesia with prolonged procedures. Our findings suggest that eliminating the clinical VT, avoiding intraoperative IABP insertion if possible, and reducing procedure duration are important strategies for improving hospital mortality, particularly in patients with moderately to severely reduced ejection fraction (EF $\leq$ 25%) who are at increased risk for hospital death.

Nonlethal postoperative complications

Procedure duration was associated with increased nonlethal postoperative complications after controlling for significant baseline covariates, but procedure duration per se was not related to nonlethal postoperative complications after adjusting for significant intraoperative variables. This suggests that the association between procedure duration and nonlethal postoperative complications may have been a reflection of other factors that prolong procedure duration, such as surgical epicardial access, intraoperative complications, or prolonged extrastimulus testing resulting in more inducible VTs.

The number of inducible VTs correlated with increased nonlethal postoperative complication, but the exact mechanism is unclear from this analysis. Although patients with more inducible VTs have been shown to also have lower baseline EFs, our multivariate analysis adjusted for this with the baseline covariates.¹³ Cardioversion and hypoperfusion during ventricular fibrillation have been shown to cause myocardial stunning and may explain the association between increased number of inducible VTs and nonlethal postoperative complications.^{14,15} However, our study is underpowered to show a relationship between the number of intraoperative cardioversions and nonlethal postoperative complications (adjusted OR 1.10, $P = .39$).

Surgical epicardial access

Surgical epicardial access was significantly associated with increased nonlethal postoperative complications and a trend toward increased hospital mortality in our cohort. In our 17 cases of limited surgical access, there were 4 (24%) cases of significant intraoperative bleeding, 7 (41%) nonlethal postoperative complications, and 2 (12%) hospital deaths, both due to recurrent VT in patients with unsuccessful ablation of clinical VT. In comparison, in a series of 8 patients with NICM who underwent more extensive median sternotomy for surgical ablation, Anter et al¹⁶ reported 2 (25%) hospital deaths, due to sepsis and progressive heart failure. Despite these risks, surgical epicardial access has been a useful adjunct for performing epicardial ablation in patients with prior cardiac surgeries, inflammatory pericardial adhesions, or epicardial targets at sites that cannot be accessed with a percutaneous approach. Our group previously reported a series of 14 patients (9 ICM, 4 NICM, 1 idiopathic VT) who underwent surgical epicardial access for VT ablation (12 with prior cardiac surgery, 1 with pericardial adhesions, 1 found on prior ablation to have an ablation target close to a coronary artery and phrenic nerve).⁸ Of these 14 patients, 10 (71 %) were found to have a VT target at the epicardial surface, and 7 (50%) had VT-free survival at mean of 583 days.

Effect of VT storm

VT storm, defined as ≥ 3 appropriate therapies for VT in a 24-hour period, was the admission diagnosis in 39% of our patients, and 84% presented with recurrent ICD shocks, which have been associated with increased mortality and decreased quality of life.¹⁷ In addition to a recent large European single-center study showing improved cardiovascular mortality in patients who underwent successful ablation,¹¹ a contemporary U.S. study found that in patients with ICD shocks, those who underwent catheter ablation had significantly lower all-cause mortality at 5 years than those who were managed medically (17.6% vs

34.8%).¹⁸ Thus, despite the risks of complex VT ablation, the benefits likely outweigh the risks, especially when considering that the majority of patients presenting with VT storm or recurrent shocks.

Study limitations

This is a single-center retrospective observational study with the inherent patient selection bias in a referred population. The sample size and number of outcome events relative to the number of covariates present an important limitation in this study. Our backward stepwise variable screening allows adjustment for only the strongest covariates and does not allow one to distinguish between true non-significance and low statistical power for covariates not chosen.

It also is possible that other unrecognized variables not considered in this analysis may partially account for the relationship between procedure duration and in-hospital mortality. Furthermore, this is largely a quaternary referral population, and the findings may have less applicability to the more common tertiary VT population with more stable VTs undergoing initial VT ablation procedures. A large prospective multicenter study could further clarify and validate our results.

Conclusion

Prolonged procedure duration was associated with increased hospital mortality after adjustment for baseline variables and the most significant intraoperative variables (insertion of IABP and unsuccessful ablation of the clinical VT). Our clinical outcomes demonstrated no association between procedure duration and nonlethal postoperative complications, and 6-month VT recurrence and survival.

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ABBREVIATIONS

CI	confidence interval
EF	ejection fraction
IABP	intraaortic balloon pump
ICD	implantable cardioverter-defibrillator
ICM	ischemic cardiomyopathy
NICM	nonischemic cardiomyopathy
OR	odds ratio
VT	ventricular tachycardia

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CLINICAL PERSPECTIVES

This is the first study to show a relationship between procedure duration and in-hospital mortality after VT ablation procedures. This persisted after accounting for other expected major risk factors such as clinical and hemodynamic status, the number of inducible VTs, and the use of pressors or intraaortic balloon pump support.

Although this is a very high-risk patient population at baseline, many factors contribute to the procedure duration, including complexity of the cardiac substrate, addition of an epicardial approach, the number of inducible VTs, operator experience, and procedure end-points. In addition, extended procedures with prolonged general anesthesia may result in higher rates of heart failure exacerbation, pneumonia, and sepsis. Because the number of induced VT morphologies increases the risk of VT recurrence and procedure duration, prolonged procedures may be justified on clinical grounds in some cases.

Optimization of the patient's clinical condition, particularly heart failure status, before VT ablation is essential. Careful planning of the procedure, with prompt vascular access and efficient substrate mapping, avoidance of multiple VT inductions and shocks, and a focused ablation strategy, will help expedite the procedure. Continuous monitoring of the patient with input from anesthesia and nursing staff and adjusting the end-point to account for the patient's condition as the procedure progresses is critical. Consideration of the operator and staff level of focus and fatigue also is relevant for procedures of very long duration. Undertaking a staged procedure rather than a single very prolonged procedure may be the optimal approach for selected patients.

Procedure Duration Distribution and Surfaces Mapped

Figure 1. Procedure duration distribution and surfaces mapped for all ventricular tachycardia ablation procedures.

Figure 2.

A: Hospital mortality and procedure duration, stratified by each additional hour after 3 hours. **B:** Estimated risk of hospital mortality as a function of procedure duration, adjusted for baseline covariates. This model adjusts for confounding variables of ventricular tachycardia storm, pressor use before ablation, age, prior cardiac surgery, and ischemic cardiomyopathy. **C:** Estimated risk of hospital mortality as a function of procedure duration, adjusted for intraoperative covariates. This model adjusts for confounding variables of intraoperative intraaortic balloon pump insertion and acute/partial procedure success.

Surgical epicardial access did not significantly contribute to hospital mortality after adjusting for these 2 intraoperative variables.

Table 1A

Baseline clinical characteristics of the cohort (N = 148)

ICM (%) / NICM (%)	75 (51%) / 73 (49%)
Age (years)	63 ± 12
Male	128 (86%)
Ejection fraction (%)	30 ± 14
NYHA class III or IV	67 (45%)
Hypertension	80 (54%)
Renal failure (Cr ≥ 1.5 m/dL)	34 (23%)
Previous ablation	74 (50%)
No. of prior failed ablations	0.9 ± 1.3
Previous cardiac surgery	55 (37%)
ICD implanted	138 (93%)
Presentation	
Syncope	19 (13%)
VT storm	58 (39%)
Recurrent shocks	124 (84%)
Medications	
Beta-blockers	128 (86%)
Any antiarrhythmic agent	129 (87%)
Amiodarone	100 (68%)
Other antiarrhythmic agents	72 (49%)
≥ 2 Antiarrhythmic agents	51 (34%)
Hemodynamic support before ablation	
Pacemakers	6 (4%)
Left ventricular assist device	2 (1%)

Cr = creatinine; ICD = implantable cardioverter-defibrillator; ICM = ischemic cardiomyopathy; NICM = nonischemic cardiomyopathy; NYHA = New York Heart Association; VT = ventricular storm.

Table 1B

Procedure characteristics of the cohort (N = 148)

Epicardial access	
Percutaneous (total attempted)	67 (45%)
Surgical epicardial access	17 (11%)
Surface mapped	
Endo-only	69 (47%)
Epi-only	11 (7%)
Epi-endo	68 (46%)
Surface ablated	
Endo-only	92 (62%)
Epi-only	16 (11%)
Epi-endo	38 (26%)
Ablation was not performed *	2 (1%)
VTs induced (no. per patients)	2.5 ± 1.9
VT cycle length (ms)	409 ± 91
Cases with [n (%)]	
Only mappable VT(s)	15 (10%)
Only unmappable VT(s)	106 (72%)
Mappable and unmappable VTs	27 (18%)
Intraoperative IABP insertion	13 (9%)
Cardioversions (no. per patient)	2.0 ± 2.1
Fluoroscopy time (min)	82 ± 34
RF lesions (no. per patient)	37 ± 25
Procedure duration (hours)	5.7 ± 1.8
Acute outcome	
Acute success	66 (45%)
Partial success	63 (42%)
Failure	19 (13%)

Endo = endocardial; Epi = epicardial; Epi-endo = combined epicardial and endocardial; IABP = intraaortic balloon pump; RF = radio frequency; VT = ventricular tachycardia.

* Two patients underwent procedures without ablation.

One because of lack of appropriate targets; the other because of procedure termination after pericardial bleeding.

Table 2A**Intraoperative complications in the cohort (N = 148)**

Total cases with intraoperative complications	16 (11%)
Endocardial access related	
Retroperitoneal bleeding from femoral access	2 (1%)
Ischemic stroke	1 (1%)
Pericardial bleeding (> 80 mL) from endocardial puncture	1 (1%)
AV block	2 (1%)
RV lead damage	1 (1%)
Pseudoaneurysm	1 (1%)
Neck hematoma	1 (1%)
Percutaneous epicardial access related	
Pericardial bleeding (> 80 mL)	3 (2%)
RV puncture resulting in pericardial bleeding (>80 mL)	1 (1%)
Subxiphoid hematoma	1 (1%)
Surgical epicardial access related	
Bleeding (> 200 mL)	4 (3%)

One patient with pericardial bleeding from percutaneous epicardial access also developed retroperitoneal bleeding from femoral access.

One patient with bleeding from surgical epicardial access also developed retroperitoneal bleeding from femoral access.

AV = atrioventricular; RV = right ventricle.

Table 2B

Postoperative complications in the cohort, subcategorized as nonlethal postoperative complications or hospital deaths (N = 148)

Total cases with postoperative complications	37 (25%)
Nonlethal postoperative complications	24 (16%)
Sepsis	5 (3%)
Pneumonia	6 (4%)
Heart failure exacerbation	9 (6%)
Pulmonary flash edema from blood transfusion	1 (1%)
Pleural effusion requiring diuresis	1 (1%)
Wound infection from surgical epicardial access	1 (1%)
Pericarditis from percutaneous epicardial access	1 (1%)
Thromboembolism from IABP	1 (1%)
Hospital deaths	13 (9%)
Heart failure resulting in death	3 (2%)
Recurrent VT resulting in death	6 (4%)
Pneumonia resulting in death	1 (1%)
Hypoxic encephalopathy resulting in death	1 (1%)
Lung collapse resulting in death	1 (1%)
Voluntary withdrawal of support resulting in death	1 (1%)

One patient with thromboembolism from IABP also developed sepsis.

IABP = intraaortic balloon pump; VT = ventricular tachycardia.

Table 3
Multivariate analysis of VT ablation outcomes, in relation to procedure duration, adjusted for baseline covariates

	Unadjusted			Adjusted		
	Odds ratio	95% CI	P value	Odds ratio	95% CI	P value
Acute procedural outcome						
Acute Success	0.99	0.83–1.19	.92	1.13	0.92–1.4	.24
Acute or partial success	0.96	0.74–1.26	.79	0.99	0.73–1.34	.95
Complications						
Hospital mortality	1.6	1.15–2.21	.0051	1.75	1.14–2.68	.0098
Nonlethal post operative complications	1.25	0.97–1.61	.08	1.25	0.96–1.62	.103
Clinical outcomes						
Recurrence at 6 months	1.05	0.88–1.27	.57	1.03	0.83–1.28	.79
Survival at 6 months	0.88	0.69–1.11	.27	1.01	0.74–1.39	.93

Odds ratio for outcome per one hour increase in procedure duration. This model adjusts for the most significant of 13 baseline covariates using a stepdown logistic regression method.
CI = confidence interval.

Table 4A

Multivariate logistic of most significant baseline covariates for hospital mortality, using a stepdown logistic regression method

	Odds ratio	95% CI	p value
VT storm	8.29	1.22–56.42	.03
Ischemic cardiomyopathy	0.07	0.01–0.47	.006
Pressors prior to ablation	10.88	1.28–92.71	.03
Age (per year)	1.09	1.01–1.19	.003
Prior cardiac surgery	5.01	0.95–26.48	.058
Procedure duration (per hour)	1.75	1.14–2.68	.0098

Procedure duration was included as a variable in this analysis.

CI = confidence interval; VT = ventricular tachycardia.

Table 4B

Multivariate logistic of most significant baseline covariates for nonlethal postoperative complications, using a stepdown logistic regression method

	Odds ratio	95% CI	p Value
Ejection fraction (per 1% increase)	0.95	0.9–1.0	.04
Ischemic cardiomyopathy	2.28	0.8–6.3	.11
No. prior failed ablations (per ablation)	1.4	0.98–2.01	.07
Procedure duration (per hour)	1.25	0.96–1.62	.103

Procedure duration was included as a variable in this analysis.

CI = confidence interval.

Table 5

Multivariate analysis of hospital mortality and nonlethal postoperative complications, in relation to intraoperative covariates

Intraoperative variable	Hospital mortality			Nonlethal Postoperative Complications		
	Adjusted odds ratio	95% CI	P value	Adjusted odds ratio	95% CI	P value
Surgical epicardial access	5.50	0.77–39.19	.09	6.38	1.73–23.5	.0053
Mapping site (epi-endo vs one-sided)	3.38	0.63–18.18	.16	1.35	0.5–3.66	.56
Ablation site (epi-endo vs one-sided)	3.32	0.68–16.30	.14	0.74	0.22–2.50	.63
No. of RF lesions (per lesion)	0.99	0.96–1.03	.64	1.01	0.99–1.03	.37
No. of VTs induced (per VT)	0.89	0.62–1.27	.52	1.30	1.03–1.64	.03
No. of cardioversions (per cardioversion)	0.96	0.67–1.36	.80	1.10	0.88–1.38	.39
Intraoperative complications	1.10	0.15–8.34	.92	3.12	0.98–9.89	.054
Intraoperative IABP insertion	13.7	2.35–79.94	.004	2.8	0.72–10.5	.14
Acute success	0.68	0.13–3.59	.65	1.31	0.5–3.43	.59
Acute partial success	0.13	0.03–0.54	.0050	0.55	0.12–2.43	.43

For each intraoperative variable analyzed, this model adjusts for the most significant baseline covariates, using a stepdown logistic regression method.

CI = confidence interval; epi-endo = combined epicardial and endocardial; IABP = intraaortic balloon pump; RF = radio frequency; VT = ventricular tachycardia.

Table 6

Baseline and intraoperative characteristics of 13 patients with hospital deaths

Pt. no.	Age (years)	ICM/ NICM	EF (%)	VT storm	Intraoperative IABP	Surgical epi cardiac access	Intraoperative complication	Acute/partial success	Cause of hospital death
1	75	ICM	28	Yes	No	No	None	Yes	Recurrent VT
2	61	NICM	23	Yes	Yes	No	None	No	Recurrent VT
3	75	NICM	20	Yes	No	No	None	No	Aspiration pneumonia
4	78	ICM	23	Yes	No	No	Pericardial bleeding	Yes	Heart failure
5	55	NICM	35	Yes	No	No	None	Yes	Recurrent VT
6	50	NICM	35	Yes	Yes	Yes	None	No	Recurrent VT
7	65	NICM	21	Yes	Yes	No	None	No	Lung collapse
8	66	NICM	23	Yes	Yes	No	None	Yes	Heart failure
9	86	ICM	14	Yes	No	No	Groin bleeding	Yes	Hypoxic encephalopathy
10	60	NICM	18	Yes	No	Yes	None	No	Recurrent VT
11	71	ICM	28	No	Yes	No	None	No	Voluntary withdrawal of support
12	66	ICM	18	Yes	No	No	None	Yes	Recurrent VT
13	67	NICM	20	No	No	No	None	Yes	Heart failure

Patient 4 developed pericardial bleeding from percutaneous epicardial access.

Patient 9 developed groin bleeding, which required 2 packed red blood cell transfusions and resolved with hemostasis.

EF = ejection fraction; IABP = intraaortic balloon pump; ICM = ischemic cardiomyopathy; NICM = nonischemic cardiomyopathy; VT = ventricular tachycardia.