Totally Thoracoscopic Ablation for Atrial Fibrillation: All-Box Clamping

A Study from the German Cardiosurgical Atrial Fibrillation Registry

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Abstract

Background Epicardial surgical ablation is an effective strategy to treat non-paroxysmal forms of atrial fibrillation. Current thoracoscopic epicardial surgical strategies are complex, and are therefore often avoided. With slight modifications to the thoracoscopic maze procedure, totally thoracoscopic all-box clamping may facilitate the performance of epicardial thoracoscopic ablation, while maintaining good results.

Methods Between December 2023 and December 2024, 42 patients underwent thoracoscopic all-box clamping at a single center. All-box clamping uses commercially available bipolar radiofrequency clamps for isolation of the ipsilateral pulmonary veins and posterior left atrial wall through right and then left-sided thoracoscopic access. The left atrial appendage is occluded using a clip device, and the ligament of Marshall is transected. Assessment of a bidirectional block confirmed electrical isolation. Data from the CASE-AF registry were analyzed retrospectively. Short-term results pertaining to efficacy and safety are provided.

Results All-box clamping was successfully offered to all patients by three surgeons. There were no reported major or minor complications. The median hospital stay was 6 days (interquartile range 5–6). At discharge, a sinus rhythm was observed in 92.9%, and in 76.1% of patients off any class I/III antiarrhythmic drugs.

Conclusion Surgical ablation with a modified thoracoscopic technique is safe and feasible for the treatment of atrial fibrillation.

Keywords
- arrhythmia surgery
- minimally invasive surgery
- cardiac catheterization

Introduction

Enthusiasm regarding recently published data from randomized control trials regarding the efficacy of a hybrid endocardial–epicardial approach for the treatment of persistent and long-standing persistent atrial fibrillation (AF) has garnered momentum in favor of a hybrid approach across the electrophysiological and surgical community.[1–3]

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Pison et al originally described the details of a one-step hybrid ablation in 2012.[4] Ultimately, through a hybrid approach, a right and left atrial lesion set can be completed without a sternotomy or the need for cardiopulmonary bypass. In a single-center study, a one-stage hybrid ablation procedure for persistent atrial fibrillation (persAF) reported freedom from atrial tachyarrhythmias (ATA) off antiarrhythmic drugs (AADs) at 3 years follow-up at 79%.[5]

The rationale of a hybrid approach is to modify the complex left atrial substrate and critical mass associated with persistent forms of AF initially through thoracoscopic epicardial ablation and left atrial appendage occlusion. Thereafter, during endocardial catheter ablation (CA), not only is the transmurality of linear lesions verified, but also identified remaining gaps are touched-up.

Surgical epicardial totally thoracoscopic (TT) ablation has already been tried and tested. The results for the treatment persAF are good, and the safety profile is superlative.[6–8] Nonetheless, concern regarding the technical complexity of the procedure persists within the surgical community. Totally thoracoscopic all-box clamping (TT-ABC) has been modified to simplify the TT-maze procedure. This approach utilizes CE-certified ablative devices designed for thoracoscopic ablation. The purpose of this study was to demonstrate our approach and present the in-hospital safety and feasibility profile of the TT-ABC procedure.

Methods

Study Design

This is a single-center, retrospective, observational subgroup analysis of data from the German Cardiosurgical Atrial Fibrillation Ablation (CASE-AF) registry. The CASE-AF registry was recently introduced.[9] The study was approved by the local ethics committee.

Participants

The study included patients presenting with symptomatic long-standing persistent atrial fibrillation (LSPAF) or persAF refractory to class I or III AADs and/or previous catheter ablations. The definition of LSPAF (AF continuous for >12 months with a rhythm control strategy) and persAF (sustained AF for >7 days, including episodes after ≥7 days terminated by electrical or pharmacological cardioversion) were adopted from the European Society of Cardiology/European Association for Cardio-Thoracic Surgery (ESC/EACTS).[10] Our study included patients enrolled in the German CASE-AF registry undergoing stand-alone ablation treated by thoracoscopic bipolar radiofrequency ablation using all-box clamping at our center. All participating subjects provided written informed consent. After the blanking period, and at 1-year follow-up (currently ongoing), 24-hour electrocardiogram Holter monitoring will be used to assess patient rhythm.

Ablation Devices

Clamps and instruments used for the TT-ABC procedure were provided by AtriCure, Inc. and already hold CE certification. For left- and right-sided ablation, Isolater Synergy EML2 and EMR2 bipolar biparietal radiofrequency clamps, respectively, are used. Epicardial mapping of the pulmonary veins was performed with an Isolator Transpolar Pen in all patients who had underwent previous catheter-based ablative procedures, and to later test for bidirectional block. Left atrial appendage (LAA) occlusion was achieved with AtriClip® PRO2 Device.

Procedure

The goal of thoracoscopic all-box clamping is the simultaneous isolation of the ipsilateral pulmonary veins and posterior left atrial wall through left and then right-sided thoracoscopic access to create a box-lesion using bipolar radiofrequency clamps (►**Fig. 1**). AF trigger sites, such as the left atrial appendage and the ligament of Marshall, are additionally managed.

The procedure was performed in the supine position under general anesthesia with double lumen endotracheal intubation. A transesophageal echo initially ruled out the presence of a LAA thrombus and later confirmed successful left atrial appendage occlusion.

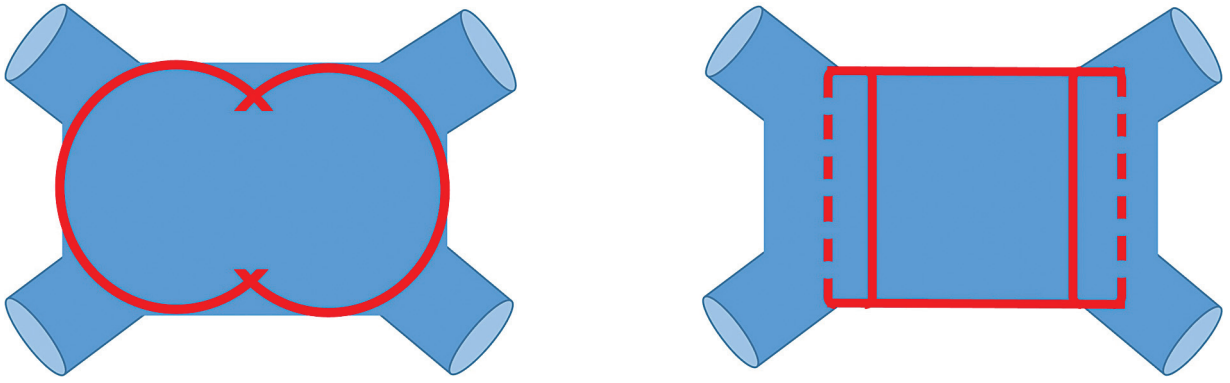

Fig. 1 Schematic representation illustrating the lesion concept during totally thoracoscopic all-box clamping (left), and thoracoscopic maze procedure (right). During a maze procedure, the roof and floor line are created with uniparietal bipolar radiofrequency instruments, whereas during all-box clamping, biparietal bipolar radiofrequency clamps are solely used. Dotted lines indicate ablation lesions created by the distal jaw clamp to the posterior left atrial surface.

Thoracoscopic access to the right hemithorax was similar to that of the conventional TT-maze procedure, and in the 4th intercostal space (ICS) anterior axillary line (AAL), a port was introduced and carbon dioxide was insufflated. In the 3rd intercostal space, *also at the anterior axillary line*, and in the 5th ICS in the mid-axillary line, two working ports were introduced, respectively (►**Fig. 2**). The medial orientation of the 3rd ICS working port later allowed for better maneuvering of the respective ablation clamp to the desired position. The pericardium was opened 3 cm above the phrenic nerve. Underneath the superior vena cava, the transverse sinus was bluntly dissected, and the entire left atrial roof was dissected from connective tissue, until the left atrial appendage was visualized. Through the oblique sinus, the glidepath tape guide, provided with isolator synergy clamps, was advanced and positioned toward the left atrial appendage. At this stage, the surgeon changed position to the left side, the right lung was ventilated and the left lung collapsed.

Thoracoscopic access to left hemithorax began in the 4th ICS AAL. A working port in the 3rd ICS AAL was also introduced similarly to later simplify maneuvering of the ablation clamp. The pericardium was incised 2 cm below the phrenic nerve. The ligament of Marshall was transected, the glidepath tape guide was located and connected to the attachment tip of the EML2 ablation clamp. The clamp was then inserted through the incision at the 3rd ICS. With gentle traction on the tape, the distal jaw of the EML2 ablation clamp was advanced beneath the left inferior pulmonary vein and maneuvered to the left atrial roof, maintaining a 1-cm distance from the pulmonary veins. When the proximal jaw of the clamp was visualized over the border of the left atrial roof, the clamp was closed and ablation commenced. Ablative cycles were completed in accordance with the instructions for use for clamps, and as such, three ablative cycles—each cycle consisting of two radiofrequency applications—were performed. Transmurality of lesions was confirmed by internal device algorithms measuring tissue conductance and impedance. Transmurality was indicated when conductance decay ceased within <5 seconds. Left-sided ablation was then completed after occlusion of the LAA with a clip. Finally, the glidepath tape guide was advanced toward the oblique sinus, a pleural drain was inserted, the left lung was ventilated, and the right lung collapsed. The surgeon commenced with right-sided ablation in a similar manner. A video demonstrating relevant steps of the TT-ABC procedure is available (►**Video 1**, available in the online version).

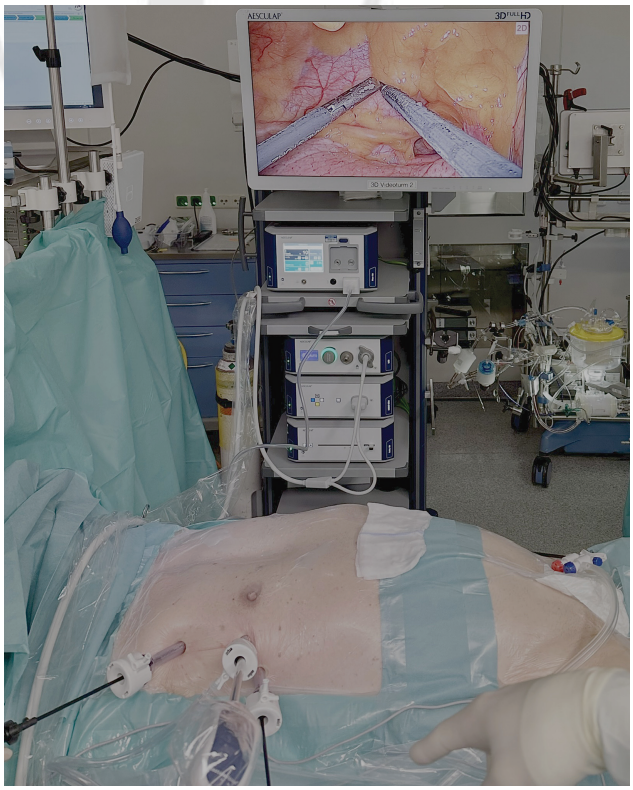

Fig. 2 Port placement access during totally thoracoscopic all-box clamping.

Video 1

The totally thoracoscopic all-box clamping procedure. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/a-2625-9617.

Endpoint Definitions

The primary efficacy endpoint was defined as freedom from documented atrial tachyarrhythmias (episodes lasting >30 seconds) without class I and class III AADs, the need for electrical cardioversion after discharge, redo-ablation, or hospitalization due to AF, and began after the 3-month blanking period throughout the 1-year follow-up period. Patients with recurrent ATAs after the blanking period will be offered CA to verify lesions, identify and re-ablate gaps ("touch-up"). Arrythmias reoccurring within the blanking period were treated with chemical or electrical cardioversion and were not considered as failure.

The primary safety endpoint were major adverse events at any period during or after thoracoscopic ablation. This was defined as freedom from death, coronary and cerebrovascular events, phrenic nerve paralysis, atrio-esophageal fistula, pneumothorax, hemothorax, blood transfusion of >2 units of packed red blood cells, high-grade atrioventricular block, new cardiac implantable electronic device, ventilation for >24 hours, renal failure, wound infection, and septicemia.

Data Analysis

The data was analyzed as per protocol definitions originally described.[9] Data editing and examination were performed by a dedicated staff of independent statisticians at the IHF (Stiftung Institut für Herzinfarktforschung) in Ludwigshafen/Rhein, Germany. Continuous variables are presented as mean

± standard deviation or as median with quartiles. Categorical variables are reported as numbers and percentages. All analyses were performed using SAS© software, version 9.4 (Cary, USA).

Results

From December 2023 and August 2024, 42 patients underwent thoracoscopic all-box clamping at our center. Patient demographic data are presented in ►**Table 1**.

A total of three trained surgeons performed all 42 procedures. All-box clamping, LAA occlusion with an epicardial clip (AtriClip PRO2, AtriCure, Inc.), and dissection of the ligament of Marshall were completed in all 42 patients (100%). No additional left or right atrial ablation lesions were performed. Intraoperative transesophageal echocardiography confirmed complete occlusion of the left atrial appendage at its base, with no residual stump and no detectable flow between the left atrium and the appendage. Using an Isolator Transpolar Pen (Atricure, Inc.)—capable of

Table 1 Patient clinical characteristics

Parameter, $n = 42$			
Age (years) mean ± SD			63.1 ± 10.1
Female, (%) *n*			28.6% (12)
Body Mass Index (kg/m^2), mean ± SD			28.6 ± 6.3
Atrial fibrillation classification, (%) *n*			
	Paroxysmal		21.4% (9)
	Persistent		66.7% (28)
	Long-standing persistent		11.9% (5)
History of, (%) *n*			
	Congestive heart failure		0%
	Hypertension		61.9% (26)
	Diabetes mellitus		21.4% (9)
	Stroke/thromboembolism		14.2% (6)
	Vascular disease		7.1% (3)
Arrhythmia refractory to:			
	Antiarrhythmic drugs (%) *n*		57.1% (24)
	Catheter pulmonary vein isolation (%) *n*		78.6% (33)
		Mean attempts ± SD	2 ± 1
CHA_2DS2-VASc Score, mean ± SD			2.5 ± 1.5
mEHRA Class, (%) *n*			
	I–IIa		4.8% (2)
	IIb–IV		95.2% (40)
NYHA Class, *n* (%)			
	I		0%
	II		61.9% (26)
	III		38.1% (16)
	IV		0%
Left atrium size (mm)			
	Mean ± SD		42 ± 5
	>45		26.2% (11)
LVEF (%) mean ± SD			52 ± 9
Medication at baseline, (%) *n*			
	Antiarrhythmic drugs (Class I/III)		23.8% (10)
	DOAK		90.5% (40)
EuroSCORE II (%)			1.9 ± 2.2

Abbreviations: DOAK, direct oral anticoagulant; LVEF, left ventricular ejection fraction; mEHRA, modified European Heart Association score; NYHA, New York Heart Association score.

Table 2 In-hospital complications

Major complications	0%	(0/42)
Atrio-esophageal fistula	0/42	
Bleeding (requiring blood transfusions)	0/42	
Cardiac vascular trauma	0/42	
Coronary artery occlusion	0/42	
Death	0/42	
Hemothorax	0/42	
Low cardiac output	0/42	
Myocardial infarction	0/42	
New cardiac implantable electronic device	0/42	
Pericardial effusions/Tamponade	0/42	
Pericarditis	0/42	
Phrenic nerve palsy	0/42	
Pneumothorax	0/42	
Prolonged intubation (>24 hours)	0/42	
Pulmonary emboli	0/42	
Pulmonary vein trauma	0/42	
Renal failure	0/42	
Respiratory insufficiency	0/42	
Septicemia	0/42	
Stroke/transient ischemic attack	0/42	
Wound infection	0/42	

pacing, sensing, and ablating—bidirectional block was confirmed in all previously ablated CA patients for pulmonary vein isolation and for the posterior left atrial wall box.

In 33 (78.6%) patients who had undergone at least two previous failed endocardial ablation attempts, intraoperative epicardial electrophysiological mapping with an Isolator Transpolar Pen (AtriCure, Inc.) revealed recovery within the wide antral circumferential ablation (WACA) set of one pulmonary vein in three patients (9%), two veins in five patients (15%), and more than two veins in 25 patients (76%). The right pulmonary veins showed recovery in nearly all of these cases ($n = 31$).

The total mean procedure time was 98.8 ± 21.2 minutes. The mean ablating time was 13.4 ± 3.6 minutes. The intraoperative course was uneventful and as such, no patients required conversion to a minimally invasive approach or use of cardiopulmonary bypass. All patients left the operating theater in a sinus rhythm.

The primary safety endpoint was not reported in any patient (►**Table 2**). There were no in-hospital complications including death, coronary and cerebrovascular events, phrenic nerve paralysis, atrio-esophageal fistula, pneumothorax, hemothorax, blood transfusion of >2 units of packed red blood cells, high-grade atrioventricular block, new cardiac implantable electronic device, ventilation for >24 hours, renal failure, wound infection, or septicemia.

At discharge, freedom from ATAs regardless of AADs was 92.9%, and freedom from ATAs off class I/III AAD was 76.1%. Within the postoperative in-hospital convalescence period, 10 patients required an electrical cardioversion; the same 10 patients were discharged on AADs. The median post-procedural hospital stay was 6 days (minimum 5 days, maximum 6 days).

A 1-year follow-up study is currently ongoing, and a detailed report will be presented after completion.

Discussion

This study systematically describes the procedural and in-hospital outcomes of totally thoracoscopic all-box clamping. Overall, the in-hospital efficacy of TT-ABC was good, there were no reported deaths, and morbidity was negligible.

For the management of paroxysmal AF, CA to isolate the PV provides excellent results.[11] However, the durability of lesion sets remains questionable, as after initial successful pulmonary vein isolation (PVI), recurrences of AF are reported to reach 50%.[12,13] With disease progression and further expansion of the left atrial substrate, success of a single CA procedure for persAF/LSPAF—reported from a systematic review—was 43%.[14] Principles such as endocardial–epicardial dissociation, epicardial breakthrough, extrapulmonary triggers,[15] and heterogenous discordant wavefront patterns, seen in chronic diseased fibrillating atria, make non-paroxysmal AF difficult to treat with CA.[16] Addition of posterior wall isolation during CA does not necessarily improve freedom from ATA[17]; conversely, if lesions are not transmural, or if PV recovery is seen, a pro-arrhythmogenic state may even be favored.[18] To date, even novel ablating energy sources, such as pulsed field ablation, still do not offer significant advantages to treat PAF over traditional ablative energy sources.[19] In CASA-AF, which randomized patients with LSPAF into a CA arm and surgical thoracoscopic arm, the single-procedure freedom from ATAs (≥30 seconds) at 1-year off AADs was 28 and 26%, respectively.[20] Hybrid ablation combines the advantages of epicardial thoracoscopic ablation and endocardial CA, while cancelling out procedural specific limitations.

To date, there exist two RCTs favoring a thoracoscopic epicardial–endocardial hybrid procedure over CA for the management of PAF and LSPAF, each of which approach hybrid ablation (HA) with a slightly different strategy, while still proving superior to catheter ablation alone. In HART-CAP, one-stage hybrid ablation demonstrated a significantly higher freedom of atrial tachyarrhythmias off AADs at 1 year than single CA alone (89% vs. 41%, $p = 0.002$). In this trial, hybrid procedures began with surgical ablation via an epicardial thoracoscopic approach (TT-Maze) and were followed by catheter ablation in the same setting.[2] In CEASE-AF, the largest of the three, HA was carried out as a two-stage procedure. At least 6 months after surgical epicardial thoracoscopic ablation (TT-Maze), patients underwent CA to verify transmurality of the ablation lines, and

if necessary, touch-up procedures were carried out. In comparison to repeat CA, hybrid ablation offered a significant freedom of ATA off AADs at 1 year (71.6% vs. 39.2%, $p < 0.001$).[3] In the latter two studies, non-PV triggers of AF, namely, left atrial appendage and the ligament of Marshall, were also isolated. Although the efficacy of a hybrid endocardial–epicardial approach was continuously superior to repeat endocardial CA alone, its integration in daily practice exposes weaknesses in current healthcare standards across Germany. Sequential hybrid ablation stipulates that a cardiac surgeon *first* intervene *followed* by mandatory electrophysiological management, even in asymptomatic patients with a documented sinus rhythm. As made evident through this registry, in Germany, thoracoscopic ablation is only offered as an *ultima ratio* alternative after at least two failed CA and just before a pace-and-ablate strategy. To mitigate this problem, it is recommended that the surgical community show more presence in this field and gain skills in thoracoscopic ablation. Current European guidelines have upgraded hybrid procedures to Class IIa/Level of Evidence A status.[11]

Study Limitations

The results of our single-center experience cannot be generalized across other centers. The surgeons performing thoracoscopic ablation have gathered substantial experience and work in a devoted AF team including specialized electrophysiologists. This limits the external validity of our performance. Nonetheless, this should serve as an example to encourage the development of AF teams consisting of electrophysiologists and cardiac surgeons to tackle AF in such a manner. Currently, there are six centers in Germany offering thoracoscopic ablation. Another limitation of the study is the lack of propensity score matched study to estimate differences between both techniques.

Conclusion

Totally thoracoscopic all-box clamping is a safe and feasible alternative to current thoracoscopic ablation techniques. A follow-up study to confirm these finding is ongoing. A multicenter experience is necessary.

Authors' Contribution

Study design: N.D., G.M., C.P., T.H., J.S., and M.W.; Data acquisition: N.D., A.D., G.H., G.M., C.P., T.H., T.O., and M.W.; data analysis and interpretation: A.D., G.H., T.O., J.S., and M.W.; manuscript drafting: A.D., G.H., J.S., and M.W.; statistical analysis: T.O. and M.W.; critical revision: N.D., G.M., C.P., J.S., and T.H.; accountability: N.D., A.D., G.H., G.M., C.P., T.H., T.O., J.S., and M.W.

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Conflict of Interest

N.D., T.H., and G.H. are proctors for AtriCure®, Inc. M.W. has received lecture honoraria from AtriCure®, Inc.

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