

Catheter Induced Mechanical Suppression of Outflow-tract Arrhythmias: Incidence, Characteristics, and Significance

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ABSTRACT: **Background:** The incidence, characteristics, and clinical significance of catheter-induced mechanical suppression (trauma) of ventricular arrhythmias originating in the outflow tract (OT) area have not been thoroughly evaluated.

Objectives: To determine these variables among our patient cohort.

Methods: All consecutive patients with right ventricular OT (RVOT) and left ventricular OT (LVOT) arrhythmias ablated at two medical centers from 1998 to 2014 were included. Patients were observed for catheter-induced trauma during ablation procedures. Procedural characteristics, as well as response to catheter-induced trauma and long term follow-up, were recorded.

Results: During 288 ablations of OT arrhythmias in 273 patients (RVOT n=238, LVOT n=50), we identified 8 RVOT cases (3.3%) and 1 LVOT (2%) case with catheter-induced trauma. Four cases of trauma were managed by immediate radiofrequency ablation (RFA), three were ablated after arrhythmia recurrence within a few minutes, and two were ablated after > 30 minutes without arrhythmia recurrence. Patients with catheter-induced trauma had higher rates of repeat ablations compared to patients without: 3/9 (33%) vs. 12/264 (0.45%), $P = 0.009$. The three patients with arrhythmia recurrence were managed differently during the first ablation procedure (immediate RFA, RFA following early recurrence, and delayed RFA). During the repeat procedure of these three patients, no catheter trauma occurred in two, and in one no arrhythmia was observed.

Conclusions: Significant catheter-induced trauma occurred in 3.1% of OT arrhythmias ablations, both at the RVOT and LVOT. Arrhythmia suppression may last > 30 minutes and may interfere with procedural success. The optimal mode of management following trauma is undetermined.

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sure over the underlying tissue may result in a conduction block and transient arrhythmia termination. This phenomenon, which is also termed catheter-induced trauma, has been reported in various arrhythmias and tissues including the conductive system [1,2], atrial tachycardia [3,4], atrial flutter [4] accessory pathways [4-6], atrioventricular nodal reentrant tachycardia [4,7], and ventricular tachycardia (VT) [8,9]. The extent and significance of catheter-induced trauma in the outflow tract (OT) region was only scarcely investigated in one study [10], which was limited to right ventricular OT (RVOT) arrhythmias. In that study, catheter-induced mechanical suppression occurred in 7 out of 18 cases (39%) and all cases were successfully ablated.

The phenomenon of mechanical suppression was suggested as a mapping tool to guide ablation [10]. However, the duration of arrhythmia suppression by mechanical trauma was not previously reported. In cases of prolonged suppression, procedural success may be hampered as activation mapping is no longer feasible. In addition, the extent of catheter trauma was not reported in the left ventricular OT (LVOT) region.

In the present study, we report the prevalence and significance of catheter trauma in the right and left OT areas among patients who underwent electrophysiologic study (EPS) and radiofrequency ablation (RFA) at the Tel Aviv Sourasky Medical Center and Assuta Medical Center.

PATIENTS AND METHODS

The study was approved by the local institutional review board. It included two center cohorts (Sourasky Medical Center and Assuta Medical Center) of all consecutive patients who underwent ablation of premature ventricular complexes (PVC) or VT originating in the OT from 1998 to 2014, at which one of the investigators (BB) was in attendance.

EPS AND RFA PROCEDURES

Obtaining baseline parameters

After obtaining informed consent from patients, we first connected them to a recording system and observed the occurrence and frequency of spontaneous PVC/VT during a several

Catheter ablation has become a standard therapy for a wide range of cardiac arrhythmias with high procedural safety and success. During catheter manipulation, mechanical pres-

minute period. In the case of scarce PVC, isoproterenol was administered and the frequency of arrhythmia was documented during administration and withdrawal of the drug. After that, catheters were placed at the His/RV and also at the right atrium and coronary sinus according to the physician's discretion. The effect of ventricular and atrial pacing on VT inducibility and PVC manifestation was also confirmed at baseline. Mapping was conducted during stable PVC frequency with or without isoproterenol infusion as needed.

Definition of catheter-induced trauma

Trauma was considered to exist when sudden disappearance of stable PVC burden occurred during catheter manipulation in the OT that was not related to delivery of RF energy. In the case of sustained VT, trauma was considered when the VT suddenly stopped and was no longer inducible despite earlier demonstration of reproducible induction.

MAPPING AND ABLATION

Patients were mapped first at the RVOT and at a second stage at the LVOT if necessary. LVOT mapping was done through the retrograde aortic approach. Heparin was administered in cases of left side mapping to maintain an activated clotting time (ACT) \geq 250 seconds. Coronary angiography was obtained during the procedure in some patients. Activation mapping was the primary mapping mode and pace mapping was also applied.

RF energy was delivered through either standard 4 mm tip ablation catheters (maximal temperature 55°C) or an irrigated catheter using power of 25–45 watts. In all trauma cases, we used 7-French EPT (Boston Scientific, Boston, MA, USA) catheters without 3D mapping systems.

In case of catheter-induced trauma, the location of the trauma was marked fluoroscopically. Catheter manipulation was stopped immediately and pace mapping from the site of trauma was performed and matched to the spontaneous PVC/VT. If the ablation catheter had not moved from the presumed site of trauma, a single pulse of radiofrequency energy was delivered (immediate RFA). However, whenever the ablation catheter had moved from the site of trauma, a more expectant attitude was observed. Ablation from the site of trauma was preferably performed after re-initiation of the arrhythmia (RFA following early recurrence). In cases of no re-initiation after 30 minutes of waiting, RF energy was delivered at the presumed site of trauma (delayed RFA).

Ablation was considered successful if no clinical arrhythmia occurred or was induced despite isoproterenol administration and withdrawal, during a waiting period of 30 minutes. Patients were observed with continuous electrocardiography (ECG) monitoring for 24 hours after the procedure and were seen again 3 months after the procedure with the results of 24 hours of Holter monitoring. Thereafter, patients were followed

annually or biannually at the outpatient clinic with the results of new 24-hour Holter monitoring.

CONTROL GROUP FOR ANALYZING TRAUMA LOCATION IN THE RVOT AND TIMING OF LOCAL EGM TO QRS

Since this data was not available for the entire cohort of patients who underwent RVOT ablation, we included as controls for this specific analysis the 3 consecutive patients of the same gender (after the patient who had catheter-induced trauma).

STATISTICAL ANALYSIS

Continuous variables were presented as mean \pm standard deviation and categorical variables were presented as number of patients and percentages. The Student *t*-test and chi-square analyses were used for analyzing continuous and categorical variables, respectively. For all statistical analyses, *P* value $<$ 0.05 was considered statistically significant. Statistical analyses were performed using Statistical Package for the Social Sciences software version (SPSS Inc., Chicago, IL, USA).

RESULTS

PATIENT POPULATION

Overall, 238 ablations of RVOT arrhythmia (in 223 patients) and 50 ablations of LVOT arrhythmias (in 50 patients) were performed at the Tel Aviv Medical Center and the Assuta Medical Center between 1998 and 2014. During these ablation procedures, we identified 8 cases (3.3%) with catheter-induced trauma in the RVOT and 1 (2%) in the LVOT ($P = 1$), [Figure 1, Figure 2, Table 1].

COMPARISON OF PATIENTS WITH OR WITHOUT CATHETER-INDUCED TRAUMA

Of the eight patients with RVOT arrhythmias who exhibited trauma, three (37.5%) underwent two ablation procedures compared to 12 in the control group (12/215, 0.6%; $P = 0.01$). The higher percentage of redo procedures among patients with catheter-induced trauma remained significant also after including the LVOT ablation procedures (3/9, 33% compared to 12/264, 0.45%; $P = 0.009$).

Patient gender and age were not different in patients with or without catheter-induced trauma [Table 2].

Trauma location in the RVOT and timing of local EGM to QRS at the site of ablation were not different between patients with catheter-induced trauma and the control group of 24 patients (selected as described in the methods section).

The site of ablation in the control group was the anteroseptal RVOT in 12 patients, the midseptal RVOT in 9, and the posteroseptal RVOT in 3 compared to 5 anteroseptal RVOT, 2 midseptal RVOT, and 1 posterolateral RVOT in the catheter-induced trauma group ($P = 0.09$). Local EGM-to-QRS time was 30.8 ± 7.5 msec in the trauma group compared to 30.6 ± 7.5 msec

Figure 1. An example of a patient with catheter induced mechanical suppression of PVC originating from the anteroseptal RVOT this patient underwent ablation in our laboratory and did not belong to the study cohort, but we used this case because it is very demonstrative for teaching purposes. **[A]** Electrogram recorded from the ablation catheter just before the trauma occurred (paper speed 100 mm/s), **[B] [C]** CARTO images of the right ventricle and catheter location (white arrow) at the time of trauma (B-RAO, C-LAO)m, PVC burden before **[D]** and just after **[E]** trauma (paper speed 13 mm/s). The arrow denotes the time of trauma. The mechanical suppression of PVC in this patient persisted for more than 30 minutes and recurrence of PVC was seen the following day

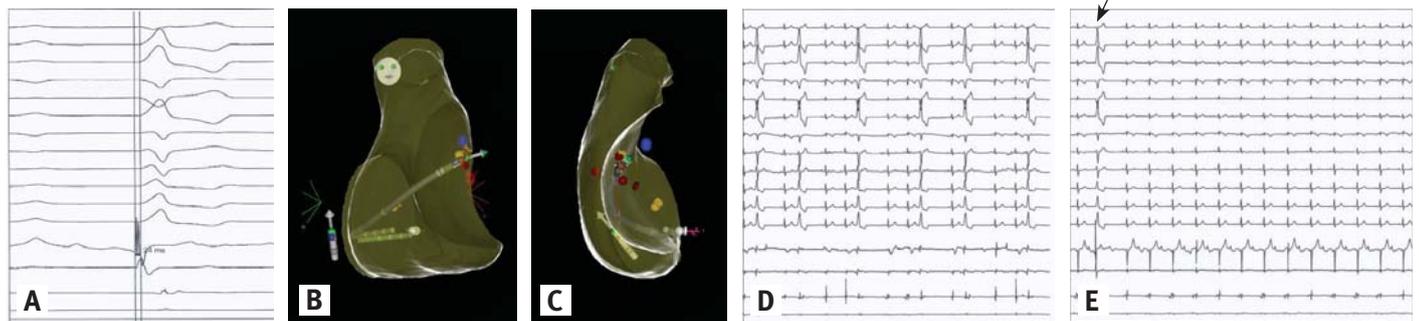


Figure 2. An example of a patient with catheter induced mechanical suppression of PVC originating from the LVOT. **[A]** Baseline bigeminy is shown, **[B]** Electrogram recorded from the ablation catheter just before the trauma occurred (paper speed 100 mm/s), **[C]** Fluoroscopy of the ablation catheter location at the time of trauma



Table 1. Clinical and procedural characteristics of patients with catheter-induced arrhythmia suppression

Patient	Age	Gender	Clinical arrhythmia	Arrhythmia during EPS	Trauma location	PM at trauma location	Pre-QRS**	Response to trauma	Recurrence
1	60	Male	PVC	Trigeminy	RVOT midseptal	11	32	Delayed RFA*	No
2	56	Female	VT	Long VT episode on Isuprel	RVOT midseptal	10	unknown	Immediate RFA	Yes
3	40	Female	VT	Couplets	RVOT anteroseptal	12	30	Early recurrence with RFA	No
4	53	Male	PVC	Bigeminy	RVOT anteroseptal	12	25	Immediate RFA	No
5	60	Male	VT	Incessant VT	RVOT anteroseptal	12	21	Delayed RFA	Yes
6	76	Female	PVC	PVC	RVOT anteroseptal	11	28	Immediate RFA	No
7	51	Female	PVC	Bigeminy on Isuprel	RVOT anteroseptal	Not performed	44	Immediate RFA	No
8	48	Female	PVC	Bigeminy	RVOT posterolat	Not performed	37	Early recurrence with RFA	Yes
9	35	Male	LVOT PVC	Bigeminy	LVOT-LCC-RCC	Not performed	35	Early recurrence with RFA	No

EPS = electrophysiologic study, Isuprel = Isoproterenol, lat = lateral, LCC = left coronary cusp, LVOT = left ventricular outflow tract, PM = pace map (the numbers below represents PM accuracy out of 12 leads), PVC = premature ventricular contraction, RCC = right coronary cusp, RFA = radiofrequency ablation, RVOT = right ventricular outflow tract, VT = ventricular tachycardia

*Had 2 episodes of catheter induced trauma during the same procedure of 10 minutes and more than 30 minutes

**Measured in milliseconds

Table 2. Comparison of patients with and without catheter-induced arrhythmia suppression

	Catheter-induced trauma (n=9)	No catheter-induced trauma (n=264)	P value
LVOT, RVOT	1, 8	49, 215	1
Redo procedures	3 (33%)	12 (0.45%)	0.009
Age, years	48.9 ± 14.9	53.2 ± 12	0.4
Females	5 (55%)	142 (54%)	1

LVOT=left ventricular outflow tract, RVOT=right ventricular outflow tract

in the control group ($P = 0.94$). Patient age was 55.5 ± 10.6 years in the trauma group compared to 46.8 ± 12.7 years in the control group ($P = 0.09$).

ACUTE MANAGEMENT OF CATHETER-INDUCED TRAUMA

Trauma-induced termination of VT without recurrence during the procedure was followed by RFA at the trauma area, whether immediate or delayed. In four cases, immediate RFA was delivered before resumption of PVC/VT. In two cases, after waiting periods of 40 and 30 minutes without recurrence, delayed RF was delivered at the site of catheter-induced trauma. Of note in patient #1, 10 minutes after catheter-induced trauma, PVC resumed; however, shortly thereafter we noticed a second catheter-induced trauma and after 30 minute without resumption of PVC, an empiric RF was delivered [Table 1]. Finally, in three cases (33%), two in the RVOT and one in the LVOT, VT or PVC spontaneously recurred in less than 10 minutes and were successfully ablated.

FOLLOW-UP

During long-term follow-up of 61 ± 75 months, three patients had recurrence of their arrhythmia. Of note, the response to trauma was different in these patients (immediate ablation, early recurrence with subsequent ablation, and delayed ablation, in one patient each). All three patients underwent redo-ablation. In one patient, the arrhythmia was absent and could not be induced and in the other two, trauma did not recur and the arrhythmia was successfully ablated.

DISCUSSION

To the best of our knowledge, the present study is the first to report on the occurrence of catheter-induced trauma in the RVOT as well as the LVOT regions in a large patient cohort. It demonstrates that catheter-induced trauma can result in temporary arrhythmia suppression, and, in a sizeable percentage of cases may suppress the arrhythmia for a prolonged period (> 30 minutes). This occurrence may hamper further arrhythmia mapping and successful ablation.

Kühne and colleagues [10] described a series of 7 patients out of a total of 18 patients (39%) with catheter-induced

mechanical suppression of RVOT related arrhythmias. When comparing patients with and without catheter-induced trauma they showed earlier activation time and a smaller 10 ms isochronal area in those with trauma. Also, ablation was successful in all patients and thus, this phenomenon was suggested as a mapping tool. Our study demonstrates other aspects of catheter-induced trauma that were not described before in regard to the OT area. We found a higher percentage of redo procedures in patients with trauma. In addition, the duration of trauma, which was not described before, may be prolonged. Therefore, as trauma may happen during catheter manipulation, the exact location of the trauma may be unknown. If trauma persists for a prolonged period, only empirical ablation lesions may be delivered at the presumed trauma site. This RFA may prove to be unsuccessful. The higher percentage of redo procedures in our cohort is probably a reflection of the high recurrence rate (37.5% of RVOT trauma-related cases in our series) as compared to the literature [10,11]. It apparently also reflects the consideration of the treating physician that a redo procedure is likely to be successful as the location of arrhythmia origin is suspected based on trauma location.

Compared to the report by Kühne and colleagues [10], we found a lower incidence (3.1%) of catheter-induced trauma. A possible explanation may be related to the strict definition of trauma in the current study. Since the frequency of PVC may change spontaneously in many cases during the procedure without any relationship to catheter manipulation, only cases with clear trauma were included. As all procedures were conducted with at least two electrophysiologists, with one of them strictly focused on the EGMs, the possibility of missed trauma episodes is unlikely. Nevertheless, Kühne et al. [10] described a different phenomenon of very short catheter-induced suppression, even 1 beat, which may aid in arrhythmia mapping.

In accordance with Kühne and collaborators [10], the location of trauma was equally distributed within the various RVOT areas between patients with and without catheter-induced trauma, thus a prone location for trauma was not found. In addition, we did not find earlier activation times in sites of catheter-induced trauma compared to successful ablation sites without trauma. Finally, to the best of our knowledge, we report for the first time a case of catheter-induced trauma in the LVOT. The frequency of RVOT versus LVOT trauma was equal in the present study; however, it should be remembered that we describe only one case of trauma in the LVOT and any possible difference in frequency of trauma between the left and right OT areas should be assessed in larger studies.

CLINICAL IMPLICATIONS

The phenomenon of catheter-induced trauma is well described in the literature, both as a mapping tool and also as a reason for failed procedures [5,8,10]. In the current study, trauma was

associated with higher incidence of procedural failures. Since we had recurrences with both early and delayed RF applications, the optimal response for catheter-induced trauma is not known. Immediate application of RF is empiric, but waiting until the arrhythmia recurs may result in catheter movement. Precisely relocating the ablation catheter may be difficult to achieve even when using 3D mapping systems. Our present policy is to wait for a few minutes before delivering empiric RF. Nevertheless, in cases when catheter manipulation toward the area of trauma is difficult and stability is marginal, immediate RF application may be desired.

LIMITATIONS

The study is retrospective and describes only cases with unequivocal significant change of arrhythmia frequency. A minor degree of trauma may thus be under reported. However, since arrhythmia frequency may change spontaneously during the procedure, we preferred to include only definitive cases. Another limitation is related to the lack of use of 3D mapping system in many patients. In addition, data related to the number of patients without trauma in whom we used 3D mapping system were not collected. Therefore, whether better ablation results could have been obtained with these systems is unknown.

CONCLUSIONS

Catheter-induced mechanical trauma can occur in the RVOT as well in the LVOT areas. The duration of arrhythmia suppression may be long, hampering procedural success. Awareness of this phenomenon and immediate tagging the area for RF may result in procedural success.

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Capsule

Dysbiotic subgingival microbial communities in periodontally healthy patients with rheumatoid arthritis

Studies that demonstrate an association between rheumatoid arthritis (RA) and dysbiotic oral microbiomes are often confounded by the presence of extensive periodontitis in these individuals. **Lopez-Olivia** and colleagues investigated the role of RA in modulating the periodontal microbiome by comparing periodontally healthy individuals with RA to those without RA. Subgingival plaque was collected from periodontally healthy individuals (22 with RA and 19 without RA), and the 16S gene was sequenced on an Illumina MiSeq platform. Bacterial biodiversity and co-occurrence patterns were examined using the QIIME and PhyloToAST pipelines. The subgingival microbiomes differed significantly between patients with RA and controls based on both community membership and the abundance of lineages, with 41.9% of the community differing in abundance and 19% in member-

ship. In contrast to the sparse and predominantly congeneric co-occurrence networks seen in controls, RA patients revealed a highly connected grid containing a large intergeneric hubanchored by known periodontal pathogens. Predictive metagenomic analysis demonstrated that arachidonic acid and ester lipid metabolism pathways might partly explain the robustness of this clustering. As expected from a periodontally healthy cohort, *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* were not significantly different between groups; however, *Cryptobacterium curtum*, another organism capable of producing large amounts of citrulline, emerged as a robust discriminant of the microbiome in individuals with RA.

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