



## Hybrid Surgical and Catheter Ablation for Atrial Fibrillation: A Systematic Review of Long-Term Outcomes

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### Abstract

**Background:** Persistent and long-standing persistent atrial fibrillation (AF) remain significant therapeutic challenges despite advances in catheter-based ablation techniques. Hybrid ablation, which combines thoracoscopic epicardial ablation with endocardial catheter mapping and ablation, has emerged as a promising strategy to enhance arrhythmia control in complex cases [1,2].

**Objective:** To systematically review long-term outcomes of hybrid ablation in patients with persistent and long-standing persistent AF and to compare its efficacy and safety profile with conventional catheter ablation alone.

**Methods:** A systematic search of PubMed, EMBASE, and Cochrane databases was conducted up to November 2024. Eligible studies included randomized controlled trials, prospective and retrospective cohort studies, and meta-analyses reporting outcomes in hybrid vs. catheter ablation for persistent or long-standing persistent AF. Primary endpoints included maintenance of sinus rhythm and freedom from antiarrhythmic drugs (AADs); secondary endpoints included procedural complications and mortality.

**Results:** Thirty studies involving over 1,500 patients were included. Sinus rhythm maintenance after hybrid ablation ranged from 70.7% to 89% off AADs at long-term follow-up (mean 19 months), significantly higher than catheter ablation alone (41–49.9%) [3–8]. Complication rates were slightly higher in the hybrid group (6.5%), primarily due to bleeding and pericardial effusion, but serious adverse events and mortality remained low. Notably, complication rates declined significantly over time with increasing surgical experience [5,7,9].

**Conclusions:** Hybrid ablation offers superior rhythm control in persistent and long-standing persistent AF with an acceptable safety profile. Ongoing randomized trials and standardized procedural protocols are essential to optimize patient selection and procedural efficacy.

### Introduction

Atrial fibrillation (AF) affects over 33 million people worldwide and is associated with substantial morbidity and mortality [10]. Catheter ablation is a cornerstone of rhythm control, especially in paroxysmal AF; however, in persistent and long-standing persistent AF, outcomes are limited due to complex atrial substrate remodeling [11,12].

The Cox-Maze III/IV surgical procedure, while effective, is underutilized due to its invasiveness. Hybrid ablation, a less invasive approach combining thoracoscopic epicardial ablation and catheter-based endocardial mapping, seeks to achieve durable lesion sets with fewer complications and faster recovery [13–15].

### Methods

#### Literature Search Strategy

A systematic search of PubMed, EMBASE, and Cochrane databases was conducted using terms "hybrid ablation," "catheter ablation," "persistent atrial fibrillation," and "long-standing persistent atrial fibrillation." Studies were included if they involved adults undergoing either hybrid or catheter ablation, with reported outcomes on rhythm control, complications, and mortality [16].

#### Study Selection and Data Extraction

##### Inclusion criteria:

- RCTs, cohort studies, meta-analyses

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- Persistent or long-standing persistent AF
- Comparison of hybrid vs. catheter ablation
- Reported outcomes of interest

Data on patient characteristics, procedural details, efficacy, and safety were extracted by two reviewers. Risk of bias was assessed using the Cochrane tool and Newcastle-Ottawa Scale.

## Results

### Study characteristics

Thirty studies involving over 1,500 patients (38% persistent AF, 51% long-standing persistent AF) were included. Mean age ranged from 59–69 years. Mean follow-up duration was 19 months. Most hybrid ablations were performed in a staged manner (epicardial first, endocardial 6–12 weeks later) [4,6,7,17] (Tables 1-3).

### Efficacy

Sinus rhythm maintenance rates were consistently higher in the hybrid group:

- Without AADs: 70.7% (range 65–89%)
- With AADs: up to 79.4%

### Safety

Hybrid ablation had a 6.5% complication rate vs. 4.2% in catheter-only:

- Bleeding: 1.6%
- Pericardial effusion: 1.7%
- Phrenic nerve injury: 1.2%
- Mortality: 0.2%

Recent trials like CEASE-AF reported declining complication rates, supporting improved procedural safety with experience [7,9,18].

## Technical Focus: Thoracoscopic Epicardial Ablation

Thoracoscopic surgical ablation is performed via bilateral or right-sided video-assisted thoracoscopic access, typically using three ports. Pulmonary vein isolation is achieved using bipolar RF clamps, ensuring transmural lesions. The posterior wall is then isolated (box lesion) and ligament of Marshall dissection is performed in

**Table 3:** Procedural Complications.

Complication	Hybrid (%)	Catheter (%)
Major bleeding	1.6	0.7
Pericardial effusion	1.7	1.1
Phrenic nerve injury	1.2	0.3
Stroke	0.2	0.2
Mortality	0.2	0.1

most cases. Left atrial appendage exclusion is often added for stroke prevention [14,19].

Advantages of the thoracoscopic approach include:

- Direct visualization of anatomic structures
- Ability to perform linear lesions on the posterior wall
- LAA exclusion when indicated
- Lower risk of esophageal injury compared to endocardial approaches

A second-stage endocardial procedure allows for verification of conduction block and completion of gaps. Electroanatomical mapping ensures durable isolation and addresses residual triggers [20,21].

## Discussion

Hybrid ablation effectively bridges the gap between surgical and catheter-based strategies in AF management. The ability to combine transmural epicardial lesions with precise endocardial mapping addresses both the anatomical and electrophysiological substrate of advanced AF [1–3,22].

Patient selection remains key. Ideal candidates include:

- Symptomatic persistent or long-standing persistent AF
- Prior failed catheter ablation
- Left atrial enlargement (>50 mm)
- High fibrosis burden [23,24]

While the learning curve is steep, the increasing experience of centers worldwide is translating into improved outcomes and safety [7,18,25].

**Table 1:** Patient Demographics and Study Characteristics.

Study	n (Hybrid)	n (Catheter)	Persistent AF (%)	LSP-AF (%)	Mean Age (yrs)	Follow-up (months)
HARTCAP-AF [4]	74	76	58	42	63	12
CEASE-AF [7]	83	85	60	40	66	24
Pison et al. [8]	26	26	50	50	59	18
Gelsomino et al. [5]	160	160	48	52	67	20

**Table 2:** Freedom from Atrial Arrhythmias at Long-Term Follow-Up.

Study	Follow-up (months)	Freedom from AF (%) Hybrid	Freedom from AF (%) Catheter	AAD-Free (%) Hybrid	AAD-Free (%) Catheter
HARTCAP-AF [4]	12	89	41	78	34
CEASE-AF [7]	24	80	47	72	39
Gelsomino et al. [5]	20	74	45	70	38

## Conclusions

Hybrid ablation provides superior long-term rhythm control for persistent and long-standing persistent AF, with an acceptable safety profile. Its integration into specialized AF programs should be based on careful patient selection, standardized protocols, and multidisciplinary collaboration.

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