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POSITION STATEMENT

2023 Cardiac Society of Australia and New Zealand Expert Position Statement on Catheter and Surgical Ablation for Atrial Fibrillation

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Catheter ablation for atrial fibrillation (AF) has increased exponentially in many developed countries, including Australia and New Zealand. This Expert Position Statement on Catheter and Surgical Ablation for Atrial Fibrillation from the Cardiac Society of Australia and New Zealand (CSANZ) recognises healthcare factors, expertise and expenditure relevant to the Australian and New Zealand healthcare environments including considerations of potential implications for First Nations Peoples. The statement is cognisant of international advice but tailored to local conditions and populations, and is intended to be used by electrophysiologists, cardiologists and general physicians across all disciplines caring for patients with AF. They are also intended to provide guidance to healthcare facilities seeking to establish or maintain catheter ablation for AF.

Keywords Atrial fibrillation • Catheter ablation • Surgical ablation • Guidelines

Contents

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Introduction

Rationale for These Guidelines

Atrial fibrillation (AF) is increasing in prevalence in concert with an ageing population which is increasingly becoming overweight and obese. AF is associated with an increase in risk of heart failure, stroke and a doubling in all-cause mortality. It is a leading cause for presentation to emergency departments and hospital admissions. Recent randomised studies have demonstrated a reduction in adverse cardiovascular outcomes with rhythm control where management strategies using medication and catheter ablation are pursued to maintain sinus rhythm [1]. Randomised studies have also demonstrated that catheter ablation is more effective than antiarrhythmic drugs in preventing recurrent AF and healthcare utilisation [2,3]. In patients with AF and heart failure with reduced ejection fraction (HFrEF), catheter ablation is established to improve left ventricular (LV) systolic function and reduce heart failure hospitalisation and mortality compared with medical therapy [4,5]. There is increasing support for first line catheter ablation which has traditionally been reserved for patients who have trialled antiarrhythmic drug therapy [6]. Additionally, with the evolution in ablation and mapping technology the procedure has become more effective and safer [7]. With the advent of electroporation or pulsed field ablation, catheter ablation procedures are likely to become faster and with a shorter learning curve [8]. Patients can often be discharged from hospital the same day and return to work and their community with minimal discomfort or delay [9]. However, catheter ablation is invasive, may need to be repeated and is associated with the potential for serious complications, including death. Catheter ablation for AF has increased exponentially in many developed countries including Australia and New Zealand. The Cardiac Society of Australia and New Zealand (CSANZ) recommended the formulation of local guidelines to recognise healthcare factors, expertise and expenditure relevant to the Australian and New Zealand healthcare environments including considerations of potential implications for First Nations Peoples.

International guidelines on catheter ablation for AF are available but are currently being updated. As expected, there are regional differences in recommendations between guidelines. Guidelines developed by Australian and New Zealand healthcare practitioners and technologists provide an opportunity to inform recommendations cognisant of international advice but tailored to local conditions and populations. They are intended to be used by electrophysiologists, cardiologists and general physicians across all disciplines caring for patients with AF. They are also intended to provide guidance to healthcare facilities seeking to establish or maintain catheter ablation for AF. The present AF ablation guidelines draw, in part, on the *2018 National Heart Foundation of Australia and the Cardiac Society of Australia and New Zealand: Australian Clinical Guidelines for the Diagnosis and Management of Atrial Fibrillation* [10].

The purpose of the document was not to provide a state-of-the art review of catheter and surgical ablation for AF, as this information can be found in current and upcoming international guidelines. A number of the key recommendations were informed by existing international guidelines, including the 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of AF [11] and the 2020 ESC Guidelines for the diagnosis

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and management of AF developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS) [12]. In addition to providing important information for the electrophysiologist performing AF ablation, these guidelines include dedicated sections on the anaesthetic requirements for AF ablation (Section 7), as well as individual and institutional training and competency guidance (Section 10). Categorisation of Clinical Urgency for AF ablation is also addressed (Section 12). Ms Tanya Hall, a consumer advocate, provided insights into patient perspectives to be considered for AF ablation in Appendix A. Professor's Alex Brown and Chris X. Wong provided the section on AF in First Nations People.

The Writing Group comprised 28 people including 19 electrophysiologists, three cardiac technologists, two cardiac anaesthetists, one general physician, one general cardiologist, one cardiac surgeon and a patient advocate. The composition of the writing group included consideration of diversity of gender and geographical regions with inclusion of members from all states of Australia and New Zealand.

In constructing a consensus document, it is recognised that unanimous agreement is not always possible among all the writing group members. Each recommendation was presented to the group with an open discussion before each was systematically balloted by 27 of the 28 writing group members. The patient advocate did not vote on medical recommendations. A minimum of 80% of members were required to approve a recommendation before it was passed. If this level of agreement was not reached, the recommendation could be revised and resubmitted for voting or withdrawn.

Members of the writing and review panels provided declaration of interest forms for all relationships that might be perceived as real or potential sources of conflicts of interest. The declarations of interest were reviewed according to the CSANZ declaration of interest policies to ensure transparency and prevent potential biases. Any changes in declarations of interest that arose during the writing period were notified to the CSANZ and updated. All author and peer reviewer disclosure information is provided in Appendix B. The Writing Group and reviewers received no financial remuneration from CSANZ and there was no involvement from the medical device and pharmaceutical industry. Secretarial and editorial support was provided by CSANZ.

The grading system for indication of class of evidence level was adapted based on that used by the 2020 European Society of Cardiology guidelines [12]. The indications for catheter and surgical ablation of AF are presented with a Class and Level of Evidence. A Class 1 recommendation means that the benefits markedly exceed the risks, and that AF ablation is recommended or indicated; a Class 2A recommendation means that the benefits exceed the risks, and that it should be considered; a Class 2B recommendation means that the benefit is greater or equal to the risks, and that AF ablation may be considered; and a Class 3 recommendation means that AF ablation is of no proven benefit and is not recommended (see Table 1).

The writing group reviewed and ranked evidence supporting current recommendations (see Table 2), with the weight of evidence ranked as Level A, if the data were derived from high-quality evidence from more than one randomised clinical trial, meta-analyses of high-quality randomised clinical trials, or one or more randomised clinical trials corroborated by high-quality registry studies. Level B when there was moderate-quality evidence from one or more randomised clinical trials, or meta-analyses of moderate-quality randomised clinical trials or well-designed, well-executed non-randomised studies or observational studies. This designation was also used to denote moderate-quality evidence from meta-analyses of such studies. Evidence was ranked as Level C when the primary source of the recommendation was randomised or nonrandomised observational or registry studies with limitations of design or execution, meta-analyses of such studies, or physiological or mechanistic studies of human subjects. Level C also included expert opinion based on the clinical experience of the writing group.

Box 1 provides a summary of the recommendations, their class, and the level of evidence in support of each recommendation.

The position statement was reviewed and approved by the Quality Assurance Committee of CSANZ. External review

Table 1 Classes of Recommendations.

	Definition	Wording to use
Class 1	Evidence and/or general agreement that a given treatment or procedure is beneficial, useful or effective.	Is recommended or is indicated
Class 2A	Weight of evidence/opinion is in favour of usefulness/efficacy	Should be considered
Class 2B	Usefulness/efficacy is less well established by evidence/opinion	May be considered
Class 3	Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful	Is not recommended

Source: 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS) [12].

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Table 2 Levels of Evidence.*

Level of Evidence	
A	Data derived from multiple high quality randomised clinical trials or meta-analyses.
B	Data derived from a single randomised clinical trial or large non-randomised studies.
C	Consensus of opinion of the experts and/or small studies, retrospective studies, registries.

*Source: 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS) [12].

Recommendation	Class	Level of Evidence
1.1 Diagnosis of AF requires ECG documentation with absence of discernible repeating P-waves associated with irregular R-R intervals (in the absence of heart block), either through the entirety of a 12 lead ECG or >30 seconds on single lead ECG monitoring.	1	B

was provided by Professor Edward Gerstenfeld, Chief of Electrophysiology at the University of California San Francisco, and Dr Jason Andrade, director of the Electrophysiology Laboratory at Vancouver General Hospital, Canada.

1. Definitions, Mechanisms, and Rationale for AF Ablation

Definition

Atrial Fibrillation is the most prevalent sustained arrhythmia in the community and is characterised by rapid and irregular activation of the atria [11].

AF is diagnosed with a surface electrocardiogram (ECG) or intra-cardiac electrogram recording of complete irregularity of the R-R interval (apart from AF in the setting of complete atrioventricular block) AND an absence of P-waves [11]. The diagnosis would require either AF long enough to be documented through the entirety of a 12-lead ECG, or otherwise AF >30 second duration on a single-lead ECG [12] (Recommendation 1.1).

AF may be defined as paroxysmal, persistent, or permanent [11] (see Table 3). Paroxysmal AF is defined as AF terminating spontaneously or with intervention within 7 days of AF onset. Persistent AF is continuous AF sustained >7 days and can be further identified as early persistent AF (continuous duration 7 days to 3 months) or longstanding persistent AF (>12 months continuous AF). Permanent AF is defined as AF where the presence of AF has been accepted by the patient (and physician) such that further attempts at restoration of sinus rhythm have been abandoned.

Relationship Between Atrial Flutter and AF

Atrial flutter and AF are closely inter-related, and a transitional rhythm of AF may be required to support the initiation of atrial flutter through the establishment of functional block at the crista terminalis in the right atrium [13]. Whereas AF is characterised by disorganised atrial activity with no discernible repeating P-waves [12], typical atrial flutter is an organised macro re-entrant atrial tachycardia with a characteristic sawtooth pattern in the inferior leads of the ECG [14]. Typical atrial flutter is confined to the right atrium, with a circuit bounded anteriorly by the tricuspid annulus and posteriorly by both anatomical and functional barriers. The cycle length is generally 220–250ms, though may be affected by conduction delay secondary to medications, structural heart disease, or prior ablation procedures [14].

Atrial flutter is associated with thromboembolic events such as ischaemic stroke, presence of left atrial (LA) thrombus and spontaneous echo contrast on echocardiographic studies [15]. Consensus guidelines recommend anticoagulation for patients with atrial flutter follow the same principles as for patients with AF [10,12].

In patients undergoing AF ablation who also have documented typical atrial flutter (AFL), addition of cavo-tricuspid isthmus (CTI) ablation to pulmonary vein isolation (PVI) may be considered (Recommendation 1.2). In a randomised controlled trial (RCT) of 108 patients with documented AF and AFL randomised to PVI alone or PVI plus CTI ablation, there was a significant reduction in early recurrence of early atrial flutter in the group with additional CTI ablation. However, there was no significant difference in recurrent atrial arrhythmias of any type between ablation strategies during longer term follow up [16]. In 360 patients with documented AF and AFL randomised to PVI plus CTI ablation versus CTI ablation alone, markedly higher recurrence rates of AF were seen in the group undergoing CTI alone [17].

In patients who have undergone ablation for typical flutter, a systematic review identified new onset AF in 45% of patients when assessed with >7 days Holter monitoring per year or via CIED over follow-up of 15 months post flutter ablation [18]. Although there is a high incidence of AF in patients with atrial flutter, prophylactic PVI is generally not routinely performed in patients without documentation of AF [19].

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Box 1. Summary of Recommendations.*

Recommendation	Class	Level of Evidence
1. Definitions, Mechanisms, and Rationale for AF Ablation		
1.1 Diagnosis of AF requires ECG documentation with absence of discernible repeating P-waves associated with irregular R-R intervals (in the absence of heart block), either through the entirety of a 12-lead ECG or >30 seconds on single lead ECG monitoring.	1	B
1.2 In patients undergoing AF ablation who have a history of documented typical atrial flutter, or atrial flutter identified at time of AF ablation, a cavotricuspid isthmus ablation may be considered.	2B	B
1.3 An early rhythm control strategy, as part of integrated AF management, improves cardiovascular outcomes compared with rate control, particularly when implemented within the first year after diagnosis.	2A	B
2. Modifiable Risk Factors for AF and Impact on Ablation		
2.1 Comprehensive AF risk factor management* is recommended to improve outcomes of AF ablation.	1	B
* AF risk factors include hypertension, alcohol, smoking, obesity, sleep apnoea and physical inactivity.		
3. Indications and Recommendations for AF Ablation in Specific Populations		
3.1 Catheter ablation is recommended to improve LV function in select patients with concurrent AF and HFrEF, where AF is thought to be the primary cause of ventricular dysfunction irrespective of the presence of symptoms.	1	A
3.2 Catheter ablation for selected patients with concurrent AF and HFrEF (EF <35% with NYHA class 2–4) should be considered to reduce mortality and heart failure hospitalisation.	2A	A
3.3 Catheter ablation should be considered in preference to amiodarone for rhythm control of AF in patients with NYHA class 2–3 symptoms and HFrEF (EF <40%).	2A	A
4. Strategies, Techniques, and Endpoints for AF Ablation		
4.1 Electrical isolation of the pulmonary veins (PVs) is recommended during all AF ablation procedures.	1	A
4.2 Electrical re-isolation of the PVs is recommended during re-do AF ablation procedures, if PV reconnection is present.	1	A
4.3 Same day discharge may be considered in select patients undergoing AF ablation.	2B	B
6. Approaches to Minimise and Manage Complications Related to AF Ablation		
6.1 Transoesophageal, intracardiac echo or computed tomography (CT) should be considered to exclude pre-existing thrombus in patients with CHA_2DS_2-VA score ≥1 undergoing catheter ablation of AF without adequate preprocedural anticoagulation.	2A	C
6.2 In anticoagulated patients, AF ablation should be performed with minimal or no interruption of anticoagulation.	2A	B
6.3 It is recommended that the therapeutic anticoagulation be continued for at least 6 weeks after AF ablation.	1	B
6.4 It is recommended that therapeutic anticoagulation be continued after ablation for non-valvular AF independent of the apparent success of the procedure, if the CHA_2DS_2-VA score is ≥2.	1	C
6.5 Oesophageal temperature monitoring may be considered during thermal ablation to minimise the risk of oesophageal injury.	2B	C
6.6 Phrenic nerve monitoring is recommended during cryoballoon isolation of the pulmonary veins.	1	B
6.7 Ultrasound-guided vascular access is recommended to reduce femoral vascular complications.	1	B
6.8 An echocardiogram (echo) should be considered in patients with unexplained hypotension post AF ablation, to exclude cardiac tamponade.	2A	C
7. Anaesthesia for AF Ablation		
7.1 General anaesthesia or deep sedation in collaboration with a specialist anaesthesiologist is recommended for catheter ablation of AF as part of patient-centred care, and to optimise clinical outcomes.	1	B

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(continued).

Recommendation	Class	Level of Evidence
8. Outcomes and Efficacy of AF Ablation		
8.1 Catheter ablation (CA) for rhythm control to improve symptoms and QoL in symptomatic AF *refractory* to medical treatment with antiarrhythmic drug therapy:		
• Paroxysmal: CA is recommended.	1	A
• Persistent: CA is recommended.	1	B
• Long-standing persistent: CA may be considered.	2B	B
8.2 Catheter ablation for rhythm control to improve symptoms and QoL in symptomatic AF *prior* to medical treatment with antiarrhythmic drug therapy:		
• Paroxysmal: CA should be considered in-keeping with shared decision making after discussion of the potential risks and benefits.	2A	A
• Persistent: CA should be considered.	2A	B
• Long-standing persistent: CA may be considered.	2B	C
8.3 Catheter ablation for AF may be considered in selected *asymptomatic* patients with recurrent AF following an informed discussion of the potential risks and benefits.	2B	C
8.4 Catheter ablation for AF should be considered in patients with AF and symptomatic bradycardia, or prolonged AF termination pauses, to avoid pacemaker implantation.	2A	B
10. Training Requirements		
10.1 A Cardiac Physiologist (CP) is recommended to be present for the completion of an AF ablation procedure.	1	C
10.2 In addition to holding a health science degree or equivalent, a CP is recommended to have undertaken advanced sub-specialist training and been actively involved in a minimum of 30 AF ablation procedures with a minimum of 10 AF ablations per year to maintain competence.	1	C
10.3 It is recommended that Cardiologists wanting to perform catheter ablation for AF must complete subspecialty training in adult cardiac clinical electrophysiology as specified in the relevant 2017 CSANZ guidelines.	1	C
10.4 It is recommended that Cardiologists wanting to perform catheter ablation for AF must participate in 100 AF ablation procedures including 50 as the first operator.	1	C
10.5 It is recommended that Cardiologists wanting to perform catheter ablation for AF should perform at least 25 AF ablation procedures on average per year to maintain professional standards.	1	C
10.6 Centres performing ablation for AF should have onsite intensive care facilities, emergency teams and echocardiography.	1	C
10.7 A management plan with rapid access to emergency treatment of serious complications including cardiac tamponade, stroke and vascular complications is recommended.	1	C
10.8 For centres without onsite surgical back-up, patients should be made aware of the potential need for urgent interhospital transfer in the event of complications.	1	B
10.9 It is recommended that institutions wanting to perform catheter ablation for AF should support at least 50 AF ablation procedures per year to maintain competency.	1	B
12. Surgical AF Ablation		
12.1 Surgical ablation should be considered during concomitant cardiac surgery in select patients with AF, where safe and practical.	2A	A
12.2 Stand-alone surgical or hybrid ablation may be considered in patients with persistent AF with prior unsuccessful catheter ablation and, also, in those where antiarrhythmic drugs have been ineffective and who prefer a surgical/hybrid approach, after informed discussion with an electrophysiologist and cardiac surgeon.	2B	B

*Recommendations are numbered by document section. There are no specific recommendations listed for Sections 5 (*AF Ablation: Technology and Tools*), 9 (*Follow Up after AF* Ablation) and 11 (*Clinical Urgency*). For Clinical Urgency recommendations see Box 2.

Abbreviations: AF, atrial fibrillation; ECG, electrocardiogram; HFrEF, heart failure with reduced ejection fraction; LV, left ventricular; EF, ejection fraction; NYHA, New York Heart Association; CA, catheter ablation; QoL, quality of life; CP, cardiac physiologist.

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Recommendation	Class	Level of Evidence
1.2 In patients undergoing AF ablation who have a history of documented typical atrial flutter, or atrial flutter identified at time of AF ablation, a cavo-tricuspid isthmus ablation may be considered.	2B	B

Risk Factors for Development of AF

There are non-modifiable and modifiable risk factors that predispose to the development of new-onset AF. The Framingham Study demonstrated that non-modifiable risk factors included age (for each decade of advancing age, odds ratio [OR] 2.1 [men], 2.2 [women]) and male gender (OR 1.5) [20]. While approximately 2%–4% of the adult population have AF [21], this rises to 9% in those older than eighty years of age [22]. It has been estimated that the lifetime risk of developing AF after the age of 40 years is approximately 1 in 4 [23]. Genetic factors, such as European ancestry, increase the risk of developing AF, and lifetime risk in this population from age 50 years is 1 in 3 [24].

Suboptimal control of modifiable cardiovascular risk factors accounts for more than half of new onset AF [25]. Modifiable risk factors identified by the Framingham Study included diabetes, hypertension, and lifestyle risk factors (see below) [20]. Echocardiographic and structural cardiac features which increase the risk of AF include heart failure, valvular heart disease, myocardial infarction, LA size, reduction in LV function, LV hypertrophy, and diastolic dysfunction [26–28].

Table 3 Definitions of Atrial fibrillation (AF).

AF type	Definition
Paroxysmal	AF episode that terminates spontaneously or with intervention within 7 days of onset
Persistent	AF episode which is sustained beyond 7 days, including episodes terminated by pharmacologic or electrical cardioversion after >7 days
Long-standing persistent	Continuous AF duration of >12 months' duration when a rhythm control strategy is being pursued
Permanent AF	AF is accepted by the patient and physician with a strategy of rate control and that no further attempts to restore/maintain sinus rhythm will be pursued.

Lifestyle risk factors are increasingly recognised as critical in the development of AF and will be discussed in detail in Section 2 (*Modifiable Risk Factors for AF and Impact on Ablation*). Alcohol, obesity, hypertension, obstructive sleep apnoea (OSA), smoking, physical inactivity, and diabetes, have all been variously associated with AF occurrence. Conversely, patients who undertake extremes of exercise are also at risk of AF [29,30]. Various AF risk scores have been developed and may help physicians identify at-risk individuals and potentially institute management that may alter AF symptom burden, disease progression, and complications. In a longitudinal follow-up of 314,280 participants in the UK Biobank, the HARMS2-AF risk score was formulated and validated as a user-friendly assessment of lifestyle factors to help predict AF occurrence [31].

AF occurrence following cardiothoracic surgery is also exceedingly common with a reported incidence of 10%–30% after pulmonary resection or coronary artery bypass surgery and 60% after combined bypass and valve surgery [32]. While the majority of AF postoperative AF will be in the first week post-surgery, postoperative AF is associated with a 5-fold risk of incident AF at follow-up [33].

Natural History of AF

AF is characterised by progressive atrial remodelling perpetuating the development of AF, and is encapsulated in the phrase 'AF begets AF' [34]. Atrial remodelling may manifest as electrical, cellular, structural, or mechanical remodelling, and plays an important role in the pathogenesis of AF. Atrial electrical remodelling may occur within days to weeks of AF and is characterised by shortening of atrial effective refractory periods and conduction slowing leading to increased inducibility of AF [34]. Atrial structural remodelling is characterised by atrial dilatation and development of atrial fibrosis, and is identified in both AF [35,36] and conditions associated with AF, such as hypertension [37,38], valvular heart disease [39], and increasing age [40].

The natural history of AF regarding progression from paroxysmal to persistent AF is not completely uniform, and is dependent on risk factors including age and comorbidities such as heart disease, hypertension, OSA, chronic obstructive pulmonary disease (COPD), and obesity [11]. Follow-up of 1,219 patients with paroxysmal AF in the EuroHeart Survey on AF identified progression to sustained AF in 15% [41]. In a 30 year follow-up of patients aged ≤60 years old with lone AF, 22% progressed to persistent AF [42]. A meta-analysis on progression of paroxysmal to persistent AF identified that in general population-based studies (where treatment was essentially medical therapy), progression of AF occurred in 10%–20% of patients at 1–3 years, whereas it was significantly lower, at 2.4%–2.7% at 5 years follow-up, in patients undergoing catheter ablation for AF progression [43].

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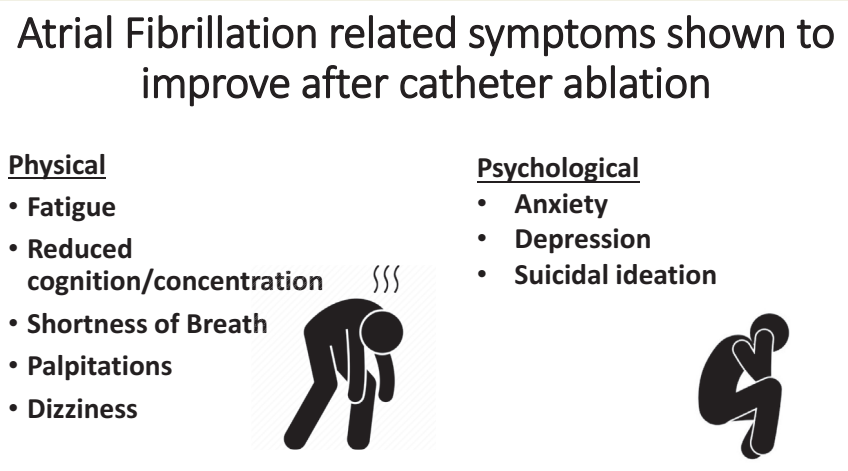

Figure 1 Atrial fibrillation related symptoms shown to improve after catheter ablation.

Defining Symptoms: Physical and Psychological

The clinical presentation of AF may range from incidentally detected asymptomatic AF to debilitating physical and psychological symptoms (Figure 1). In population based studies the incidence of asymptomatic AF is 30%–40% [44–46], with asymptomatic AF being associated with a two- to three-fold increase in mortality compared with symptomatic patients [46,47]. AF is associated with significant morbidity including a three-fold increased risk of heart failure [48], a five-fold increased risk of stroke [49], and doubling of risk of dementia [50]. After adjustment for comorbidity and age, AF is associated with a 1.5- and 1.9-fold increase in mortality risk in men and women respectively [51]. Physical symptoms include palpitations, shortness of breath, syncope, fatigue/ exertional intolerance, chest pain, and patients may present with heart failure or rapid rates may contribute to myocardial ischaemia [12]. More than 60% of patients report moderate symptoms [52], and 17% have disabling symptoms [53]. AF is associated with anxiety in 67% and depression in 38% patients, with suicidal ideation in 20% [52,54]. Depression was the greatest predictor of future quality of life [54]. Stress perception and personality type were key determinants of symptomatic AF, rather than conventional measures of AF burden, ventricular rate or diastolic dysfunction [52]. The REMEDIAL study demonstrated a significant reduction in psychological symptoms in patients randomised to catheter ablation compared with antiarrhythmic medications [55].

Rate vs Rhythm Control

A decision regarding rate versus (vs) rhythm control is a cornerstone of AF management. Rate control is defined as acceptance of AF and an aim to control the ventricular rate. Rhythm control involves the use of pharmacological, electrical, or ablation-based strategies to restore and maintain sinus rhythm. The AFFIRM study randomised 4,060 patients with AF and risk factors to a pharmacological strategy of rate vs rhythm control and reported no difference in survival [56,57]. A sub-study suggested better outcomes for patients in those who maintained sinus rhythm [58]; however, a rhythm control strategy was associated with higher adverse events and increased stroke largely due to the discontinuation of Warfarin [56,57]. The advent of catheter ablation for AF—the most effective tool for rhythm control—has changed the contemporary landscape and treatment paradigm.

The EAST-AFNET 4 trial randomised 2,789 patients with early AF and cardiovascular risk factors to rhythm control vs usual care [1]. Guideline-directed integrated AF management including stroke prevention was mandated in both arms. After a median follow-up of 5.1 years, there was a significant reduction in a composite of death, stroke, hospitalisation for worsening heart failure or acute coronary syndrome in the rhythm control arm (3.9 per 100 patient years vs rate control 5.0 per 100 patient years; hazard ratio [HR] 0.79, p=0.005). Catheter ablation (CA) was performed in 19% in the rhythm control group at 2 years. Multiple RCTs have demonstrated the superiority of CA over antiarrhythmic drugs [6,59,60] in achieving rhythm control in AF both in those who have trialled antiarrhythmic drugs but also in the drug naive [61]. Catheter ablation has been shown to prevent progression from paroxysmal to persistent AF [61]. The ATTEST trial randomised older patients (>60 years of age) with symptomatic paroxysmal AF refractory to antiarrhythmic drug therapy and an elevated HATCH score (a predictor of AF progression) to either continued antiarrhythmic drug therapy or CA, and reported a reduction in progression to persistent AF with ablation (2.4% vs 17.5% with AADs; p=0.0009) [61]. An RCT by Andrade et al. reported the three-year follow-up of 303 patients with untreated paroxysmal AF and implantable loop recorders,

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randomised to initial rhythm control with AF ablation versus antiarrhythmic medication [62]. Progression to persistent AF was significantly lower in patients with initial ablation strategy (n=3, 1.9%) versus patients with antiarrhythmic medication (n=11, 7.4%). Given the relatively low prevalence of progression to persistent AF, opportunity to manage lifestyle risk factors and responsiveness to PVI in early persistent AF, a recommendation for ablation to prevent AF progression was not made. Contemporary AF management should involve patient-centred informed discussion regarding the relative risks and benefits of a rate control vs rhythm control strategy. When a rhythm control strategy is preferred, prompt access to rhythm control interventions including cardioversion and CA should be available (Recommendation 1.3).

Recommendation	Class	Level of Evidence
1.3 An early rhythm control strategy, as part of integrated AF management, improves cardiovascular outcomes compared with rate control, particularly when implemented within the first year after diagnosis.	2A	B

Rationale for and Benefits of AF Ablation

AF is associated with a significant burden of disease, including symptoms which affect physical, cognitive and psychosocial health, LV function and congestive cardiac failure, thromboembolism, dementia, and premature death [12]. The indications for AF ablation are presented in Figure 2.

In 1998, Haissaguerre and colleagues made the landmark observation that the triggers responsible for AF predominantly originate from the pulmonary veins [63]. The pulmonary vein muscular sleeves and junction with the LA tissue have multiple unique characteristics that predispose to arrhythmogenesis, which include automaticity or triggered firing, anisotropy, stretch mediated ion channels, and parasympathetic cardiac ganglia. The maintenance of AF requires an atrial substrate with electrical and structural properties which facilitate AF. The concept that "AF begets AF" was termed by Allessie et al. to describe the concept that AF in itself causes electrical and structural changes within the atrium which favour the recurrence of AF [34]. The atrial substrate is characterised by dynamic shorter refractory periods, dispersion and changes in conduction velocity and structural tissue changes including chamber dilatation, tissue fibrosis, and inflammation [12].

Catheter ablation (CA) aims to create an anatomic barrier to electrically isolate the pulmonary veins with the use of thermal energy or, more recently, electroporation. Randomised trials have established the clear superiority of catheter ablation over antiarrhythmic medication as first-line therapy or in those having previously trialled antiarrhythmic medication in the reduction of recurrent AF and burden of AF [2,6]. Significant reductions or elimination of AF episodes are associated with reductions or discontinuation of antiarrhythmic medication, and improved health outcomes and quality of life [4]. Ablation also causes a reduction in perception of symptomatic episodes that can contribute to improvements in quality of life [64]. The CABANA trial randomised 2,204 patients with AF and risk factors to catheter ablation vs medical

Indications for AF ablation

	Class	Level of Evidence
Symptomatic AF refractory to medical treatment with antiarrhythmic drug therapy:		
• Paroxysmal: CA is recommended	1	A
• Persistent: CA is recommended	1	B
• Long-standing persistent: CA may be considered	2B	B
Symptomatic AF prior to medical treatment with antiarrhythmic drug therapy (First Line):		
• Paroxysmal: CA should be considered with shared decision making after discussion of the risk/benefit profile	2A	A
• Persistent: CA may be considered	2A	B
• Long-standing persistent: CA may be considered	2B	C
Asymptomatic patients with recurrent AF following an informed discussion of potential risks & benefits	2B	C
In select patients with concurrent AF and HFrEF where AF is thought to be the primary cause of ventricular dysfunction irrespective of the presence of symptoms	1	A

Figure 2 Indications for AF ablation.
Abbreviations: CA, catheter ablation; HFrEF, heart failure with reduced ejection fraction.

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therapy. On intention-to-treat analysis there was no significant reduction in the primary composite end point of death, disabling stroke, serious bleeding, or cardiac arrest. However, the estimated treatment effect of CA was affected by lower-than-expected event rates and treatment crossovers [2]. Strategies to further improve outcomes particularly in patients with persistent AF are discussed in Section 4 (*Strategies, Techniques and Endpoints for AF Ablation*).

The success of AF ablation is, in part, determined by the duration of continuous AF, atrial dimensions, presence of structural heart disease, and lifestyle risk factors discussed in Section 2 (*Modifiable Risk Factors for AF and Impact on Ablation*) [65,66]. An integrated, patient-centred approach should provide a clear expectation of expected benefits and outcomes from catheter ablation. Very long-term follow-up after catheter ablation for AF has demonstrated significant and progressive recurrence of AF arrhythmia episodes with time [65,66]. Catheter ablation therapy should therefore not be promulgated as a curative therapy but as one component of long-term integrated AF management. For patients embarking on a rhythm control strategy for AF, management includes the potential need for antiarrhythmic medications, importance of treating risk factors and comorbid conditions, and periodic review of stroke prevention.

2. Modifiable Risk Factors for AF and Impact on Ablation

Comprehensive risk factor management is now considered an integral component of the management of patients with AF including those undergoing ablation (Recommendation 2.1). Epidemiological data suggest clustering of interrelated cardiometabolic risk factors in patients with AF. Obstructive sleep apnoea (OSA), impaired glucose tolerance, hypertension, and dyslipidaemia are often seen in obese individuals, all associated with an increased AF risk in the general population [67,68]. Each additional factor increases the risk of AF and its progression, incrementally [67,69,70]. These risk factors cause structural and electrical remodelling of the atria [71,72]. The hallmark of "microscopic remodelling" is atrial fibrosis, cellular hypertrophy, apoptosis, and fatty infiltration [36,73,74,75,76]. The structural changes contribute to slow conduction, promoting re-entry and AF perpetuation. The atrial substrate may progress even after successful catheter ablation of AF [77]. Although initial reports suggested irreversibility of atrial fibrosis [78], recent preclinical data show regression of interstitial atrial fibrosis [79]. This has been confirmed in clinical studies with a reduction in AF burden with modification of risk factors [80,81,82]. This concept of a progressive but reversible atrial substrate forms the basis of managing the modifiable risk factors [79]. It is also recommended that a structured program support risk factor management with a focus on integrated care [80,81,83,84,85]. Comprehensive risk factor management involving the simultaneous management of multiple modifiable risk factors is associated with improved freedom from AF in both the medium and long term, improved outcomes after AF ablation, and reversal of persistent AF into shorter, paroxysmal episodes or elimination of AF [80,81,82,86]. HEAD-2-TOES (see Figure 3) is a useful acronym which reminds physicians of risk factors to be targeted. This section reviews individual risk factors

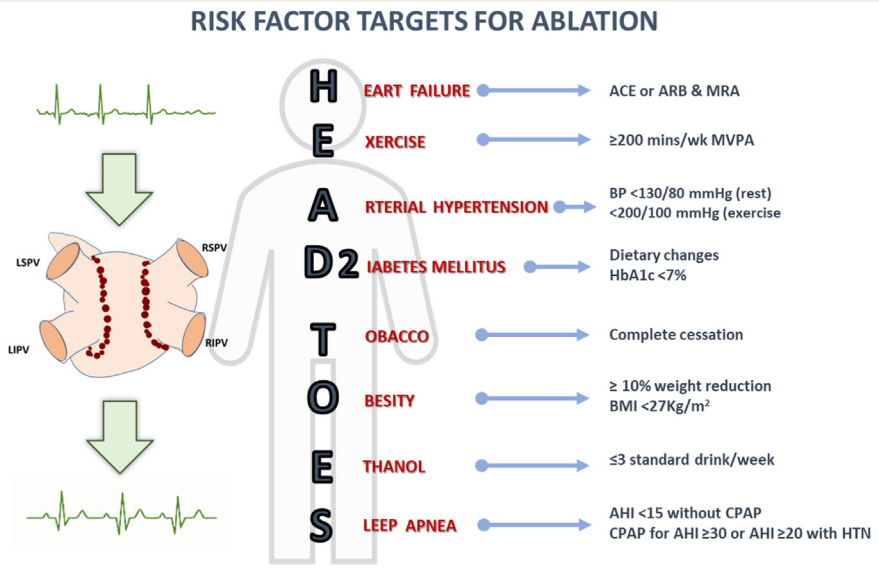

Figure 3 Risk factor targets for ablation. HEAD2TOES provides an acronym for health care providers and patients to identify and manage AF lifestyle risk factors.

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and the impact of modifying risk factors on the outcomes of catheter ablation for AF.

Recommendation	Class	Level of Evidence
2.1 Comprehensive AF risk factor management* is recommended to improve outcomes of AF ablation.	1	B

* AF risk factors include hypertension, alcohol, smoking, obesity, sleep apnoea and physical inactivity.

Obesity

Obesity tends to cluster with other modifiable risk factors. There is sound evidence that weight loss not only improves AF outcomes but also yields beneficial effects on OSA, hypertension, insulin resistance, and dyslipidaemia [80–82]. Obesity is associated with atrial stretch, fibrosis and fatty infiltration manifesting as slow inhomogeneous atrial conduction [71,76,87,88]. Preclinical data suggest weight loss is associated with reduced LA stretch, reversal in interstitial fibrosis, improved connexin expression, and less inflammation resulting in improvement in atrial conduction and reduced AF inducibility [79]. Population-based studies show that obesity is correlated with a greater frequency of developing AF and that this relationship is dynamic [89]. An RCT found that 10% weight loss over 15 months reduced AF burden and symptoms in obese patients (BMI >27 kg/m^2) with AF[80]. The benefits were confirmed to be sustained over 48 months in a larger prospective cohort [82], including post-AF ablation patients [81]. A meta-analysis confirmed lower recurrence of AF with weight loss (RR 0.35; 95% CI 0.18–0.67, p<0.01) in patients undergoing rhythm control strategy, including catheter ablation. Further sub-analysis demonstrated benefit in studies where weight loss was achieved prior to ablation. Also, a benefit was noted in studies with >10% weight loss in the study group. This is similar to observations from the Long-Term Effect of Goal-Directed Weight Management in an Atrial Fibrillation Cohort (LEGACY) study, which showed a dose-dependent relationship with maximum benefits in those with >10% weight loss [82]. A recent RCT did not show the benefit of weight loss in patients undergoing catheter ablation for AF. However, only 3.9% weight loss was achieved in the study group, with 33% non-compliance with the structured weight loss program [90]. Medication including glucagon-like peptide-1 (GLP-1) agonists have become established as superior to diet and exercise in achieving long term weight loss in multiple RCTs, although their impact on AF occurrence in obesity is yet to be established [91]. Observational studies have shown lower AF recurrence in morbidly obese patients undergoing bariatric surgery [92,93].

Obstructive Sleep Apnoea

The prevalence of OSA ranges from 3% to 49% in the general population and from 21% to 74% in patients with AF [94,95]. A joint survey by the European Heart Rhythm Association (EHRA) and the Association of Cardiovascular Nurses and Allied Professions (ACNAP) showed low rates of systematic evaluation for OSA as a component of rhythm control therapy in patients with AF [96]. While continuous positive airway pressure (CPAP) is the treatment of choice, mandibular advancement devices may be considered in patients intolerant to CPAP. Lifestyle modifications such as weight loss and avoidance of alcohol are also advisable. Observational studies suggest that CPAP use significantly reduces AF recurrence after catheter ablation [97–99]. Meta-analyses of non-randomised trials reported the benefit of CPAP treatment in reducing AF burden after catheter ablation [100,101]. However, treatment with CPAP did not further reduce the risk of AF recurrence after ablation in a small RCT in patients with paroxysmal AF and OSA [102,103]. However, this study was limited by sample size as it was powered with an assumption of an effect size of 50% with an assumed recurrence rate of AF ablation of 70%.

The beneficial effects of CPAP are mediated through modulation of the neurohumoral axis, reduced sympathetic activity and sympathovagal imbalance, decreased inflammation, oxidative stress, and mechanical stretch [104]. Additionally, treatment with CPAP has a beneficial effect on associated risk factors such as hypertension [105].

Alcohol

Alcohol is an important treatable cause for AF episodes, including after catheter ablation. Several meta-analyses have shown that moderate habitual alcohol consumption, even after correcting for binge drinking, increases the incidence of AF in a dose-dependent manner [106–108]. Acute alcohol intake slows interatrial conduction, and shortens atrial and pulmonary vein action potential, promoting re-entry [109–112]. Acute intake leads to sympathetic activation and may cause early depolarisation and triggered activity promoting AF. Long-term moderate alcohol consumption has been shown to be associated with adverse LA structural and electrical remodelling in patients undergoing catheter ablation for AF [113,114]. Moderate-to-heavy alcohol intake is associated with obesity (>21 standard drinks [SD] per week), hypertension (>14 SD per week) and worsening of sleep apnoea (0.5–1 gm/kg/day) again highlighting interdependence of risk factors [112]. An RCT of 140 patients demonstrated a reduction in AF recurrence and burden at 6 months in patients abstaining from alcohol intake. In this study, 61% of the patients in the abstinence group were able

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to adhere to complete abstinence, with an overall reduction from 17 to 2 drinks per week. Patients who achieved complete abstinence had a lower risk of recurrence of AF than those who consumed 1 to 9 drinks per week (HR 2.1; 95% CI 1.2 to 3.7) and those who consumed 10 or more drinks per week (HR 2.3; 95% CI 1.3 to 4.0) [115]. In an observational study of 1,361 patients undergoing AF ablation, patients who consumed alcohol had greater risk of recurrence of AF than those who did not consume alcohol (42% vs 34%; p-value 0.003; mean follow-up 44±31 months) [106,116,117]. Although light-to-moderate alcohol consumption in healthy individuals without AF may be associated with long term cardiovascular benefits, a safe level of alcohol consumption in patients with established AF is not well established. In studies reporting comprehensive risk factor management, the recommended intake of alcohol was <3 SD per week [82].

Physical Activity

There is an inverse relationship between incident AF and physical activity, supporting the role of physical inactivity as a modifiable risk factor [118–120]. In a large observational study, participants with the lowest levels of physical fitness had a five-fold increased risk of AF [120]. In the Cardiovascular Health Study, a 46% reduction in the incidence of AF was observed in those with the highest self-reported physical activity [121]. In an observational study of symptomatic obese patients with AF undergoing comprehensive risk factor management, cardiorespiratory fitness gain was associated with greater long-term maintenance of sinus rhythm [122]. The ACTIVE-AF study demonstrated a significant increase in freedom from recurrent AF in patients randomised to a supervised exercise intervention compared with controls [123].

In contrast, the risk of AF is increased in endurance athletes [30,124,125] with an OR of 3.88 (1.55–9.73) in those with an accumulated lifetime endurance sport activity ≥2,000 hours compared with sedentary individuals [126]. Endurance-trained animal models confirmed AF inducibility is reversible, at least in part, by detraining. A brief period of complete detraining has been advocated as an initial trial to stabilise sinus rhythm [127] however catheter ablation is often the preferred approach in athletes and has been shown to be efficacious [128,129].

Hypertension and Other Cardiovascular Risk Factors

Observational studies have demonstrated a significant reduction in AF occurrence with improved management of hypertension [82,130]. In the UK Biobank, hypertension was the strongest lifestyle risk factor associated with incident AF [31]. In patients with existing AF, uncontrolled hypertension increased rates of AF progression and resulted in poorer outcomes after ablation and cardioversion [27,131,132]. There is a lack of evidence to support glycaemic control in managing AF. In the ACCORD trial, intense glycaemic control defined as $HbA1_c$ <6.0% was not superior to the less stringent target of 7.0%–7.9% in preventing new AF [133]. A meta-analysis reported that the presence of diabetes had no impact on the outcomes of AF ablation [134].

Similarly, there is a lack of evidence to support the isolated role of statin therapy, outside of a comprehensive risk factor approach, in altering outcomes after AF ablation [135–137]. Figure 4 provides practical information for patients to address lifestyle risk factors related to AF episodes.

3. Indications and Recommendations for AF Ablation in Specific Populations

Catheter Ablation for AF in Patients with HFrEF

Background

AF and ventricular dysfunction co-exist in up to 30% of patients [138]. Both conditions have interdependent pathophysiological mechanisms which make each more likely to occur [139]. The presence of heart failure—be it HFrEF or heart failure with preserved ejection fraction (HFpEF)—in patients with AF, confers a worse prognosis with respect to mortality, stroke and hospitalisation [140]. AF can cause LV dysfunction via several mechanisms, including tachycardia [141], ventricular irregularity [142,143], and the loss of atrial contractile function. Conversely, heart failure can promote the development of atrial substrate capable of sustaining AF by means of raised filling pressures [144,145], abnormal calcium handling [146], and the activation of neurohormonal pathways resulting in adverse atrial remodelling [147,148].

Rationale

Impact of catheter ablation on death, hospitalisation and other clinical outcomes. In patients with AF and HFrEF, catheter ablation improves survival [4,149], reduces heart failure hospitalisation [4,149] and improves quality of life [150] compared with standard medical therapy (Recommendations 3.1, 3,2). In patients with HFrEF without an identifiable cause aside from AF, restoration of sinus rhythm with catheter ablation leads to substantial improvements and often complete recovery of LV dysfunction [5,151]. In such patients, AF can in fact be an underappreciated reversible cause of heart failure—now termed AF mediated cardiomyopathy (see Figure 5).

The CASTLE-AF study randomised 398 patients with paroxysmal or persistent AF and LV ejection fraction (LVEF) ≤35%, to catheter ablation or standard medical therapy with follow up of 38±20 months. The predetermined composite primary endpoint of all-cause mortality and hospitalisation for worsening heart failure occurred significantly less in the catheter ablation arm (28.5

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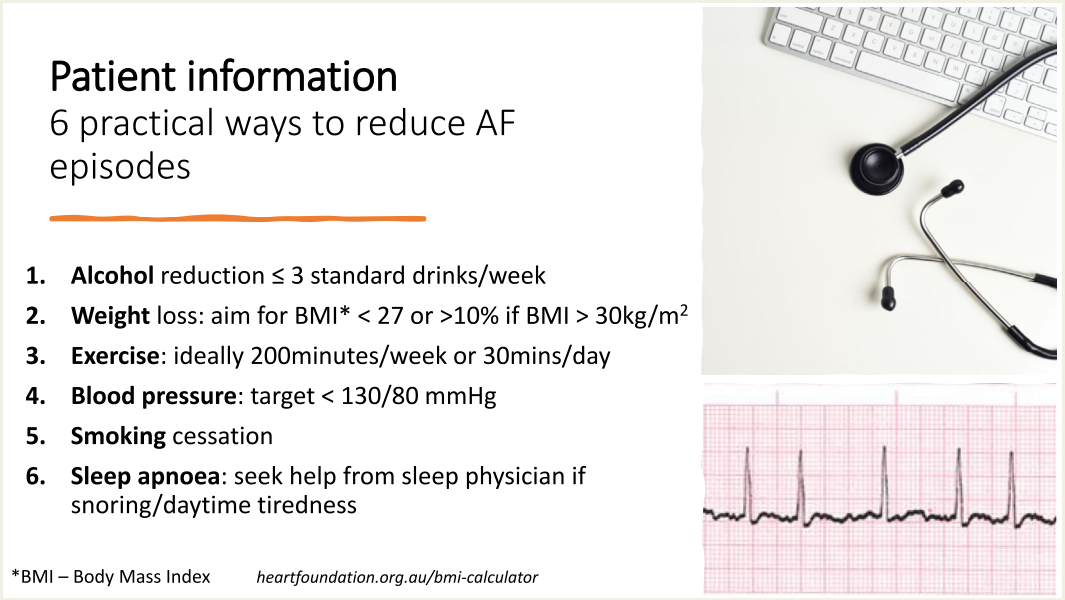

Figure 4 Patient information: 6 practical ways for patients to make life style changes which may reduce the frequency of atrial fibrillation (AF) episodes independent of AF ablation.

vs 44.6%, p=0.006) [4]. The components of the primary endpoint, including overall mortality (0.53, 0.32–0.86, p=0.01), cardiovascular mortality (0.49, 0.29–0.84, p=0.009) and heart failure related admissions (0.56, 0.37–0.83, p=0.004), were individually significant. The AATAC-AF randomised clinical trial demonstrated a significant reduction in AF recurrence with catheter ablation versus amiodarone in 203 patients with persistent AF and LVEF

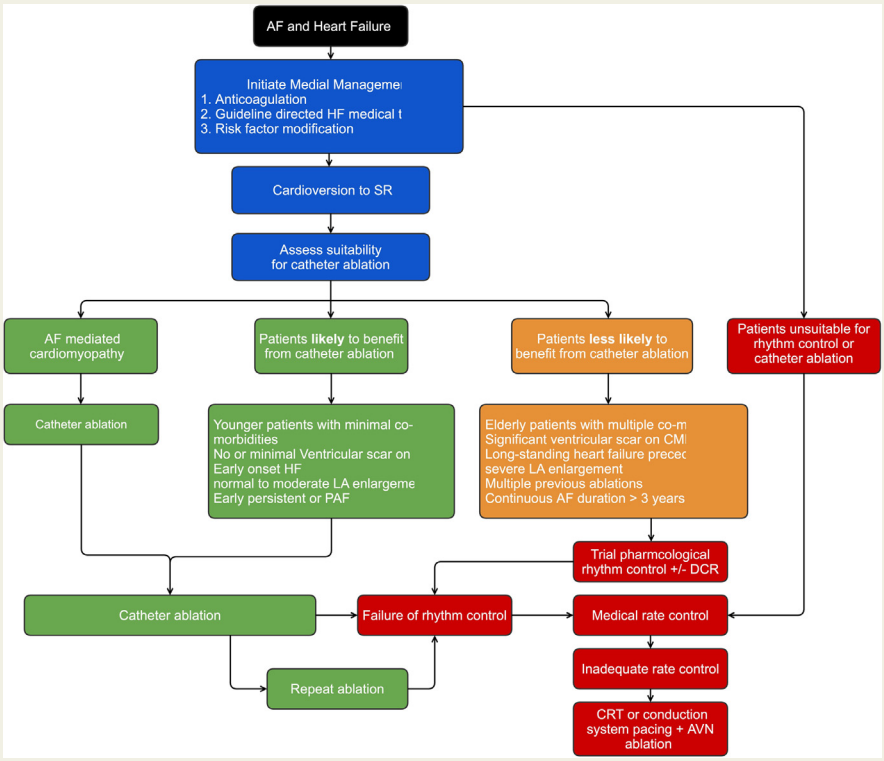

Figure 5 Management of AF in HFrEF. Schematic flow chart providing guidelines on the management of atrial fibrillation (AF) in the presence of heart failure with reduced ejection fraction (HFrEF).

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≤40% (Recommendation 3.3). Catheter ablation was also associated with a significant reduction in unplanned hospitalisation and overall mortality [149]. A 2021 meta-analysis encompassing 242,371 patients (27,711 in the ablation group, 213,661 in the non-ablation group) demonstrated reductions in mortality (0.62, 95% CI 0.54–0.72), in stroke (0.63, 95% CI 0.56–0.70) and in heart failure related hospitalisation (0.64, 95% CI 0.51–0.88) [152], with CA. A single-centre study of 194 patients with AF and end-stage heart failure was stopped after one year due to a significant reduction in the composite of all-cause mortality, implantation of a LV assist device, or urgent heart transplantation in the CA arm compared with medical therapy alone [153].

Impact of catheter ablation on left ventricular (LV) function, symptoms and quality of life. Randomised studies have reported an absolute improvement in LVEF of up to 8% in patients undergoing CA compared with usual medical therapy on a background of guideline directed heart failure medical therapy in both groups [4,154,155]. The CAMERA-MRI study [5] demonstrated much larger improvements in LVEF in patients with persistent AF and LVEF ≤45% with otherwise unexplained cardiomyopathy(18.3% with CA vs 4.4% with medical rate control, p<0.001) assessed on cardiac magnetic resonance imaging (MRI), with the benefit maintained out to 4 years of follow-up [156]. Improvements in LVEF were greatest in the absence of ventricular late gadolinium enhancement. Catheter ablation is also associated with significant improvements in 6-minute walk test, quality of life and a reduction in BNP [5,157] compared with medical therapy (Recommendations 3.1, 3.2).

Recommendations	Class	Level of Evidence
3.1. Catheter ablation is recommended to improve LV function in select patients with concurrent AF and HFrEF, where AF is thought to be the primary cause of ventricular dysfunction irrespective of the presence of symptoms.	1	A
3.2 Catheter ablation for selected patients with concurrent AF and HFrEF (EF <35% with NYHA class 2–3) should be considered to reduce mortality and heart failure hospitalisation.	2A	A
3.3 Catheter ablation should be considered in preference to amiodarone for rhythm control of AF in patients with NYHA class 2–3 symptoms and HFrEF (EF <35%).	2A	A

Practical advice

Patients who present for the first time with AF and LV dysfunction [5,154] should be considered to have an AF-mediated cardiomyopathy and undergo restoration of sinus rhythm. Symptoms are unhelpful, as both conditions present with fatigue, dyspnoea, and reduced exercise tolerance. The absence of scarring (late gadolinium enhancement) on cardiac MRI, identifies patients likely to experience greater recovery of LV systolic function [5]. Although patients with AF and co-existing HFrEF may represent clinical and technical challenges when undergoing catheter ablation, the outcomes from large studies suggest the overall rate of procedural complications is comparable with patients who have normal ventricular function. Nonetheless, practical steps, such as performing procedures in a high-volume electrophysiology (EP) centre with advanced heart failure therapies on site, including cardiac anaesthetists, would be recommended, particularly for patients with severely reduced LVEF. Peri-procedural cardioversion to sinus rhythm (where possible) may optimise patient haemodynamics during the procedure. Careful attention should be paid to fluid volume status, including the use of an indwelling urinary catheter (with or without transient diuretic therapy) for close fluid balance monitoring if required. Careful attention should also be paid to periprocedural anticoagulation to minimise the risk of thrombus, including uninterrupted anticoagulation, particularly where patients are in AF at the time of procedure. The optimal ablation strategy, beyond PVI, for patients with HFrEF remains unknown with no prospective data available.

Catheter Ablation for AF in Patients with HFpEF

Background

Heart failure with preserved ejection fraction (HFpEF) constitutes around 50%–60% of clinical heart failure [158,159]. Given the contribution of atrial function to physiological diastolic filling [160], the co-existence of AF in the setting of HFpEF worsens symptoms and clinical outcomes. Unlike HFrEF, effective medical and device therapies are lacking [161]. In this context, catheter ablation may provide an attractive treatment option for HFpEF that is clinically worsened by co-existing AF.

Rationale

A secondary analysis of patients with heart failure, of whom the majority had HFpEF, enrolled in the CABANA randomised clinical trial demonstrated a reduction in the composite primary endpoint of death, disabling stroke, serious bleeding or cardiac arrest (RR=0.66, 95%CI 0.41–0.99)—with CA vs medical therapy [150]. A meta-analysis of 1,505 patients reported equivalent outcomes with AF ablation in patients with HFpEF and HFrEF. A small single-centre, observational study prospectively evaluated clinical and haemodynamic outcomes in 20 patients undergoing catheter ablation with AF and HFpEF. Freedom from AF was associated with significant improvements in peak exercise pulmonary capillary wedge pressure (PCWP) and Minnesota Living with Heart Failure scores [162]. The RAFT-AF trial [157] randomised 411 patients with AF and heart failure,

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which included HFrEF and HFpEF, to either catheter ablation or medical rate control, and was stopped early due to apparent futility. At follow-up, there was a non-significant trend to a reduction in the primary endpoint of all-cause mortality and heart failure events in the ablation group (23.4%) compared with rate control (32.5%, RR 0.71 [0.49–1.03], p=0.066). Larger randomised studies are planned to determine the role of AF ablation in heart failure. Given the relative paucity of prospective data for catheter ablation in patients with HFpEF, there is insufficient data to support the routine use of catheter ablation in reducing hard clinical endpoints. The committee recommends that patients be selected for AF ablation based on symptoms and quality of life.

Catheter Ablation to Reduce Stroke Risk

Catheter ablation is generally not indicated to avoid the need for long-term anticoagulation. Small observational and registry studies report a low incidence of thromboembolism following the discontinuation of anticoagulation after successful catheter ablation [163–167], although generally in low-risk patients. The OCEAN study is a randomised trial comparing aspirin with rivaroxaban (15 mg) after successful CA with the primary endpoint of stroke or systemic embolism which has now completed recruitment [168]. Given the lack of prospective data regarding the safety of discontinuing anticoagulation post CA, the significant prevalence of asymptomatic AF and the lack of a temporal relationship between AF episodes and stroke, the committee recommends the ongoing need for anticoagulation to be determined by CHA_2DS_2VA score rather than apparent procedural success, with an informed discussion with the patient.

Catheter Ablation of Asymptomatic Patients

Symptoms related to AF include fatigue, reduced exercise tolerance and palpitations as well the psychological symptoms of depression, anxiety, and impaired cognition. In general, patients who appear "asymptomatic" with the incidental finding of AF should be considered for a trial of cardioversion depending on comorbidities. Reassessment of the impact of sinus rhythm on physical and mental health should guide a longer-term strategy of rhythm vs rate control.

While the main benefit of catheter ablation of AF is symptom control and improved quality of life, a rhythm control strategy including catheter ablation may provide a treatment benefit in terms of reduced mortality, cardiac hospitalisation, and stroke risk. The EAST-AFNET 4 study demonstrated that rhythm control which included AF ablation in a minority was associated with a significant reduction in cardiovascular death, stroke, or hospitalisation for heart failure or acute coronary syndrome [1]. The clinical benefit of early rhythm control was equivalent in the presence or absence of symptoms [169]. In contemporary practice, catheter ablation may be considered in asymptomatic patients who are younger and physically active with relatively preserved LA size, rather than acceptance of permanent AF with its potential complications and need for long term anticoagulation. Shared decision making should include expected outcomes and potential risks of CA.

In apparently asymptomatic patients with impaired LV systolic function, catheter ablation is associated with a significant improvement in LV systolic function together with a reduction in all-cause mortality and hospitalisation for worsening heart failure. Patients with AF and HFrEF, particularly when no other cause apart from AF is responsible for systolic dysfunction, should be considered for CA [4,5].

AF and Ablation in First Nations People

There is emerging evidence to suggest that AF is more problematic amongst First Nations people, including those in Australia and New Zealand. Several studies have reported that the hospitalised prevalence of AF is significantly higher amongst Indigenous Australians [170–172], although less community-based data are available [173,174]. Similarly, primary care estimates suggest a higher prevalence of AF amongst Māori and Pacific people in New Zealand [175,176]. Importantly, AF is increasingly being diagnosed at a young age in First Nations people [171,172,175]. The reasons for the greater prevalence of AF amongst First Nations people requires further investigation but is likely to be related to a higher incidence of cardiometabolic risk factors [170,172]. Given the burden of cardiometabolic disease and rheumatic heart disease amongst First Nations people, it is surprising that the incidence of AF rates is not greater [172]. Given the complications of AF such as stroke, heart failure, and premature mortality are significantly higher amongst First Nations people [177,178], strategies to prevent the development and progression of AF may be particularly beneficial in these individuals.

There are few studies on the management of AF amongst First Nations people in Australia and New Zealand. There is some evidence to suggest that anticoagulation is less frequent and, although non-vitamin K antagonists are increasingly utilised, those prescribed warfarin spent less time in therapeutic range [179,180]. These trends mirror those seen overseas in other racial and ethnic minorities [181,182]. There are no published data on the outcomes of AF ablation amongst First Nations people in Australia and New Zealand. Prior studies have reported that racial and ethnic minorities are less likely to receive rhythm control strategies, including AF ablation [182]. A similar inequity of access to rhythm control strategies and AF ablation procedures likely exists amongst First Nations people in Australia and New Zealand.

Atrial fibrillation ablation may be particularly beneficial in selected First Nations people in Australia and New Zealand. Institution of rhythm control and ablation early in the disease course amongst younger people may limit disease progression and reduce the incidence of AF-related complications,

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such as heart failure and stroke, which are already more prevalent amongst First Nations people [1,62,177]. The benefits of AF ablation over medical therapy may vary by race and ethnicity, with superior outcomes reported in some minorities [183]. Conversely, there are theoretical concerns that might temper enthusiasm for AF ablation amongst First Nations people. Optimal outcomes with AF ablation require the management of cardiometabolic risk factors [82,184]. Rheumatic heart disease is prevalent in First Nations people and may be associated with increased AF recurrence after ablation [185]. A patient-centred approach involving comprehensive multidisciplinary care with cultural awareness and sensitivity is suggested in First Nations people.

Who Should Not be Considered for AF Ablation

Other Options for Management of AF

The model of Shared Decision Making is important in the delivery of catheter ablation for AF [186]. A discussion about the likely benefits and risks applying to each individual should be had with the patient and their whānau/family. Benefits are greatest in highly symptomatic younger patients with self-terminating episodes who have a structurally normal heart including normal LA size. The success of CA declines as patients age, the left atrium dilates, and the AF becomes more persistent. Furthermore, those who are truly asymptomatic cannot expect improvements in quality of life [4].

For those in whom the risks of ablation do not justify the expected benefits, there are alternative treatment strategies available. These include both pharmacological and non-drug strategies to pursue rhythm or rate control. Rate control with beta blockers, non-dihydropyridine calcium channel blockers and/or digoxin has been shown to provide good symptomatic relief with equivalent prognosis in randomised studies [57,187]. Failure to achieve sufficient rate control or continuing symptoms of palpitations due to irregularity of the heart rhythm is often effectively treated by a "pace and ablate" strategy; that is, implantation of a pacemaker and subsequent ablation of the atrioventricular node, thereby severing conduction to the ventricles and providing rate support via the pacemaker. This gives excellent rate control and is particularly effective in the elderly who present with AF with rapid ventricular response despite medication, or when rate control medication is not tolerated. Patients should be counselled regarding potential long-term issues regarding pacemaker infection, the need for pacemaker generator and or lead replacement, tricuspid regurgitation, and the possibility of ventricular dyssynchrony leading to congestive heart failure [188]. Dyssynchrony can be managed or avoided with biventricular or conduction system pacing [189].

Some patients unsuitable for AF ablation may do well with a continued rhythm control strategy with drugs, supplemented with intermittent electrical cardioversion. For those with infrequent but persistent AF, cardioversion, as required, may be pursued in the longer term, depending on the frequency and inconvenience of such a strategy. For patients in whom drugs, such as flecainide, convert AF into atrial flutter, a hybrid strategy of cavo-tricuspid isthmus ablation and continued anti-arrhythmic therapy can be effective [190].

Patients who elect for AF ablation should do so in the knowledge that multiple procedures may be required. This may be required to restore electrical isolation or bidirectional block, or to target abnormal atrial substrate beyond the PVs.

4. Strategies, Techniques, and Endpoints for AF Ablation

Pulmonary Vein Isolation

In 1998, the pulmonary veins were identified as the trigger for AF in 95% of spontaneous AF initiations in just 45 patients, with CA to target the responsible focus [63]. The procedure has evolved from focal to ostial and, now, antral encirclement, with the cornerstone being the electrical isolation of all pulmonary veins (Recommendation 4.1). The challenge of CA is in creating durable lesions while avoiding damage to surrounding structures and complications. Power, impedance, temperature, duration, and contact force all determine lesion size and depth.

Radio frequency (RF) ablation for AF involves the use of irrigated tip catheters, which cool the endocardium to prevent char and minimise steam pops, which can precipitate tamponade. Irrigation results in greater lesion size compared with solid tip catheters [191]. Contact force (CF) impacts lesion size, and CF-sensing catheters have become widely utilised [192]. However, RCTs have not consistently shown better outcomes or fewer complications with CF-sensing ablation [193,194,195]. High-power short-duration (HPSD) ablation shortens procedure time, without compromising efficacy or safety. Several multicentre randomised trials and meta-analyses have shown similar safety and efficacy, but shorter procedure time, with powers of 40–50 W vs 25–30 W [196,197,198,199]. A very HPSD strategy of radiofrequency ablation (RFA; 90 W for 4 sec), using a specifically designed catheter optimised for temperature-controlled ablation [200], has shown clinical feasibility and safety.

Recommendation	Class	Level of Evidence
4.1. Electrical isolation of the pulmonary veins is recommended during all AF ablation procedures.	1	A

AF Ablation Endpoints

The endpoint for CA of AF is PVI including both entrance and exit block [11]. Ablation of persistent AF until sinus

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rhythm is achieved has largely been abandoned due to disappointing long-term outcomes, with the associated risks of pro-arrhythmia and atrial mechanical dysfunction [201]. If additional ablation is performed, electrophysiological endpoints of bidirectional block for linear ablation, electrical isolation of anatomic targets such as the posterior wall or superior vena cava (SVC), and non-inducibility of non-PV triggers after repeated isoprenaline challenge should be established.

Waiting Time and Adenosine

Reconnection of PVs can be as high as 62%–91%, even in those who are AF-free after initial PVI [202,203]. Two strategies that may improve the likelihood of achieving durable PVI include a waiting time after PVI, and adenosine testing (which restores excitability in damaged but viable cardiac myocytes). In 2015, a multicentre, international, randomised trial demonstrated improved freedom from AF in patients randomised to adenosine testing with ablation of dormant PV conduction [204]. A larger RCT of 538 patients reported no difference in AF recurrence at 3 years when comparing various combinations of waiting times and adenosine use [205]. These findings were supported by the UNDER-ATP study, which did not show any significant reduction in recurrent atrial arrhythmias by ATP-guided PVI compared with conventional PVI in 2,113 patients [206]. The impact of waiting time and adenosine may have diminished further with the advent of CF sensing, ablation index guided ablation, and HPSD. Adenosine is not useful for alternate energy sources, such as the cryoballoon and electroporation [207]. As such, waiting and/or adenosine challenge may be considered to identify acute pulmonary vein reconnection following initial PVI with RF; however, there are conflicting data on improving outcomes.

Creation of Durable Pulmonary Vein Isolation Using the Cryoballoon

Acute PVI is achieved in almost 100% of cases using the 2nd generation cryoballoon. Early studies used two 4- or 5-minute freezes per vein, but current practice supports 3-minute freezes with a high acute isolation rate [208]. Predictors of durable PVI include: early time to isolation (<40 seconds), colder cryoballoon freezing temperature (colder than –35°C after 60 seconds), and prolonged rewarming time (>67 seconds) [209–212]. If these are not met, an additional freeze(s) should be considered.

Adjunctive Ablation Strategies to be Considered in Addition to PVI

The cornerstone of catheter ablation is the complete isolation of pulmonary veins by creating a barrier within the antrum, either using point-by-point RFA or single-shot ablation techniques [59,213–216]. However, due to the high recurrence rate observed in patients with persistent and long-standing persistent AF with PVI alone, continued efforts are underway to identify additive strategies to improve outcomes. However, any additional benefit of these approaches beyond PVI alone hass not been supported by large multicentre randomised trials [217–237].

Additional strategies may include:

- **Linear:** The most common sites for linear ablation are the left atrial (LA) roof connecting the superior aspects of the left and right upper PVI lesions, the region between the mitral valve (MV) and the left inferior PV (the lateral mitral isthmus), and anteriorly between the roof line near the left or right circumferential lesion and the mitral annulus (the anterior line). The role of additional lines remains controversial unless a macro–re-entrant atrial tachycardia or left-sided atrial flutter is seen clinically [222,234,238,239].
- **Posterior Wall Isolation:** Posterior wall isolation (PWI) involves a roof line and floor line connecting the most inferior aspects of the inferior PVs. The CAPLA study demonstrated no improvement in outcomes with the addition of PWI to PVI alone in patients with persistent AF [240]. This strategy may be considered in patients with long standing persistent AF and in those with recurrent AF in the presence of enduring PVI, although randomised studies are lacking. There is conflicting data to support the role of PWI in the presence of low tissue voltage/scar on the posterior wall [241–243].
- **Non-PV Triggers:** Non-PV "triggers" can be identified in up to one-third of patients referred for catheter ablation of persistent AF [244]. Common sites include posterior wall, SVC, crista terminalis, septum, coronary sinus, ligament of Marshall, and atrioventricular (AV) annuli [244–248]. Observational studies have shown improved arrhythmia-free survival when non-PV triggers are targeted for ablation and effectively eliminated at the time of PVI, however, randomised data are lacking [245,247,249–253]. In rare cases, supraventricular tachycardias (SVT) such as atrioventricular nodal re-entrant tachycardia (AVNRT) or atrioventricular re-entrant tachycardia (AVRT) can be a triggering mechanism for AF [247]. There are conflicting reports regarding the prevalence of triggers from the left atrial appendage (LAA). Generally, isolation of the LAA is not recommended due to the long-term need for strict thromboembolic prophylaxis and consideration of LAA closure [254]. Isoprenaline is the most used agent to provoke non-PV triggers. Graded infusion of isoproterenol using up to 10–30 mg per minute for at least 10 minutes is recommended. If there is no effect with isoproterenol infusion, burst pacing into AF and then cardioversion during low-dose isoproterenol infusion (2–6 mg per minute) may be considered. Localisation of non-PV AF triggers is challenging, due to limited ectopy for mapping coupled with often multifocal activity [244,251].
- **Fibrosis-guided ablation:** A patient-tailored approach targeting regions of abnormal atrial substrate has provided conflicting results. The DECAAF2 study reported no

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improvement in freedom from AF in 843 patients randomised to MRI-guided ablation, coupled with an increased stroke risk vs PVI alone [243]. In contrast, the ERASE-AF study demonstrated a significant improvement in freedom from AF with linear or electrical isolation of regions of low tissue voltage beyond PVI alone [242].

- **Vein of Marshall ethanol injection:** The vein of Marshall may be a source of AF triggers, houses autonomic tissue, and occupies the mitral isthmus; and, as such, may be a target for ablation beyond the PVs. Valderrabano et al. reported reduced AF recurrence in persistent AF patients randomised to vein of Marshall ethanol ablation compared with PVI+additional ablation [255]. Randomised studies are ongoing [256].

Recommendation	Class	Level of Evidence
4.2 Electrical re-isolation of the PVs is recommended during redo AF ablation procedures if PV reconnection is present.	1	A

Recurrent AF With or Without PV Reconnection Endpoints for Ablation of Paroxysmal and Persistent AF

Pulmonary vein reconnection is frequently observed in patients experiencing recurrent AF post catheter ablation [257]. Electrical re-isolation of the PVs is recommended during redo AF ablation procedures (Recommendation 4.2), and this may be all that is required. In patients with recurrent AF with enduring PVI, non-PV-based strategies need to be considered. There is a lack of RCTs to guide approaches in this increasingly common clinical scenario, with a range of adjunctive ablation strategies discussed above.

Same-Day Discharge

Same-day discharge (SDD) following AF ablation has gained traction due to advancements in technology, improved procedural techniques, and the push for cost-effective care. Several studies have demonstrated the safety and feasibility of SDD post AF ablation in selected patient populations [258,259,260]. Deyell et al. found a strategy of routine SDD to be feasible without increased 30-day readmissions or major adverse events for patients with paroxysmal and persistent AF undergoing RF and cryoballoon ablation [9]. Use of a standardised protocol including defined eligibility criteria showed safety of SDD in a large cohort of paroxysmal and persistent AF ablation patients [259]. Patient selection, close post-procedure monitoring, and clear discharge instructions are crucial to minimise potential risks. An echocardiogram to exclude a pericardial effusion and a minimum period of 6 hours post procedure are generally recommended (Recommendation 4.3).

Recommendation	Class	Level of Evidence
4.3 Same day discharge may be considered in select patients undergoing AF ablation.	2B	B

5. AF Ablation: Technology and Tools

This section provides an overview of technologies and tools available for AF ablation procedures; there are no **Recommendations** within this section.

Imaging of the Left Atrium and Pulmonary Veins

Pre-procedure imaging of the pulmonary veins, antra, and left atrium may be performed to acquire a three-dimensional (3D) volumetric model to guide catheter ablation [261]. Alternatively, intraprocedural imaging techniques based on fluoroscopy, ultrasound and/or electroanatomical mapping may be used. An appropriately timed contrast computed tomography (CT) or MRI provides a detailed model of relevant anatomy, defining the size, number, and bifurcations of the PVs. Variations in PV anatomy occur in 30%, including: left common trunk, left or right common ostium, and right middle or right top PV [262,263]. Such imaging facilitates lesion application, minimising inadvertent ablation beyond the ostia and associated pulmonary vein stenosis [264]. Intraprocedural techniques to define PV anatomy include PV venography following selective PV injection, left/right pulmonary arterial injection or LA injection, as well as rotational angiography in a capable lab [265].

Vascular Ultrasound

Ultrasound imaging is used intra-procedurally to facilitate central venous access, transseptal LA access, and catheter navigation. The routine use of ultrasound guidance for access to the femoral, internal jugular, and subclavian veins has led to a significant reduction in post-procedure vascular complications [266,267], which is pertinent given the frequent presence of obesity and anticoagulation in patients with AF [11].

Echocardiography

Intraprocedural transoesophageal echocardiography (TOE) is routinely used to exclude LA thrombus and facilitate transseptal access; and, has been associated with a reduced rate of cardiac tamponade [268]. Intracardiac echocardiography/echo (ICE) is an alternative that has comparable utility in identifying LA thrombus, guiding transseptal access, defining the PVs and anatomical relations, facilitating catheter placement, and identifying pericardial effusion [269–272]. Intracardiac echo is less frequently used for AF

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ablation in Australia/New Zealand, due to a lack of perceived benefit beyond TOE, cost, and additional venous access; however, it avoids instrumentation of the oesophagus and may be used under conscious sedation.

Radiofrequency Ablation

Radiofrequency energy is the most commonly used energy source to perform AF ablation. Successful AF ablation depends on reliable delivery of transmural lesions to achieve PVI and substrate modification. The conventional technique involves unipolar RFA with thermal energy delivered from the catheter tip to a large dispersive surface electrode causing local resistive myocardial heating and conductive heating to deeper tissue layers. While phased and multipolar RF delivery systems have been developed, they have yet to enter routine clinical use.

Lesion size and depth are determined by power, impedance, temperature, duration, and CF. Derived indices including Ablation Index (Biosense Webster, Diamond Bar, CA, USA) and Lesion Size Index (LSI, Abbott, Minneapolis, MN, USA) combine a number of variables to provide a real-time endpoint for each RF application. Fluoroscopy appearance, tactile feedback, impendence changes, and electrogram (EGM) characteristics are surrogate markers of catheter contact that are poor predictors of CF [273,274]. Two technologies are widely used to determine real-time CF, based on measurement of catheter tip deformation. SmartTouch technology (Biosense Webster) uses a magnetic sensor in the distal catheter shaft to detect micro-deformation of a small spring positioned between it and a magnetic transmitter in the catheter tip. Tacticath technology (Abbott) uses three optical fibres to measure deformation within the catheter tip.

Catheter tip irrigation is routinely used in RF-based AF ablation. Saline irrigation cools the electrode-tissue interface, reduces the risk of coagulum and char formation, and allows higher delivered power, which increases lesion size. Myocardium heated beyond 50 °C undergoes cell death, with evolution into non-conductive myocardial scar [275]. Uncontrolled power delivery may result in temperatures rising beyond 100 °C. At the tissue interface, this results in coagulum and char formation. Intramurally, this results in steam pops and risk of cardiac perforation. Techniques to minimise the risk of uncontrolled power delivery and collateral damage include safety mechanisms on RF generators, use of CF-sensing catheters, and impedance monitoring.

RF balloon technologies have been developed to provide "single shot" delivery of RF lesions, which are more typically applied in point-by-point fashion. These include the Heliostar (Biosense Webster, CA), Satake Host Balloon (Toray Industries, Tokyo, Japan), and Sphere-9 (Affera [Medtronic, MN) catheter systems [276]. Further data are required to establish the efficacy and safety profiles of these technologies.

Electroanatomic Mapping (EAM) Systems

Radiofrequency ablation for AF is normally delivered in conjunction with an electroanatomical mapping (EAM) system. This allows real-time visualisation of multipolar mapping and ablation catheters in 3D space, and the construction of a 3D model of the atrium, combined with electrical information such as electrogram voltage and activation timing. Operators may integrate the 3D images derived from CT or MRI into the electroanatomical map, to improve the anatomical accuracy of the model. This requires accurate registration of fiduciary points on the radiographic model matched with the EAM system.

Cryoballoon Ablation

Cryoballoon (CB) ablation has become a widely used alternative to RFA for PVI. This "single shot" approach has been validated in many studies, and has an efficacy and safety profile comparable with RFA [277,278]. Randomised trials comparing RF and CB ablation have shown no significant differences in arrhythmia-free survival, cardiovascular readmission rate, and repeat ablation procedures.

Pulsed Field Ablation

Pulsed field (PF) ablation utilises high-voltage, short-duration electrical pulses to injure tissue via irreversible electroporation. As the current is delivered to the target tissue, pores in the cell membrane develop, resulting in irrecoverable non-thermal injury and cell death. Because cardiomyocytes have a low electroporation threshold compared with other tissue, myocardium can be selectively ablated while minimising collateral damage to the oesophagus and phrenic nerve that can occur with thermal ablation. Pulsed field ablation may be configured with direct or alternating current, monophasic or biphasic waveform, unipolar or bipolar current, and varying pulse trains, pulses per train, pulse width, voltage gradient, delivery time, electrodes configuration, and catheter shape. Optimal settings are under intense investigation with early clinical data available for several systems developed by Farapulse [279], Affera [280], and Medtronic [281], and pre-clinical data from other investigators [282].

The first system to be approved for human use incorporates a custom PF waveform generator, 13-F steerable sheath, and over-the-wire variable-shaped catheter that can assume a basket or flower shaped configuration. The IMPULSE, PEFCAT, and PEFCAT II trials demonstrated 85% 1-year freedom for atrial arrhythmia, and an excellent safety profile with no strokes, atrio-oesophageal fistula, phrenic nerve injury, or PV stenosis recorded among 121 patients [279]. Notably, planned invasive remapping at 2–3 months showed durable PVI in 96%. The ADVENT trial was the first trial to randomise patients to PFA vs thermal ablation (CB or RFA). In 305 patients with paroxysmal AF (PAF), there was no significant difference in success or safety between the technologies; however, procedure

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duration was significantly shorter [283]. Transient phrenic nerve injury was reported in four patients who underwent PFA, despite prior reports of an absence of collateral injury. Given the promise of PF ablation for shorter procedure times, larger trials are required to clarify the longer-term outcomes and safety profiles of the individual systems.

6. Approaches to Minimise and Manage Complications Related to AF Ablation

Minimising Risk of Thromboembolism During AF Ablation

General considerations

Patients undergoing catheter ablation for AF are at an increased risk of periprocedural thromboembolism. The risk may be mitigated by careful periprocedural management, especially screening for pre-existing thrombus (where appropriate) and meticulous attention to anticoagulation.

Screening for left atrial (LA) thrombus prior to ablation

There is a risk of mechanically dislodging pre-existing thrombus during catheter manipulation in the left atrium. Hence, it has been a long-standing practice of many centres to exclude LAthrombus with transoesophageal echocardiogram (TOE) immediately prior to catheter ablation [284]. However, the practice is not universal with some physicians only performing TOE in selected patients, while others proceed to ablation without prior TOE [285].

Despite therapeutic anticoagulation for at least 3 weeks, the incidence of LA thrombus is ~3% based on a recent meta-analysis of observational data [286]. Although the incidence is generally lower in patients undergoing elective catheter ablation compared with urgent cardioversion, the incidence is still ~1.5%–2% [287]. Predictors of thrombus include age >75 years, non-paroxysmal AF, hypertension, prior transient ischaemic attack/stroke, LV dysfunction, dilated LA, and CHA_2DS_2-VA score ≥3 [287–291].

In contrast, the incidence of LA thrombus is low (≤1%) in younger patients (aged <60 years) with paroxysmal AF, CHA_2DS_2-VA score ≤1, minimal LA dilatation (LA diameter <4.5 cm), and on reliable therapeutic anticoagulation for 4 weeks [286,288,291–293]. Although the omission of preprocedural TOE may be considered in this subset of patients, there are no randomised data to support this recommendation. Moreover, compliance with anticoagulation would be a prerequisite, and it is challenging to confirm compliance with direct-acting oral anticoagulants (DOACs).

A survey of the writing committee members showed that 89% routinely exclude intracardiac thrombus prior to catheter ablation of AF, independent of the presenting rhythm and anticoagulation status.

TOE remains the gold standard for the diagnosis of LAA thrombus, and it remains the only technique that has been assessed in a large RCT as a strategy for detecting LA thrombus, albeit in the setting of cardioversion [294]. Moreover, TOE is widely available, and most cardiologists and cardiac anaesthetists achieve competence in its use as part of their training. It also provides additional information that may be useful for ablation (e.g., assessment of inter-atrial septum, pulmonary vein anatomy, MV anatomy, LV function, and pericardial effusion).

Other techniques such as ICE, CT, and MRI have been reported to have comparable sensitivity and specificity to TOE, and may be viable alternatives [295,296]. Intra-cardiac echocardiography is limited by availability, cost, and specialised training. However, it provides real-time assessment of the LA and LAA (particularly with views from the RV inflow tract or pulmonary artery) and it may detect *de novo* thrombus formation during the ablation procedure [297]. CT is often performed routinely to provide information on PV and LA anatomy prior to catheter ablation and it approaches TOE in accuracy for detection of LA thrombus, especially with delayed imaging protocols to differentiate sluggish filling of contrast from true thrombus in the LAA [298]. Although there are theoretical concerns that new thrombus may develop in the time interval between the CT scan and catheter ablation procedure, the risk is likely to be low if anticoagulation is uninterrupted [299].

A survey of the writing committee members showed that 80%, 65%, and 10% currently perform TOE, CT, and ICE respectively, as part of their routine AF ablation strategy. For the specific purpose of excluding LA thrombus, 95% of members nominated TOE as their preferred strategy (Recommendation 6.1).

Recommendation	Class	Level of Evidence
6.1 Transoesophageal, intracardiac echo or CT should be considered to exclude pre-existing thrombus in patients with CHA_2DS_2-VA score ≥ 1 undergoing catheter ablation of AF without adequate preprocedural anticoagulation.	2A	C

Anticoagulation for AF Ablation

Contemporary guidelines generally recommended that patients undergoing AF ablation have at least 3 weeks of therapeutic anticoagulation prior to the procedure [11,12,300]. The advice is based on the duration of anticoagulation before cardioversion without TOE guidance, although there are very few clinical trials in this area and certainly none with respect to duration of anticoagulation prior to ablation [301–303]. There was discussion amongst the group as to the need for anticoagulation and screening for LA thrombus in patients in sinus rhythm with a CHA_2DS_2-VA of zero (0). Although most working group members perform imaging to exclude LA thrombus, it was

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acknowledged that some operators do not, given the low–risk LA thrombus risk. There was discussion supporting the merits of a trial of anticoagulation prior to ablation, to ensure that anticoagulation is tolerated without bleeding.

With respect to the choice of anticoagulant, most AF guidelines suggest that a DOAC is preferred over vitamin K antagonists for prevention of stroke and systemic embolism. There is abundant evidence that DOACs are non-inferior or superior to warfarin in stroke prevention in patients with AF and that bleeding is reduced or similar to warfarin in this population [304,305,306]; however, DOACs would generally be recommended in preference to warfarin in patients undergoing ablation.

Recommendation	Class	Level of Evidence
6.2 In anticoagulated patients, AF ablation should be performed with minimal or no interruption of anticoagulation.	2A	B

Two studies have demonstrated that uninterrupted DOAC therapy is associated with similar or less bleeding compared with vitamin K antagonists in patients undergoing AF ablation, without an increase in ischaemic events [307,308]. The RE-CIRCUIT study showed that uninterrupted dabigatran had much lower bleeding rates than uninterrupted warfarin with no increase in ischaemic events post ablation. Most patients received dabigatran less than 4 hours prior to the procedure. Uninterrupted anticoagulation was preferable to discontinuation of anticoagulation; however, some operators omit a dose or two of DOAC immediately prior to the ablative procedure, although there are no trial data to support this approach. If an ablation was to be performed whilst on a vitamin K antagonist, it was recommended the INR be in the target range of 2–3 before and during the procedure. Irrespective of background anticoagulation, it was recommended intravenous heparin be administered prior to or immediately following transseptal puncture with a target ACT of ≥300 seconds. It was noted that this was using the current haemostat machines and that new ACT measurement devices are becoming available where the target ACT may vary from above.

Recommendation	Class	Level of Evidence
6.3 It is recommended that the therapeutic anticoagulation be continued for at least 6 weeks after AF ablation.	1	B

Current recommendations from most international guidelines recommend that therapeutic anticoagulation be continued for at least 6–8 weeks post ablation [11,12,300], even if the ablation is successful, to reduce risk of stroke or systemic embolism from thrombus formation on the healing atrial tissue after ablation and /or atrial stunning with reduced contractile function post reversion to sinus rhythm. However, the group felt that, in select CHA_2DS_2-VA 0 PAF patients, anticoagulation could be discontinued as early as 4 weeks, similar to treatment discontinuation recommendations post Direct Current (DC) cardioversion.

Recommendation	Class	Level of Evidence
6.4 It is recommended that therapeutic anticoagulation be continued after AF ablation independent of the apparent success of the procedure, if the CHADS-VA score is ≥2.	1	C

There are no RCTs looking at duration of anticoagulation post AF ablation in patients whose CHA_2DS_2-VA score indicates an increased risk of stroke and systemic embolism. However, in general terms, if the patient's CHA_2DS_2-VA score is ≥2, anticoagulation is recommended indefinitely to reduce the risk of thromboembolic stroke, even if the ablation is deemed to have been successful. This recommendation for long term anticoagulation is derived from the AF literature [11,12,300], mindful of a lack of temporal association between AF events and stroke. Long-term anticoagulation is recommended if patients have a history of AF and a CHA_2DS_2-VA score ≥2. There was some discussion as to whether anticoagulation could be discontinued in patients whose CHA_2DS_2-VA score was ≥2 who appeared to have no recurrence of AF years after ablation, but this would only be considered if the risks of continuation of anticoagulation outweighed the benefits.

Management of Thromboembolic Complications

General considerations

Embolic complications can result from several mechanisms including dislodgment of pre-existing LA thrombus, embolisation of *de novo* thrombus or 'char' related to RFA or air embolisation. Based on recent meta-analyses and real-world practice, the risk of clinically apparent stroke/transient ischaemic attack following catheter ablation is estimated at 0.5%–1% [309–311]. Most events occur during the procedure or within 48 hours of ablation [312,313].

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Prompt diagnosis of cerebral thromboembolic events is critical to management. Delays may occur because neurological symptoms/signs may be non-specific following general anaesthesia. A high index of suspicion is required, with early referral for cerebral imaging (MRI having higher sensitivity for identifying acute ischaemia) and specialist neurological evaluation. Subject to local availability, interventional acute thrombus retrieval may be considered depending on the timing of stroke, severity of deficit, location and size of the stroke (and associated risk of haemorrhagic transformation). Thrombolysis is generally contraindicated as the patients are anticoagulated.

Asymptomatic cerebral embolism (ACE) refers to the presence of acute ischaemic cerebral injury without clinical symptoms. The presumed mechanism is the occlusion of small arteries by embolic material including thrombus and air. Lesions are usually identified by diffusion-weighted MRI. Although ACE is not limited to any modality for ablation [314], initial reports have centred on the high incidence of ACE following non-irrigated circumferential multielectrode ablation catheters utilising phased RF energy [315]. The incidence of ACE varies widely between reports depending on the imaging protocol used, but it may exceed 50% if high-resolution diffusion-weighted imaging is used [310,316,317]. Follow-up MRI studies suggest that most lesions resolve spontaneously [318]. Recent reports have not demonstrated an association between ACE and cognitive impairment.

Air embolism is a known but rare complication of catheter ablation [319], minimised by meticulous sheath management. Massive air embolism causes profound hypotension and bradycardia, often due to air embolism in the right coronary artery, and/or circulatory obstruction by air in the LV and ascending aorta. Supportive management includes intravenous fluids, pacing, and supplemental high flow oxygen, the latter theoretically increasing nitrogen resorption from the air bubbles into blood, thus reducing their size. The patient should be kept in a flat supine position to prevent cerebral air embolism. Direct aspiration of air using catheters has also been reported [319,320]. In the event of cerebral air embolism, early hyperbaric oxygen therapy reduces the size of air emboli and, also, limits ischaemic reperfusion injury [321,322].

An important differential diagnosis of acute stroke in the post-ablation setting is the phenomenon of *de novo* migraines related to transeptal access (with a reported incidence of 0.5%–2.3%) [323,324]. Patients often present within 1 week of ablation, with self-limiting visual aura such as fortification spectra, scintillating scotomas, and zigzag lines which may or may not be accompanied by headache [325]. Cerebral MRI and ophthalmic evaluation are normal, excluding vascular aetiology. The exact mechanism is unknown but may relate to cerebral microembolism due to migration of platelets or thrombin, or the exposure of the cerebral circulation to vasoactive factors such as 5-hydroxytryptamine via the iatrogenic interatrial shunt. Symptoms usually resolve completely within 3 months without specific treatment, likely related to spontaneous closure of the iatrogenic atrial septal defect [324].

Minimising Risk of an Oesophageal Injury

Atrio-oesophageal fistula (AOF) is a rare but serious complication from thermal AF ablation. While the incidence is reported at 0.03%-0.08%, this may be underestimated due to misdiagnosis or under-reporting [326–328]. AOF is a life-threatening connection between the atrium and oesophagus because of oesophageal injury during ablation, due to the close proximity of the oesophagus behind the posterior wall of the left atrium. The exact mechanisms are incompletely understood, but include direct thermal injury, gastro-oesophageal acid reflux, super-imposing infection, ischaemic injury and damage to the peri-oesophageal vagal plexus [11,326,329]. AOF leads to sepsis, stroke, and carries a very high mortality rate (close to 100% if undiagnosed or managed conservatively. AOF has been reported to occur across various ablation modalities including radiofrequency, cryoablation, surgical ablation and high-intensity focussed ultrasound [326]. An international registry reported an incidence of AOF of 0.038% with RF vs 0.0015% with CB (p-value$<$0.0001) in 553,729 AF ablation procedures with an overall mortality of 66% [330].

Visualisation of the oesophagus

The oesophagus may be visualised several ways, including from the location of the oesophageal temperature monitor (OTM), through fluoroscopy, barium, ICE, or integrating the oesophageal position from CT to the electroanatomical mapping system [11,329,331]. It is important to remember that the oesophageal position may move during the procedure and may differ from when imaged on preprocedural CT, with real-time visualisation preferred [332]. ICE could aid in improving OTM positioning [329,333]. With visualisation of the oesophagus, the ablation lesion set may be tailored to minimise ablation in close proximity to the oesophagus.

Oesophageal temperature monitoring

Luminal OTM is a useful tool to monitor for excessive heating or cooling of the oesophagus during thermal ablation (Recommendation 6.5). The temperature monitoring probe also provides an indication of the anatomical course of the oesophagus. Significant temperature rises during radiofrequency (e.g. 39/40 °C or acute rises), or decreases during cryoablation trigger an alarm which prompts interruption of ablation [11,329,331]. Multi-sensor oesophageal temperature probes are designed to cover a larger surface area and may provide a better thermodynamic profile compared with single-sensor probes [334]. However, some studies have found an increased number of thermal lesions with multi-sensor probes, potentially due to an "antenna" effect [334–336]. If a single-sensor probe is used, the sensor should

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be repositioned to reflect the closest point to the ablation catheter. Linear probes do not provide an estimate of the width of the oesophagus. The OTM probe and site of oesophageal temperature heating may be visualised and tagged on the electroanatomical map.

Although OTM is commonly used in AF ablation procedures, recent studies have shown mixed outcomes including two randomised studies which did not demonstrate a difference in oesophageal lesions with the use of OTM [337,338,339,340]. A surrogate endpoint of oesophageal injury on endoscopy has been used in clinical trials, given the rare incidence of AOF. The routine use of OTM is variable given the additional expense, rare incidence of AOF, and lack of supportive evidence from clinical trials.

Recommendation	Class	Level of Evidence
6.5 Oesophageal temperature monitoring may be considered during thermal ablation to minimise the risk of oesophageal injury.	2B	C

High-power short-duration ablation

In recent times. there has been a shift to HPSD ablation, to deliver much higher power and energy in short durations, resulting in significantly shorter procedure times [198]. This is based on the concept of reducing deeper conductive heating toward preferential superficial resistive heating, with the aim of shallower broader lesions [341,342]. Recent meta-analyses have demonstrated no significant differences in oesophageal injury, or in major and total complications with HPSD compared with conventional RFA [196,343,344]. In the HiLo HEAT study patients with multi-sensor OTM randomised to 40–50 W ablation at the posterior wall had a similar rate of oesophageal temperature alerts and low incidence endoscopically-detected oesophageal lesions (EDOL) compared with 25 W [345]. In the AI-HP ESO II study, among patients undergoing HPSD ablation, the incidences of EDOL with and without the use of OTM were comparably low [341]. In a small, randomised study, HPSD ablation led to better freedom from AF but a trend towards a larger number of asymptomatic cerebral events detected on MRI [198].

Proton pump inhibitors

Proton pump inhibitors (PPIs) can be used with the aim of preventing subsequent oesophageal ulcer erosion from gastro-oesophageal reflux [11]. Prophylactic use of PPIs is commonly practiced, although randomised data are lacking [346]. It is important to note that AOF cases have been reported despite the use of PPIs [326]. Physicians may choose to commence PPIs leading up to ablation, or intravenously on the day of ablation, and to continue up to 4 weeks post-ablation [11,326].

Other approaches and factors

Mechanical displacement aims to move the oesophagus away from the site of ablation at the posterior LA wall. This may be achieved through specially designed instruments, with the initial studies performed using a TOE probe [329,331,347–352]. In the DEFLECT GUT study, patients undergoing AF ablation with mechanical oesophageal deviation using a nitinol stylet within an orogastric tube had significantly less OTM temperature rises [350]. This technique may be promising but currently is not widely practiced. Care must be taken as oesophageal injury may occur secondary to displacement [352]. The TOE probe itself could also contribute to oesophageal injury [353].

Several studies have examined the effect of oesophageal cooling to theoretically reduce the oesophageal temperature and, hence, any thermal injury. A recent meta-analysis indicated that oesophageal cooling reduced the severity of lesions resulting from RFA [354]. The use of general anaesthesia appears to be associated with an increased risk of EDOL compared with conscious sedation [329,333,355], perhaps due to decreased oesophageal motility.

Pulsed-field ablation is selective to the myocardium and as such should avoid collateral injury to oesophageal smooth muscle, which has a higher threshold for injury to these electrical currents. To date, there have been no reports of AOF [279]. Nor of oesophageal lesions detected by late gadolinium enhancement on cardiac MRI [356].

Management of Atrial Oesophageal Fistula

Atrial oesophageal fistule (AOF) is one of the most devastating complications of AF ablation, due to its high mortality. Management includes education of patients and treating doctors to increase awareness, early diagnosis and the requirement for emergency surgery.

Presentation and awareness

Patients with AOF usually present with varied symptoms that are non-cardiac, leading to a delay in diagnosis. The most common initial symptom is unexplained fever. Other symptoms include neurological (72%), with focal neurology, seizure, confusion, and syncope, and gastrointestinal (41%), including haematemesis and melaena, dysphagia, odynophagia, nausea, and vomiting [326]. About one-third have cardiac symptoms, including chest pain, dyspnoea and palpitations [326]. Patients with AOF typically present 2–4 weeks post ablation. The median time from procedure to

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clinical presentation of AOF was 21 days (range 0–60 days) [326,357].

Hence, patients who present with unexplained fever, neurological or gastrointestinal symptoms within 2-months of AF ablation should raise the suspicion of AOF [326,358]. All patients undergoing AF ablation should be educated regarding this potential serious complication, and patients, family physicians and emergency physicians should be informed to contact the treating electrophysiologist/cardiac surgeon or ablation centre *urgently*, if patients present with suspicious symptoms [326,358].

Diagnosis

The investigation of choice is contrast CT scan of the chest [326]. However, it is important to note that radiological findings can be non-specific, and initial scans may be normal [358]. When findings from CT chest were examined in a series of 126 patients with AOF, a clear diagnosis of AOF (fistula/perforation) was only detected in about one-third (35%) [358]. The spectrum of radiological abnormalities include: **A**ir (mediastinum/LA), **E**ffusion (pleural/pericardial), **F**istula/perforation, and **T**hickening (oesophagus/LA)—"***AEF-T****ests*" [358].

Abnormal findings on transthoracic echocardiography include pericardial effusion, LA thrombus, air in the LA and wall akinesia [326,358]. Blood cultures may be positive in a significant number of patients when the initial CT scan was normal [358]. *Streptococcus* species are frequently isolated in blood cultures, and other organisms have included bacteria from the oral cavity and gastrointestinal tract [326,358]. Abnormal CT and MRI brain imaging findings, particularly diffuse air emboli and ischaemic changes, should raise suspicion of this complication [326,357,358]. An oesophagram can be complementary in demonstrating contrast extravasation, although sensitivity is low [11,326,358].

Endoscopy should be avoided in suspected cases of AOF, as it can lead to acute clinical deterioration [11,326,358]. In particular, insufflation of the oesophagus with air can result in air emboli and stroke [11,326,358]. Transoesophageal echocardiography, similarly, carries the risk of acute clinical deterioration [11,326,358,359].

Treatment

Atrial oesophageal fistula is a surgical emergency that warrants urgent surgical intervention. Overall mortality has been estimated at 55%, but if left untreated or managed conservatively, mortality is 97% [326]. Surgery offers the best chance of survival, with an associated mortality of 33%. Endoscopic intervention, such as stenting, is less effective with a mortality rate of 65% [11,326]. Neurological symptoms and gastrointestinal bleed are independent predictors of increased mortality [326].

Urgent surgical management is the mainstay of successful intervention [11,326,358,360,361]. Once the condition is diagnosed, surgery should not be delayed due to risk of ongoing emboli and sudden acute deterioration. A right lateral thoracotomy is the preferred approach. Cardiopulmonary bypass is performed via cannulation of the femoral vessels. Cardioplegia and aortic cross clamping may be required for localising the atrial lesion and avoiding air embolism. An intercostal muscle flap is required to repair the oesophageal tear and prevent future recanalisation [11,326,358,360,361]. The atrial lesion can be repaired with an autologous or bovine pericardial patch. The atrial lesion is usually repaired first prior to repair of the oesophageal lesion. At the most severe end of the spectrum, oesophageal resection may be necessary with a second-stage gastric tube operation.

Oesophageal stenting has been offered in patients deemed unfit for surgical intervention or as part of hybrid management if early surgical intervention is not available. While yielding marginally improved outcome compared with conservative management, overall mortality was still very high at 65%, and may be closer to 100% in cases of true AOF compared with oesophageal perforation or oesophageal pericardial fistula [11,326,358,360]. Conservative management includes treatment of sepsis with antibiotics and aggressive chest tube drainage [11,326,360], although this is palliative. Only one patient in a series of reported cases survived conservative management with intravenous antibiotics but sustained significant neurological deficits [326,359].

Approaches to Minimise Risk of Cardiac Tamponade

Cardiac tamponade is the most common life-threatening complication in AF ablation [11,362]. The incidence of cardiac tamponade has been estimated at 1.2%, from worldwide surveys of AF ablation [11,285,311,362]. Reported rates of cardiac tamponade in randomised trials comparing uninterrupted DOAC and warfarin vary between 0% and 1.9% [307,308,363–366]. Risk factors include female sex, obesity and absence of ICE [366–368]. The common causes of cardiac tamponade during AF ablation are (1) difficult transseptal punctures; (2) direct trauma/perforation; and (3) overheating due to excessive ablation or complicated by steam pops [11,369].

A standardised approach to performing the transseptal puncture, with trained staff meeting the recommended credentialing requirements (see Section 10, *Training Requirements*) is crucial to minimise risks of complications. Fluoroscopy, LA pressure monitoring, use of contrast injection to confirm access to the LA and use of echocardiography to guide transseptal access are useful adjuncts. Transoesophageal echocardiography (TOE) is useful to image tenting of the inter-atrial septum and to direct the needle away from the aortic root or posterior LA [370,371]. In cases of severely aneurysmal interatrial septum, the RF needle or

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diathermy may be additional methods to gain LA access, rather than use of excessive force [372,373]. It is important to recognise when the contrast stains the posterior LA wall, pericardial space, pericardial recesses or aortic root [370,371].

Contact force is a useful tool to measure the degree and direction of contact of the catheter tip on the LA wall, and thus avoid excessive forces. The incidence of cardiac tamponade did not differ in a randomised trial comparing force-sensing catheters versus standard irrigated tip catheters, although this may be underpowered given the low incidence of tamponade [195]. Care should be taken when manoeuvring near the thinner parts of the LA, such as the LA appendage, roof and posterior wall. Operators should beware of using excessive power, temperature or CF, and be watchful for any impedance changes or steam pops [11,369].

Management of Cardiac Tamponade

Cardiac tamponade presents with hypotension. An arterial line for blood pressure (BP) monitoring during the procedure helps to detect acute changes. Access to echo imaging is critical to provide rapid assessment of the pericardium in patients with unexplained hypotension [11,370,371]. Fluoroscopy is useful to detect any loss of excursion of the lateral border of the cardiac silhouette in the left anterior oblique (LAO) view. Once it is diagnosed, cardiac tamponade is managed by reversal of anticoagulation and immediate pericardiocentesis. Unfractionated heparin should be reversed with protamine in the case of increasing pericardial effusion. For patients on dabigatran, idarucizumab is a monoclonal antibody fragment that rapidly reverses the anticoagulant effects of dabigatran [374]. Having the agent preapproved and readily accessible is advantageous. For other DOACs (apixaban and rivoraxaban), prothrombin complex concentrates (e.g., prothrombinex-VF) and fresh frozen plasma may be used in consultation with haematology [375]. Andexanet alfa may be used to reverse the effects of factor Xa inhibitors, if available [376]. However, use of these reversal agents has the risk of creating a prothrombotic state that may lead to embolic sequelae. In general, use of DOAC reversal agents is reserved for ongoing bleeding that does not stop after pericardiocentesis and drainage. For patients on warfarin, prothrombin complex concentrates may be used for rapid reversal; or, fresh frozen plasma when prothrombin complex concentrates are unavailable [377].

A pericardiocentesis set should always be readily available in the laboratory/theatre. Percutaneous drainage, typically via subxiphoid access, should be immediately performed, guided by fluoroscopy or echocardiography [11,378,379]. Access to the pericardial space can be confirmed by ensuring that the guidewire wraps around the left and right cardiac silhouette in the LAO projection [379]. Once access is confirmed, a pigtail catheter may be inserted following the dilator, which is then connected to a 3-way tap and drainage bag. With drainage, the BP should improve immediately in line with echocardiographic demonstration of decrease in effusion size. The drainage catheter is usually left in situ for at least 12 hours, and should be continuously monitored for ongoing bleeding [11]. Following removal of the drainage catheter, the timing of recommencement of anticoagulation needs to be assessed on a case-by-case basis, balancing the risks of recurrent bleeding (factors including type of lesion associated with tamponade and whether this was repaired, blood collected from drainage catheter, coagulation profile, cardioversion from persistent AF during the procedure, and HAS-BLED score) with the risks of thromboembolic stroke (factors including CHA_2DS_2-VASc score, AF burden and LA size) [11,367]. Surgical repair is not usually required and reserved for ongoing blood loss despite percutaneous drainage, or suspicion of a tear [11,380].

Cross-matching, transfusion or cell-salvage may be considered in cases of ongoing blood loss.

Approaches to Minimise Risk of Phrenic Nerve Injury

Phrenic nerve injury (PNI) is a recognised complication of catheter ablation of AF [381]. Right PNI is much more frequent than left PNI, since the right phrenic nerve lies closer to the right pulmonary veins. PNI may be asymptomatic or present with dyspnoea (particularly when supine), cough, and hiccough [382].

Although PNI has been described following both radiofrequency (RF) and cryoballoon (CB) ablation, the incidence is much higher following CB ablation. The prevalence of PNI at hospital discharge following CB ablation was 2.7% and 1.6% in the FIRE AND ICE trial and FREEZE-AF trials, respectively, whereas no cases of PNI were reported in the RFA group [383,384]. The majority of phrenic nerve injuries recover completely within days or weeks, but rarely can persist [382,385]. With contemporary monitoring, the incidence of persistent PNI is $<0.5\%$ [386].

Prevention of Phrenic Nerve Injury

Radiofrequency or CB energy should be delivered to the PV antrum rather than within the PV to decrease the risk of PNI. When undertaking RFA, high output stimulation of intended ablation sites can establish the proximity of the phrenic nerve and lessen the risk of PNI.

During cryoballoon ablation, the phrenic nerve should be paced from within the subclavian veins or SVC. Diaphragmatic contraction is monitored to detect a reduction in phrenic nerve function so that energy can be interrupted before significant damage occurs (Recommendation 6.6).

Diaphragmatic contraction can be monitored by palpation, fluoroscopy, ICE, and monitoring the diaphragmatic compound motor action potential (CMAP) or the venous pressure wave recorded from the side-arm of the sheaths in the femoral veins used for catheter insertion [387,388]. Monitoring using palpation requires no extra equipment but gives less warning of impending injury. CMAP and venous pressure monitoring are inexpensive and effective adjunctive techniques.

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Rapid cryoballoon deflation using the "double stop (immediate deflation)" technique results in rapid warming of the pulmonary veins and should be used if PNI appears imminent [389]. Using this technique, Ghosh et al. reported that all cases of PNI in 130 consecutive patients had recovered before leaving the procedure room [389].

Recommendation	Class	Level of Evidence
6.6 Phrenic nerve monitoring is recommended during cryoballoon isolation of the pulmonary veins.	1	B

Gastroparesis

Gastroparesis or delayed gastric emptying has been described following RF and CB ablation [390,391]. The probable mechanism is damage to the peri-oesophageal fibres of the vagus nerve lying anterior to the oesophagus and posterior to the left atrium [392]. These nerves supply the gastric antrum and pyloric sphincter.

Most patients with gastroparesis are asymptomatic or have minimal symptoms [393]. Symptoms include abdominal bloating, belching, weight loss, anorexia, and halitosis [394]. Most cases recover within a few months [393,394]. Both endoscopy and gastric emptying studies can be used to confirm the diagnosis. One study performed in 27 mostly asymptomatic patients undergoing RFA found an incidence of 48% [395], while another study reported an incidence of 17% in 140 patients undergoing CB ablation [396].

No effective method of preventing gastroparesis has been proven. Suggested treatments for gastroparesis include smaller meal sizes, prokinetic drugs such as erythromycin, metoclopramide and domperidone, endoscopic injection of botulinum toxin into to the pyloric sphincter, and endoscopic or surgical myotomy of the pyloric sphincter.

Minor Complications

Groin bleeding

Multiple femoral venous punctures in anticoagulated patients are required for AF ablation and may result in vascular complications estimated at up to 1.9% [11,309,362]. These include groin haematoma, retroperitoneal haematoma, pseudoaneurysm, and arteriovenous fistula. Adequate haemostasis post sheath removal is essential to reduce complications, and avoid prolonged hospital stay.

The approach to femoral venous access can impact the risk of complications. Small medical branches of the femoral artery can cross the femoral vein more inferiorly, and may be transsected prior to venous access, with potential for a pseudoaneurysm or arteriovenous fistula. A more superior approach has an increased risk of retroperitoneal haematoma.

Ultrasound-guided puncture is a useful method to avoid major and minor groin complications. In particular, it allows direct visualisation of arterial and venous anatomy, and evaluates the anatomic variants of the vessels [266,397,398]. Prospective studies have demonstrated a significant reduction in total vascular complications with ultrasound guidance [397] (Recommendation 6.7).

Recommendation	Class	Level of Evidence
6.7 Ultrasound guided vascular access is recommended to reduce femoral vascular complications.	1	B

Once the sheaths are removed, manual pressure is applied for haemostasis. A figure-of-eight groin stitch may be used and removed 4 hours later. Compared with manual pressure, the groin stitch reduces the incidence of major haematoma and duration of bed rest [399]. It has been shown to be safe and efficacious in achieving immediate haemostasis with larger bore catheters compared with manual compression [400]. Venous closure devices can be used, which allow earlier mobilisation, and may reduce groin complications [401,402].

Ultrasound imaging of the groin should be considered if there is ongoing bleeding, or significant pain or swelling, to exclude a pseudoaneurysm or an AV fistula, which may require further intervention with an injection of thrombin or, rarely, surgical repair. Most vascular complications are managed conservatively, with manual pressure or ultrasound-guided compression. Anticoagulation should generally be continued.

Pericardial pain

Mild pleuritic chest pain is not unusual in the days following AF ablation and typically responds to paracetamol or colchicine. Pericarditis with fever and ECG changes is rare. Epicardial inflammation from catheter ablation is thought responsible. Occasionally, more extensive inflammation may cause ongoing pericardial chest pain and/or a pericardial effusion. Dressler syndrome and constriction have been reported, albeit rarely [403].

The ECG is usually normal. Echocardiography may detect pericardial fluid, and can exclude other causes of chest pain, such as ischaemia with associated regional wall motion abnormalities or raised right heart pressures seen with a pulmonary embolus. Treatment is supportive, aiming to manage symptoms, with analgesia. Colchicine can be effective.

Hypotension in the first 12 hours post procedure

The approach to hypotension post AF ablation procedure

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should be stepwise and systematic, to promptly diagnose and treat the underlying cause. It can be a sign of a potentially life threatening complication such as cardiac tamponade [404].

An urgent echo is generally indicated to assess valvular and ventricular function and to identify a pericardial effusion as a cause of hypotension (Recommendation 6.8). A major groin bleed or retroperitoneal haematoma may also cause hypotension. The venous access site should be reviewed with palpation, auscultation, and imaging with ultrasound, if there is significant swelling, bleeding, or discomfort.

Anaphylaxis following anaesthetic agents or contrast may be associated with a rash and bronchospasm. If present, steroids, antihistamines and adrenaline are used. A blood sample should be sent for a serum tryptase level.

Other rare causes of hypotension to consider include acute pulmonary embolism (RV dilated on echo) and oesophageal haemorrhage/perforation. A chest CT is valuable to exclude these causes.

A vagal reaction is the most common explanation for hypotension post AF ablation. Some patients may have vagal nerve injury following either RF or CB ablation [218,405]. The ganglionated plexi sit within epicardial fat pads, close to the pulmonary vein–atrium junctions and may be modified during ablation. Additionally, acute pain and urinary retention can precipitate a vagal response.

More prolonged vagal reactions can be seen in the 6–12 hours post procedure, with hypotension and low heart rate. Intravenous fluids, atropine and vasopressor support may be indicated.

Recommendation	Class	Level of Evidence
6.8 An echocardiogram (echo) should be considered in patients with unexplained hypotension post AF ablation, to exclude cardiac tamponade.	2A	C

7. Anaesthesia for AF Ablation

Where

Catheter ablation for AF is an invasive procedure. Complications of the procedure have been discussed in section 6, *Approaches to Minimise and Manage Complications Related to AF Ablation*. Whilst uncommon, some complications require cardiac surgical support. The incidence of complications requiring cardiac surgery was reported in a recent Australian study as ranging from 1 in 400 to 1 in 1,400 cases [406]. As such, centres undertaking AF ablation should have access to on-site cardiac surgery services, or alternatively, develop local networks and retrieval strategies. High-risk patients should be cared for in high-volume centres with immediate access to cardiac surgery services, as well as high-dependency or intensive care facilities.

When: Optimisation

Preprocedural planning in communication with the patient and electrophysiologist aims to minimise risks, and to inform patients of anaesthesia-related procedures and possible complications. A separate anaesthetic consultation is of value for patients with multiple coexisting comorbidities or moderate-to-severe cardiovascular or respiratory illness (Recommendation 7). Preoperative optimisation aims to maximise patient safety during sedation or GA [407]. As much as possible, heart failure [408,409] and ventricular rate should be optimised [410,411]. The potential benefits of cessation of anti-heart failure therapy needs to be carefully considered in patients at risk of symptomatic decompensation or significant elevation of their ventricular rate prior to anaesthesia. Patients with severe pulmonary hypertension are at high risk during GA and deep sedation (DS) [412]. Careful evaluation of the benefit of catheter ablation should be weighed up against anaesthetic risks in this scenario [413].

Sodium-glucose co-transporter 2 inhibitors (SGLT2i) are increasingly being prescribed [414,415]. Due to the risk of developing euglycaemic diabetic ketoacidosis (euDKA) in the perioperative period, the Diabetes Society of Australia and the New Zealand Society for the Study of Diabetes have strongly recommended cessation for at least 3 days (2 days prior and the day of the procedure) [416]. This may require adjustment of other glucose-lowering therapies and periprocedural monitoring of blood glucose and ketones while fasting and prior to discharge [417].

Angiotensin converting enzyme inhibitors (ACEi) and angiotensin receptor blockers (ARBs) are commonly taken by patients undergoing AF ablation. Withholding ACEi/ARBs on the morning of non-cardiac surgery has been associated with reduced intra-operative hypotension, with no effect on mortality or major adverse cardiac events [418]. It is therefore reasonable to withhold ACEi/ARBs on the morning of the procedure.

How: Conscious Sedation, Deep Sedation and General Anaesthesia

The anaesthetic approach is tailored to the needs and preferences of the patient and the electrophysiologist. The use of conscious sedation (CS) combined with local anaesthesia is well described and widely utilised [419,420]. Conscious sedation as defined by the Australian and New Zealand College of Anaesthetists' (ANZCA) professional standard 9 [421] improves patients' tolerance of uncomfortable or painful elements of the procedure and avoids the complications (e.g., snoring, hypoxia, loss of airway, hypotension) associated with deeper levels of sedation [422]. However, the duration and complexity of AF ablation combined with individual patient factors (e.g., pain, anxiety, obesity, OSA) frequently results in a greater need for DS or GA [419,420]. Furthermore, the association between intraprocedural pain and patient satisfaction [423] has resulted in increased utilisation of anaesthesiologists to provide either DS or GA [420,424]. Retrospective analyses of standardised approaches using propofol and midazolam in

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relatively healthy (normal EF, BMI 26–30) patients have demonstrated that CS is both feasible and safe [425,426].

In Australia/New Zealand, GA is the most commonly used approach [420], and is both safe and efficient [427]. General anaesthesia offers distinct advantages over CS and DS, and may improve ablation outcomes. Endotracheal intubation makes possible the use of intraprocedural TOE, mid-oesophageal temperature monitoring (refer to section 6, *Approaches to Minimise and Manage Complications Related to AF Ablation*) and greater control of respiratory movement which assists catheter stability. A randomised comparison of GA and CS for 257 consecutive patients with paroxysmal AF demonstrated greater freedom from AF recurrence (88% v 69% log rank, p=0.001), lower PV reconnection (19% vs 42%, p=0.003) and shorter procedural duration (2.4±1.4h vs 3.6±1.1h; p<0.001) in the GA group [428]. The improved outcomes may have resulted from greater catheter stability [429] and CF [430]. A retrospective comparison of GA and CS for persistent AF has also demonstrated greater freedom from recurrent atrial arrhythmia with GA at one year (63.9% v 42.9%, HR 1.87, 95% CI 1.23–2.86, p=0.002) [431]. Two meta-analyses comparing GA/DS with CS have reported reduced AF recurrence [432,433]. Additionally, the complication rate was lower in the GA/DS group (1.7% vs 3.0%, p=0.07) [433].

Ventilation

Catheter stability is a critical determinant of lesion delivery and procedural success and is subject to respiratory motion. High frequency jet ventilation (HFJV) may minimise respiratory motion and has been used in some centres [434,435]. However, HFJV equipment is not widely available and requires specific training. Additionally, HFJV precludes the use of volatile anaesthetics, continuous end-tidal carbon dioxide ($ETCO_2$) monitoring and may increase the risk of intraoperative hypotension, respiratory insufficiency, barotrauma and pneumothorax [436]. Alternative ventilation strategies include low-volume high-frequency (LVHF) ventilation and intermittent apnoea. Both of these techniques utilise the standard anaesthetic ventilator and do not require specific training. It is noted that LVHF ventilation may also cause barotrauma and pneumothorax; hence, careful monitoring is required.

Although LVHF ventilation is commonly employed, the evidence supporting this technique is limited. A single–centre cohort study utilising a ventilation strategy (200mL tidal volumes, 30 breaths/min) resulted in significantly shorter procedure and ablation times [437]. The literature in this area has been summarised in a systematic review [438].

Intermittent apnoea may also be considered. Kumar and colleagues studied 12 patients undergoing PVI under GA [439]. Standard mechanical ventilation (600mL tidal volumes, 12 breaths/min) was alternated with 30 seconds of apnoea. Average force was higher during apnoea when compared with periods of ventilation. Anatomically, the greatest benefit was seen at the roof and the carina of the right pulmonary veins.

Anaesthesia Equipment

Catheter ablation for AF is very often undertaken outside of the main operating theatre complex. The minimum requirements for facilities and equipment have been defined by ANZCA (PS55A, 2021) [440]. In addition, many of the patients presenting for AF ablation have risk factors for difficult airway management. As such, equipment for difficult airway management should be immediately available including video laryngoscopes (ANZCA, PS56 2021) [441]. These guidelines should be used by centres developing an AF ablation service.

Anaesthetic Considerations

The anaesthetic goals for AF ablation centre around patient safety, patient satisfaction, and provision of effective procedural conditions. Haemodynamic instability and the need for pharmacological support (vasopressors and inotropes) is common. Anaesthesiologists should be aware of the haemodynamic challenges associated with the use of isoprenaline, adenosine and pacing. Arterial access and monitoring should be strongly considered.

The combination of obesity, OSA, metabolic syndrome (hypertension, insulin resistance, hypercholesterolaemia), AF, and heart failure can be considered a patient group at significant risk for complications relating to sedation and anaesthesia. Comprehensive guidelines regarding the preoperative evaluation of patients with known or suspected OSA [442] have been reviewed with specific consideration of patients with cardiovascular disease [443]. These patients are likely to desaturate and require airway manoeuvres such as chin support and high flow nasal oxygen during sedation [442]. Additionally, OSA is an independent risk factor for difficult mask ventilation and intubation [444]. Patients with OSA should be encouraged to use their CPAP device and bring it to hospital [442,443]. The use of the "ramped" position (tragus of the ear level with the sternum) during anaesthetic induction of obese patients may improve oxygenation, prolong time to desaturation (apnoea) and optimise conditions for intubation [445].

Intraprocedural mapping of the right phrenic nerve may be performed in RFA and is typically performed in cryoablation procedures. This precludes the use of long-acting neuromuscular blockade.

The administration of heparin during AF ablation is essential. Clear communication between the electrophysiologist and the anaesthesiologist regarding administration and monitoring is mandatory. Protamine may also be required at completion.

The insertion of an oesophageal temperature probe may be required during the procedure. The probe position is adjusted throughout the procedure to align with the ablation catheter.

Routine administration of antiemetic medication should be considered, as postoperative nausea and vomiting may be problematic in patients being nursed flat after the procedure. Electrophysiologists should be aware of the common practice of dexamethasone administration which is considered to be both safe and effective [446,447]. Urinary catheterisation should be considered after lengthy cases or in selected

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patients with urological issues. Postoperative neurological assessment is a critical component of the procedure. The anaesthetic technique employed should promote rapid emergence, allowing for neurological assessment. Anaesthesiologists should have a low threshold to escalate care and monitoring if concerned about neurological status.

Who

Anaesthesia services should be provided by anaesthesiologists who are familiar with interventional cardiology and, more specifically, electrophysiology procedures. Additionally, anaesthesiologists should be experienced in the management of patients with complex cardiovascular disease. Subspecialist cardiac anaesthesiologists should be strongly considered for high-risk cases (e.g., decompensated cardiac failure, severe pulmonary hypertension, right ventricular dysfunction, and complex congenital heart disease).

Transoesophageal echocardiography should only be performed by anaesthesiologists with the requisite training. Comprehensive diagnostic requirements have been defined by ANZCA Professional Guideline 46 (2014) [448]. The imaging requirements for catheter ablation include, as a minimum, excluding thrombus from the LA appendage, assessing the pericardium pre- and post-procedure, and facilitating transseptal puncture.

Patient Information

Patients should be informed of the likelihood of mild sore throat, postoperative nausea and vomiting, and airway injury. The risk of airway injury (e.g., tongue and uvula) and dental damage has been reported to be 0.7%. The use of muscle relaxants and a soft bite block ensuring no soft tissue is between the teeth prior to cardioversion has also been recommended [449]. The insertion of the TOE probe is associated with lip, dental, and pharyngeal injuries [450] while the manipulation of the probe may injure the oesophagus and stomach [451]. A recent prospective, national multicentre audit demonstrated an incidence of major complications (palatal injury, gastro-oesophageal injuries) of 0.08% (17/22,314 examinations), with 35% (6/17) of the cases occurring in the cardiac catheter lab [452]. The complications were directly attributed to the deaths of seven (~40%) patients.

Recommendation	Class	Level of Evidence
7. General anaesthesia or deep sedation in collaboration with a specialist anaesthesiologist is recommended for catheter ablation of AF as part of patient-centred care, and to optimise clinical outcomes.	1	B

8. Outcomes and Efficacy of AF Ablation

Consensus is lacking regarding the optimal procedural outcome measures and the definition of success after ablation [12,300]. The optimal monitoring strategy, the minimal threshold of arrhythmia duration, and the correlation with symptoms remain unclear [12].

It is well established that the method of arrhythmia detection can greatly influence recurrence rates, with intermittent rhythm monitoring methods being significantly inferior to continuous monitoring [453–455]. "Snapshot" office ECGs or symptom-based follow-up has been shown to overestimate procedural success rates due to inferior sensitivity compared with continuous monitoring provided via implantable rhythm monitoring strategies [64,456]. Detection algorithms on implantable rhythm monitoring achieve an accuracy of 99.4% compared with contemporaneous external Holter recordings [457]. In a large (n=3,593) European registry (the ESC-EHRA atrial fibrillation ablation long-term [AFA-LT] registry), the rate of freedom from AF recurrences was 50.5% among patients using an implantable cardiac monitor (ICM), while it was 65.4%, 70.6%, and 72.8% using transtelephonic ECG monitoring (TTMON), ECG, and Holter ECG, respectively [458]. More recently, analysis from the CIRCA-DOSE (Cryoballoon Versus Contact-Force Irrigated Radiofrequency Catheter Ablation) study demonstrated that simulated intermittent (x 3) short periods of monitoring had poor sensitivity to detect recurrence over 1-year post ablation (15.8% for 24-hour, and 24.5% for 48-hour ECG monitors), which improved to ~65% with 14-day monitoring.

The most widely used definition for assessing efficacy of AF therapy has been the documentation of any episode of atrial arrhythmia ≥30 seconds, without the use of any antiarrhythmic drugs. It is important to acknowledge that this 30-second benchmark is an arbitrary measurement that was established in the 2007 AF ablation consensus document, with the aim of standardising reporting practices and facilitating the comparison of new reports with previous study results, to track the progress of ablation techniques over time [284]. This strict binary definition of success is currently being challenged, as AF burden may provide a more meaningful clinical measure.

Duration of detected arrhythmia should be utilised with consideration for the method and duration of monitoring (See Table 4). There needs to be a minimum period of arrhythmia to diagnose AF, which varies depending on the above. When using clinical review and 12-lead ECG, the 10-second duration of an ECG tracing would be significant. However, when utilising continuous ambulatory monitoring, a minimum period of 30 seconds is most frequently used. Finally, when there is continuous monitoring with an ICM or cardiac implantable electronic device (CIED), based on the detection window, a 2-minute duration of AF has been suggested. However, data from the ASSERT study would

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Table 4 Monitoring Devices.

Monitoring Type/Device	Monitoring Duration	Minimum Duration of Detection	Arrhythmia Type
Clinical with 12 lead ECG	10 seconds	10 seconds	AF/AFL/AT
Intermittent continuous ambulatory monitoring	24-48 hours up to 30 days	30 seconds	AF/AFL/AT
Implantable (cardiac [CIED], or subcutaneous [ICM])	Indefinite or up to 3 years	2 minutes	AF/AFL/AT
Wearable or intermittent mobile (e.g. PPG-based applications)	N/A	N/A	AF

suggest that a minimum duration of 6 minutes (with adjudication of the electrograms) or 6 hours (relying on device timing alone) may be more appropriate [459].

AF Ablation Effect on Symptom Burden and Quality of Life

Symptomatic improvement remains the primary goal of AF ablation in most patients [11,300]. However, it is important to recognise that even in highly symptomatic individuals, episodes of AF may occur without symptoms. In addition, based on clinical trials, the evaluation of symptoms is difficult to assess. Furthermore, the improvements in QoL have not been evaluated in a sham-controlled study. Therefore, standardised assessment of QoL has been increasingly implemented in studies to evaluate catheter ablation outcomes [2,460]. Health-related quality-of-life has been measured using a number of tools (see Table 5). Some are generic and applicable to a broad range of health conditions, such as the 12- and 36-item Short-Form General Health Survey (SF-12 and SF-36) and the 5-Dimension European Questionnaire (EQ-5D) [461,462]. Disease-specific tools to quantify the symptom burden and impact of AF on quality of life have been developed and are more increasingly utilised for clinical and research purposes, including the AF symptom severity scale (AFSS) [463], the European Heart Rhythm Association score and its modified version [464,465], and the AF effect on quality-of-life (AFEQT) [466], which has shown favourable performance [467]. Importantly, data suggests that improvements in QoL persist even in those aged ≥65 years [468] and were greater in patients with longstanding persistent AF [469].

AF Ablation Effect on AF Burden

Growing evidence suggests the role of AF burden as an important outcome measure. This is increasingly preferred as more clinically meaningful than a single brief AF recurrence being defined as procedural failure. The CIRCA-DOSE study highlighted the utility of using AF burden as a measure of ablation outcome. AF freedom was determined using an implantable loop recorder (ILR) and ranged from 52% to 54%. Freedom from symptomatic recurrence was greater at 73% to 79%. Importantly, AF burden reduction after ablation was 98.4% to 99.9% [258]. The authors identified that burden and AF duration were strongly associated, with only 4% of

Table 5 Patient Reported Outcome Measures/

Patient reported outcome measures	Questionnaire	Measures
General	Short-Form General Health Survey (SF-36)	Contains 2 domains: Physical component summary (PCS) and mental component summary (MCS); Eight (8) equally weighted scaled scores, each section scores from 0–100.
	5-Dimension European Questionnaire (EQ-5D)	Contains 2 domains: Heath state measure in 5 dimensions, and overall health status using visual analogue scale.
AF specific*	AF symptom severity scale (AFSS)	Contains 10 items: AF symptom frequency, duration and severity.
	The AF effect on quality-of-life (AFEQT)	Contains 20 items: AF symptom, daily function, AF treatment concerns
	European Heart Rhythm Association (EHRA) score	Similar to NYHA scale: I=no symptoms, II=symptoms not affecting daily activity, III=severe symptoms affecting daily activity. and IV=disabling symptoms terminating daily activities.

*Other measures include the Mayo AF specific symptom inventory (MAFSI), Arrhythmia specific questionnaire in tachycardia and arrhythmia (ASTA), Arrhythmia-related symptoms checklist (SCL).

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patients with burden ≥0.1% having a longest AF episode of <60 min in duration. In addition, they identify that AF episodes of duration <1 h or burden ≤0.1% had healthcare utilisation rates comparable with patients free of AF recurrence. Significantly increased hospitalisations, emergency presentations, cardioversions, and repeat ablations were observed only with longest AF episode duration of >1 h or burden of >0.1% [3]. In addition, in a sub-analysis of the CASTLE AF study, it was reported that a reduction in AF burden, as determined by ICD monitoring to levels <50% at 6 months, was associated with a significant decrease in all-cause mortality and heart failure hospitalisations [470]. These data provide insight into the potential use of burden as a measure of AF ablation outcomes.

AF Ablation Effect on AF Progression

The natural history of AF is highly variable. A minority of patients have progressive atrial structural change which results in more persistent forms of AF. In the Swiss AF registry, 2,869 patients with AF were followed for a median duration of 3 years [471]. The incidence of clinical AF progression was 5.2 per 100 patient-years. Progression was more common in those with risk factors of obesity, age, hypertension, heart failure, and physical inactivity. Notably, management of these modifiable risk factors has previously been demonstrated to reverse AF progression [86]. In the EARLY-AF study, 303 patients with paroxysmal AF were randomised to first-line cryoablation compared to antiarrhythmic drugs [62]. Overall, the incidence of progression to persistent AF was low. Nonetheless, only 1.9% of the ablation group compared with 7.4% of the control group (HR 0.25, 95% CI 0.09–0.7) developed persistent AF during a follow up of 36 months. Although the data on AF progression is emerging, these results support the role of catheter ablation in reducing the progression of paroxysmal to persistent AF.

AF Ablation Effect on Stroke Risk

There is emerging evidence for the role of rhythm control in reduction of stroke. In the EAST-AFNET multicentre randomised study evaluating the role of early rhythm control, there was a significant reduction in the composite primary outcome of death from cardiovascular causes, stroke and hospitalisation for heart failure or acute coronary syndrome. Importantly, stroke was significantly reduced (HR 0.65, 95% CI 0.44–0.97) [1]. However, only 19.4% of the rhythm control arm were managed with catheter ablation of AF.

Observational data support the notion that catheter ablation may be associated with reduced stroke risk, although these studies are inherently subject to residual confounding. In a Swedish Patient Register (n=361,913), two propensity-score matched cohorts of equal size (n=2,836) with similar characteristics in 51 domains were identified. After multivariable adjustments, catheter ablation was associated with lower risk of ischaemic stroke (HR 0.69, 95% CI 0.51–0.93) during a 7-year period [472]. A number of retrospective observational studies have had similar findings [473–475], and a recent meta-analysis found that catheter-based AF ablation was associated with a reduction in risk of stroke by 39% (HR 0.61, 95% CI 0.49–0.77), with a high heterogeneity identified across the 10 included studies, of which 9 were observational studies [476].

AF Ablation Effect on Mortality

The CABANA study which randomised 2,204 patients with AF age over 65 years or with risk factors to catheter ablation vs medical therapy. Based on an intention-to-treat analysis, there was no significant reduction in the primary composite end point of death, disabling stroke, serious bleeding, or cardiac arrest (8.0% vs 9.2%, respectively; HR 0.85, 95% CI 0.60–1.21) [2]. The authors note that the estimated treatment effect of catheter ablation was affected by lower-than-expected event rates and treatment crossovers, which should be considered in interpreting the results of the trial.

The Catheter Ablation Versus Standard Conventional Therapy in Patients with Left Ventricular Dysfunction and Atrial Fibrillation (CASTLE-AF) trial revealed a significant reduction in mortality rates for patients who underwent AF ablation compared with medical therapy, including rhythm and rate control therapy (all-cause mortality HR 0.53, 95% CI 0.32–0.86) [4]. In patients with end stage heart failure and symptomatic AF, there was a significant reduction in mortality in patients randomised to catheter ablation compared with ongoing medical therapy (HR 0.29; 95% CI 0.12–0.72) [153].

AF Ablation as First Line Treatment

Catheter ablation for treatment of recurrent AF in those on anti-arrhythmic drugs is well established (see Recommendations 8.1). Several studies have examined the potential of using AF ablation as the initial treatment option prior to antiarrhythmic drugs (see Recommendation 8.2). The MANTRA-PAF study randomised 294 patients with paroxysmal AF and no history of antiarrhythmic drug use to an initial treatment strategy of either radiofrequency catheter ablation or antiarrhythmic drug use. More patients in the ablation group were free from AF (85% vs 71%, p=0.004) with a similar complications rate (17% vs 15%) [477]. Long-term follow-up at 5 years showed that the occurrence and burden of AF were significantly lower with AF ablation [478]. In the Radiofrequency Ablation versus Antiarrhythmic drugs as First-line Treatment of Paroxysmal AF (RAAFT-2) trial, catheter ablation was associated with a greater reduction in atrial arrhythmia recurrence compared with antiarrhythmic drugs after a 2-year follow-up.

Andrade and colleagues randomised 303 patients with paroxysmal AF to cryoablation or antiarrhythmic drugs as the initial therapy with ILR monitoring [6]. Cryoballoon ablation was associated with a significant reduction in atrial tachyarrhythmia recurrence and the median percentage of time in AF (0% vs 0.13%) with no difference in serious adverse events [6]. Similarly, the CRYO-FIRST and STOP AF First trials demonstrated superiority of CB ablation over

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antiarrhythmic drug therapy in freedom from recurrent atrial arrhythmias in treatment naïve patients with PAF [479,480].

A meta-analysis of 6 RCTs reported that catheter ablation was associated with reductions in recurrence of atrial arrhythmias (32.3% vs 53%; risk ratio [RR] 0.62, 95% CI 0.51–0.74), symptomatic atrial arrhythmia (11.8% vs 26.4%; RR 0.44, 95% CI 0.27–0.72) and hospitalisation (5.6% vs 18.7%; RR 0.32, 95% CI 0.19–0.53), with no difference in major adverse events [481].

Other circumstances where catheter ablation can be considered is in the setting of recurrent AF without symptoms (Recommendation 8.3) and where pacemaker implantation can then be avoided (Recommendation 8.4).

Recommendation	Class	Level of Evidence
8.1 Catheter ablation (CA) for rhythm control to improve symptoms and QoL in symptomatic AF *refractory* to medical treatment with antiarrhythmic drug therapy:		
• Paroxysmal: CA is recommended.	1	A
• Persistent: CA is recommended.	1	B
• Long-standing persistent: CA may be considered.	2B	B
8.2 Catheter ablation for rhythm control to improve symptoms and QoL in symptomatic AF *prior* to medical treatment with antiarrhythmic drug therapy:		
• Paroxysmal: CA should be considered in-keeping with shared decision making after discussion of the risk/benefit profile.	2A	A
• Persistent: CA may be considered.	2B	B
• Long-standing persistent: CA may be considered.	2B	C
8.3 Catheter ablation for AF may be considered in selected *asymptomatic* patients with recurrent AF following an informed discussion of the potential risks and benefits.	2B	C
8.4 Catheter ablation for AF may be considered in patients with AF and symptomatic bradycardia or prolonged AF termination pauses, to avoid pacemaker implantation.	2A	B

9. Follow Up After AF Ablation

This section provides an overview of routine clinical review and monitoring; there are no **Recommendations** within this section.

Routine Clinical Review and Monitoring

Following a catheter ablation of AF, patients should be seen within a minimum of 3 months by an electrophysiologist. Longer term follow up should encompass lifestyle risk factor modification to reduce the risk of late AF recurrence, a plan regarding anticoagulation including monitoring of renal function and management of AF recurrence. Patient preference, recurrent symptoms, comorbidities and socioeconomic factors may influence the follow up requirements.

A 12-lead ECG is recommended [482]. The need for more intensive Holter or event monitoring is determined by symptoms. More prolonged monitoring is associated with greater likelihood of detecting both symptomatic and asymptomatic AF [483–486]. Options for monitoring include 24–48-hour Holter monitors, 30-day external monitors, wearables andILR [487].

Early Arrhythmia Recurrence: Definition, Incidence, Significance and Management

The term "blanking period" refers to any recurrence of AF within the first 3 months after ablation and has been reported in up to 50% of patients [59,488–492]. Pathophysiological mechanisms include acute inflammation secondary to atrial ablation [493], and early PV reconnection or procedural failure due to non-PV triggers or more extensive atrial substrate. Recurrence beyond 4 weeks after ablation is associated with late recurrence [490]. Generally, reinitiation or up-titration of anti-arrhythmic drugs is recommended with early repeat ablation procedures avoided, given a significant likelihood the atrial arrhythmia will resolve.

10. Training Requirements

Cardiac Physiologists

Cardiac physiologists (CPs) perform an integral, multi-faceted role in AF ablation (Recommendation 10.1). Although specific roles may vary between centres, there are several clinical and technical competencies essential to their role:

- Understanding the pathophysiology of AF and how this relates to its treatment with ablation.
- Having the ability to interpret data and signals from a range of systems and to understand how they relate to the patient and procedure.
- Providing technical support, with an understanding of equipment connectivity and having the ability to troubleshoot.

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- Maintaining clear, effective communication to provide a safe environment for patients and staff and to ensure streamlined procedural workflows.
- Recognising, preventing and managing potential complications.

There are currently no mandatory electrophysiology (EP) training or education requirements for Cardiac Physiologists in Australia or New Zealand. However, standards and guidelines do exist in the UK and US; published by the British Heart Rhythm Society (BHRS) and Intersocietal Accreditation Commission (IAC), respectively, which form the basis of the recommendations presented here.

The CP's role in AF ablation

In addition to the preparation of the patient for monitoring and procedural mapping, CPs must be proficient in the use of the EP recording system, stimulator, and RF generator. Competency in CIED testing and programming is also recommended; if the CP lacks these skills, another staff member or industry representative must be available. An understanding of 3D mapping systems and single-shot ablation concepts is beneficial.

Technical proficiency is defined by the following criteria:

- EP recording system, stimulator, and RF generator:
  - ➢ EP recording system: identify components and connections; set-up appropriate amplifier configuration; adjust ECG and intracardiac electrogram display as required; recognise and reduce muscle and machine artefact; demonstrate an understanding of key EP concepts including filtering, gain, clipping, bipolar and unipolar signal acquisition, signal interpretation and diagnostic manoeuvres; accurately measure intervals and signals throughout; set-up appropriate RF data display, archive and retrieve data as required.
  - ➢ Stimulator: identify components and connections; understand the risks associated with critical settings including rate, sensing, output, minimum interval locks and automatic features; perform pacing protocols for the induction/ termination of arrhythmias and diagnostic pacing manoeuvres such as anterograde/ retrograde curves, entrainment, synchronous pacing, burst pacing and differential pacing.
  - ➢ Radiofrequency generator: identify components and connections; understand the differences and risks of power versus temperature control modes; understand actions and variables in biophysics of ablation; understand different ablation characteristics of solid tip and irrigated catheters, RF patch(es), and the role of impedance.
- 3D mapping system:
  - ➢ Identify key components and connections, including integration into EP recording system/stimulator and ablation generators; understand key concepts in conventional mapping; set-up appropriate amplifier configuration, catheter connections, ECG and intra-cardiac electrogram display; create electroanatomical maps; understand the information provided including potential limitations; identify potential procedural complications.
- Single shot ablation system:
  - ➢ Identify components and connections, including integration into EP recording system/stimulator; understand biophysics of ablation specific to system, potential dangers and limitations of modality; identify situations where ablation should be immediately ceased; adhere to safety guidelines of gas cylinder exchange, storage, and waste management, where applicable.

Recommendation	Class	Level of Evidence
10.1 A cardiac physiologist (CP) is recommended for the completion of an AF ablation procedure.	1	C

The 3D mapping, EP recording and/or single shot ablation system may be operated by either CPs or Industry Specialists. Industry specialists must be competent in AF ablation and the use of the system. Individual centres may require additional training and compliance to local guidelines to ensure industry representation, patient and staff safety.

Recommendation	Class	Level of Evidence
10.2 In addition to holding a health science degree or equivalent, a CP is recommended to have undertaken advanced sub-specialist training and been actively involved in a minimum of 30 AF ablation procedures with a minimum of 10 AF ablations/year to maintain competence.	1	C

Advanced sub-specialist training may include post-graduate qualifications in Cardiac Electrophysiology – i.e.,. Grad Dip EP (CEPIA), IBHRE (CEPS— AP for Allied Professionals), BHRS or equivalent (Recommendation 10.2).

Prior to commencing post graduate qualifications the physiologist should undertake EP focused in-house training program to obtain:

- a comprehensive knowledge of cardiac anatomy and surrounding structures, biophysics of ablation, and radiation safety

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- the ability to recognise, anticipate, and mitigate potential adverse outcomes/complications regarding the procedure, equipment, and patient safety
- an understanding of the use of diagnostic and therapeutic catheters, sheaths, transseptal equipment, and accessories
- familiarity with the recording system and stimulator; basic pacing, and ECG/EGM interpretation.

Ideally this training program should be developed by a senior CP or Electrophysiologist and have clear learning objectives and documentation of skills acquired.

Registration

Cardiac Physiologists working in New Zealand must be registered with the Clinical Physiologists Registration Board (CPRB). In Australia, registration is voluntary for CPs. Nevertheless, it is strongly recommended to register with the Australian Council for Clinical Physiologists (ACCP).

It is also the belief of the authors that it is important to grow our own health service with the training of CPs in complex EP procedures, including 3D mapping and emerging technologies. Continuous Professional Development must be undertaken in electrophysiology and catheter ablation. Efforts should be made by the health service to provide protected education time, resources, and funding to facilitate this.

Electrophysiologists

Overview

Physicians training to perform catheter ablation need both the technical procedural skills and knowledge required to safely select patients, perform procedures, and manage patients around the time of the procedural intervention. Appropriate patient selection, preprocedural, periprocedural and post-procedural care require knowledge of the literature, including current guidelines and an ability to apply that knowledge. These skills are best practiced and assessed in supervised procedure and clinic environments during training. Most guidelines recommend trainees participate in outpatient clinics, although quantification of this involvement is arbitrary [11]. Procedural skills may be obtained partially through simulations but primarily through hands-on experience. This is best achieved through a fellowship process but could also be achieved through a mentoring process. Trainees wanting to perform catheter ablation for AF in Australia are required to meet the requirements for training in subspecialty clinical electrophysiology as outlined by the Cardiac Society of Australia and New Zealand (Recommendation 10.3).

Patient selection and preprocedural care

The proceduralist should be familiar with the indications for catheter ablation described earlier in this document. They should also understand the preparation of the patient, including plans for anticoagulation, management of other medications and preprocedural imaging options.

Periprocedural care

Operators require a thorough knowledge of underlying physiology, pathophysiology and anatomy as they relate to AF and procedures for treatment of AF. Proceduralists also require a comprehensive knowledge of ablation strategies and alternatives to catheter ablation, such as pharmacological management, surgical ablation, and pacemaker implant followed by AV node ablation.

Technical competence is required to complete the procedure and handle any complications. Operators must be able to promptly recognise complications and initiate their treatment. Proceduralists-in-training must demonstrate competence in the use of fluoroscopy, 3D mapping, and echocardiographic imaging. Technical competence must be demonstrated to the satisfaction of a skilled operator during a period of training and through the completion of a prescribed number of procedures as first operator, as described below. A radiation licence is required and an understanding of radiation dose minimisation techniques.

Operators performing procedures under sedation without an anaesthetist or similarly qualified practitioner need to have appropriate training in the administration of sedative medications. These skills and recommendations for training are described elsewhere [421,494]. The key skills required include application of patient selection criteria, understanding of the pharmacology and practical use of sedative agents, knowledge of techniques required for patient monitoring, recognition of complications of sedation, and application of criteria for calling assistance.

Training procedure numbers

The number of procedures required for completion of training is based on an estimate of the number of procedures required to achieve a high level of proficiency. The number required is estimated from the learning curve required for new procedures [495,496]. This has been assessed by observational studies examining procedure duration, safety, and efficacy. The 2015 American Heart Association/Heart Rhythm Society Advanced Training Statement on Clinical Cardiac Electrophysiology proposes 50 AF ablation procedures and ablation for 20 macro–re-entrant tachycardias including 10 non-isthmus dependent macro–re-entrant tachycardias [497]. The 2017 AF ablation guideline recommends trainees complete 50 ablation procedures during training and reiterated the requirement for 20 macro-re-entrant tachycardias [11] (Recommendation 10.4).

Maintenance of competence

There is limited evidence to indicate the number of procedures required to maintain procedural competence. In a Nationwide Inpatient Sample of 93,801 AF ablations performed in the USA from 2000 to 2010, the frequency of complications was 6.29%; combined cardiac complications (2.54%) were the most frequent, with an in-hospital mortality of 0.46%. Lower annual operator (<25

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Recommendations	Class	Level of Evidence
10.3 It is recommended that Cardiologists wanting to perform catheter ablation for AF must complete subspecialty training in adult cardiac clinical electrophysiology as specified in the relevant 2017 CSANZ guidelines.	1	C
10.4 It is recommended that Cardiologists wanting to perform catheter ablation for AF must participate in 100 AF ablation procedures, including 50 as the first operator.	1	C
10.5 It is recommended that Cardiologists wanting to perform catheter ablation for AF should perform at least 25 AF ablation procedures on average per year to maintain professional standards.	1	B
10.6 Centres performing ablation for AF should have onsite intensive care facilities, emergency teams and echocardiography.	1	C
10.7 A management plan with rapid access to emergency treatment of serious complications including cardiac tamponade, stroke and vascular complications is recommended.	1	C
10.8 For centres without onsite surgical back up, patients should be made aware of the potential need for urgent interhospital transfer in the event of complications.	1	C
10.9 It is recommended that institutions wanting to perform catheter ablation for AF should support at least 50 AF ablation procedures per year to maintain competency.	1	B

procedures) and hospital volume (<50 procedures) were significantly associated with adverse outcomes [362]. The recommendation of this document (Recommendation 10.5) is based on consensus and the precedent of previous guidelines.

Institutional requirements

The ideal institution for percutaneous ablation of AF would provide intensive care facilities and a complete range of medical and surgical specialties to cope with patient comorbidities and complications [498] (Recommendation 10.6). Preferably, services such as cardiothoracic surgery and interventional neuroradiology should be on site and available. In practice, even at the largest centres, there may be delays in the availability of services including cardiothoracic surgery in the event of complications such as tamponade or urgent clot retrieval for embolic events (Recommendation 10.7). A centre performing cardiothoracic surgery may not have a surgeon on site every day, or the surgical teams may be occupied performing other procedures. It is generally acknowledged that onsite surgical backup is desirable for performing complex catheter ablation procedures. However, studies of periprocedural deaths around the time of catheter ablation have demonstrated that most deaths occur in larger centres with cardiothoracic surgical backup. As a minimum standard, a plan for accessing urgently required services should be in place (Recommendation 10.8). This should include management of cardiac tamponade not responding to percutaneous drainage, and stroke. The centre should have an emergency team, if these resources are not already available within the operating environment.

Equipment

Procedures should be performed in an operating room or cardiac catheterisation laboratory within a hospital facility. The minimum requirement for these rooms is described elsewhere and varies depending on the jurisdiction. Preprocedural assessment and recovery areas with monitoring equipment and specialised staff are required. The operating room must be large enough to house the required electrophysiology, radiology, and anaesthetic equipment, and allow resuscitation of the patient if required. Physiological monitoring of blood pressure, oximetry, expired CO_2, and electrocardiogram are required. X-ray equipment capable of storing images, a cardiac stimulator, electroanatomical mapping, and the capacity to display and analyse intracardiac electrograms are also necessary.

Institutional volume

Institutional volume is frequently used as a measure of institutional experience and competence [499]. A centre performing complex catheter ablation procedures or training fellows for catheter ablation of AF should have a minimum procedural volume (Recommendation 10.9). This is based on estimates of volume-based complication rates. There is evidence to suggest centres with higher procedural volume have lower periprocedural complication rates.

Post procedural care

Management of patients after percutaneous catheter ablation includes education of the patient, monitoring to diagnose any procedural complication, and management to reduce the risk of, and treat, any procedural complications. The complications most likely to require diagnosis and urgent care include stroke, late tamponade, oesophageal injury, and vascular complications. The frequency of these complications is low, and a trainee is unlikely to be exposed to all potential complications during a fellowship. However, a thorough theoretical knowledge of management of these complications is required.

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11. Clinical Urgency

This section provides an overview of clinical urgency; there are no **Recommendations** within this section.

When a patient is assessed by a cardiologist for an intervention, patients may be categorised according to clinical urgency. After discussion and consideration of the available resources in the Australian and New Zealand Health Care systems, the writing group defined two categories of clinical urgency (urgent and semi-urgent) for catheter ablation for AF (see Box 2).

12. Surgical AF Ablation

James Cox introduced the Cox–Maze procedure for the surgical treatment of AF in 1987 [500,501]. Multiple strategic incisions were placed across both atria with LAA excision. Although providing durable sinus rhythm in the majority of patients, this 'cut-and-sew' maze was technically complex, time consuming, and not widely adopted.

Over time, the lesion set underwent modification as new tools became available to deliver linear ablation with RF and cryothermal technologies. The final iteration was the Cox–Maze 4 procedure, as the standard for surgical treatment of AF, performed predominantly with concomitant cardiac surgery. The largest published experience of Cox–Maze 4 procedures is 282 pts (44% were stand-alone and 56% concomitant surgery). Overall, 89% were in sinus rhythm with or without antiarrhythmic drugs (AAD), and 78% were in sinus rhythm free of AAD, at 12 months' follow-up based on three-monthly Holters [502]. Major complications including an operative mortality of 2%, stroke in 1.7%, and pacemaker implantation in 9%.

There are several settings in which surgical AF ablation may be performed (Recommendations 12.1, 12.2):

- Stand-alone AF operation which may or may not involve opening the left atrium and may be performed via sternotomy or be minimally invasive
- Open concomitant when left atriotomy is performed (MV and/or TV surgery, closure atrial septal defect)
- Closed concomitant surgical ablation where left atriotomy is not otherwise performed (AVR, CABG, CABG + AVR) and stand-alone surgical ablation, and
- Hybrid ablation, using a combination of minimally invasive surgical ablation followed by catheter ablation to complete lesion sets and validate electrical isolation.

The choice of ablation technique depends on the type and duration of AF, symptoms, prior attempts with catheter ablation, need for concomitant surgery, and ventricular function.

Surgical Ablation at Time of Concomitant Open Atrial Operation

Encirclement of the pulmonary veins is the cornerstone of surgical ablation, with posterior wall ablation and linear lesions across the mitral and tricuspid isthmus and exclusion of the LAA commonly performed [503–505]. Budera et al. performed a RCT of 224 AF patients undergoing concomitant cardiac surgery randomised 1:1 to a LA lesion set vs no ablation. Ablation was associated with sinus rhythm at 1 year in 60% vs 35% in those not receiving ablation (p=0.002), with the greatest difference in the long-standing persistent AF group [503]. For persistent AF, a bi-atrial lesion set is reported to be more effective than LA only [506]. However, bi-atrial lesion sets, particularly when in close proximity to the sinus node complex, are associated with an increased risk of pacemaker implant, compared with ablation confined to the left atrium [507]. Randomised trials of MV operations, with or without surgical AF ablation, showed no increase in significant complications aside from a doubling of the need for a pacemaker [504,508,509]. Common predictors of AF recurrence post surgical ablation are similar to catheter ablation, and included large LA dimensions, AF duration, older age, and failure to isolate the posterior wall. A procedural learning curve can impact efficacy, and the surgeon needs appropriate training before performing concomitant surgical ablation.

Box 2. Clinical Urgency.

Category 1: URGENT (to be performed within 30 days)

1. Catheter ablation of **AF** causing hemodynamic deterioration and/or heart failure that is **uncontrolled by antiarrhythmic drugs** and/or cardioversion.
2. Recurrent AF resulting in **repeated** emergency department visits and/or hospitalisations despite **antiarrhythmic drugs** and/or cardioversion.

Category 2: SEMI-URGENT (to be performed within 90 days)

1. AF ablation of arrhythmias thought to be contributing to cardiomyopathy.
2. Symptomatic AF despite anti arrhythmic medications or where medication is poorly tolerated.
3. Persistent AF.

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Surgical Ablation at Time of Concomitant Closed Atrial Operation

Ablation at the time of a surgical procedure which does not require an atriotomy generally involves an epicardial PVI, LAA excision, and may include an epicardial roof line [510]. A meta-analysis of 16 RCTs reported no difference in 30-day morbidity or mortality, when adding AF surgery to closed atrial concomitant operations [504].

Stand-alone Surgical Ablation

Stand-alone surgical ablation is generally not indicated in the initial management of AF, given it is more invasive, associated with significantly higher complication rates [511–513], and there is a limited ability to confirm conduction block compared with a catheter-based approach. There are a range of lesion sets, with most employing PVI either via a sternotomy or minimally-invasive thoracoscopic approach. Minimally invasive ablation is performed on the beating heart and avoids the need for cardiopulmonary bypass and its associated complications. The thoracoscopic (TT) Maze is video-assisted with access via three ports bilaterally. An RFA clamp is positioned across the right- and left-sided pulmonary veins, with additional linear ablation at the roof, floor and anterior wall at the surgeon's discretion. The ligament of Marshall is dissected, and the LAA can be transsected with a stapler or specific closure device, which may include appendage isolation.

The CASA-AF study recruited 120 *de novo* patients with long-standing persistent atrial fibrillation who were randomised to stand-alone TT surgical ablation (posterior box lesion set and exclusion of the LAA) or catheter ablation which included PVI+PWI and an implantable loop recorder [514]. There was no difference in freedom from AF or AF burden between groups at 12 months. Stand-alone surgery was more expensive, and associated with more symptoms and less quality of life compared with CA [514]. Several randomised trials in patients with recurrent AF post catheter ablation have generally demonstrated improved freedom from AF in those undergoing surgical ablation vs repeat catheter ablation, although continuous or daily rhythm monitoring has not been regularly performed [513,515]. The FAST AF study (2/3 prior CA) reported significantly greater AF-free survival in patients randomised to surgical ablation but at the expense of considerably higher adverse events with (34% vs 16% with CA, p=0.027) [516]. The composite clinical outcome of death, MI or stroke was similar between groups at 7 years follow up with fewer repeat procedures in the surgical group [513].

Hybrid AF Ablation (Epicardial and Endocardial Ablation)

Combining catheter and minimally invasive surgical ablation has evolved to provide epicardial ablation followed by electrophysiologic mapping and endocardial ablation for the validation of electrical isolation and conduction block. The hybrid approach allows for an electrophysiologist to map the entire atrium complete lesion sets and validate conduction block, map, and ablate focal AF triggers and atrial tachycardias. Hybrid ablation can be simultaneous (same procedure), sequential (during the same admission), or staged (up to 3 months later). Simultaneous procedures are generally not performed due to logistics, prolonged anaesthesia, and to allow resolution of oedema induced by surgical ablation.

A meta-analysis of 22 non-randomised largely single-centre studies involving 925 patients undergoing a totally thoracoscopic (TT) hybrid ablation reported maintenance of sinus rhythm in 70% (62%-78%) without antiarrhythmic drugs at 19+/-25 months. The overall complication rate was 6.5% (3.4%–10.2%), with an average length of stay of 5 days [517]. A TT maze may be considered in patients with persistent AF with prior unsuccessful catheter ablation and, also, in those where antiarrhythmic drugs have been ineffective and who prefer a surgical/hybrid approach, after informed discussion with an electrophysiologist and cardiac surgeon.

The hybrid convergent procedure refers to epicardial lesions created under surgical endoscopic visualisation, followed by EP mapping and ablation to complete the PVI and PWI [518] and may include exclusion of the LA appendage. A vacuum-assisted unipolar irrigated RF catheter is utilised via a pericardioscopic cannula, which is less invasive than a TT maze. The surgical technique and surgeons' skills have improved, and reported success rates have varied.

The CONVERGE trial was a prospective, multicentre randomised trial comparing hybrid convergent procedure in a 2:1 randomisation to CA PVI alone in 153 patients undergoing first-time ablation for persistent and long-standing persistent AF. Primary effectiveness was achieved in 68% with Hybrid Convergent ablation vs 50% with CA (p=0.036) on/off previously failed antiarrhythmic drugs. However,

Recommendations	Class	Level of Evidence
12.1 Surgical ablation should be considered during concomitant cardiac surgery, in select patients with AF when safe and practical.	2A	A
12.2 Standalone surgical or hybrid ablation may be considered in patients with persistent AF with prior unsuccessful catheter ablation and in those where antiarrhythmic drugs have been ineffective and who prefer a surgical/hybrid approach, after informed discussion with an electrophysiologist and cardiac surgeon.	2B	B

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adverse events occurred in 7.8% in the hybrid group vs 0% in CA, with a total procedure time of 294±80 minutes [519]. CEASE-AF was a 2:1 RCT of 154 patients with persistent AF which demonstrated superiority with hybrid ablation vs CA PVI with the option of additional substrate modification [520]. We await the outcomes of randomised trials comparing multiprocedural success of equivalent lesion sets with more intensive rhythm monitoring and better safety, before the hybrid surgical approach is more widely adopted.

Appendix A. Patient Perspectives on the 2023 AF Ablation Guidelines

What is the Really Important Information People Should Know About AF Ablation?

AF ablation is a procedure used to treat a type of heart rhythm disorder known as AF. It is important to be fully informed about the procedure and what it entails. Here are some key things patients should know:

- **AF ablation is not *always* a cure**: While AF ablation can be effective in reducing symptoms and improving quality of life, it is not a cure for AF. Patients may still need to take medications or undergo additional treatments to manage AF after the procedure.
- **Importance of lifestyle changes**: AF ablation alone is not enough to manage AF. Patients may need to make lifestyle changes, such as losing weight, reducing stress, or avoiding triggers such as alcohol, to manage their condition effectively. (Figure 4 provides some practical advice for patients.)
- **Risks and benefits**: As with any medical procedure, AF ablation has risks and benefits. It is important to understand and weigh these before making a decision about whether to proceed with the procedure.
- **Location of procedure**: Many hospitals have intensive care units located within the hospital where a patient would be transferred to, in the case of complications. However, not all hospitals have intensive care units and if a patient experiences complications, the patient will need to be transferred to another hospital. Not having an intensive care unit can impact the quality of care and treatment options available to patients and may result in poorer outcomes for critically ill patients. However, restricting catheter ablations to hospitals without intensive care units would restrict patient access (especially those living in rural and regional communities), and would mean longer waiting times for patients. It is important that the risks and benefits are discussed with the patient before making a decision.
- **Follow-up care**: AF ablation requires close follow-up care with the patient's healthcare team to monitor the success of the procedure and identify any additional treatment options if necessary.
- **Long-term results**: The long-term success of AF ablation varies from person to person. In some cases, multiple ablation procedures may be required, and patients may need to continue to take medications to control AF.
- **Alternative treatments**: AF ablation is not the only option for treating AF. Patients should discuss all available treatments with their healthcare team to determine which one is best.
- **Communication with healthcare team**: Good communication with the patient's healthcare team is critical for a successful outcome. Make sure all of the options are understood and allow patients to ask any questions they may have about the procedure, its risks and benefits, and follow-up care.
- **Overall, catheter ablation is considered a safe procedure and there are many benefits for patients.** The main goal of the procedure is to restore the normal rhythm of the heart, which can significantly reduce or eliminate the symptoms of AF (AF). This can lead to an improvement in the patient's quality of life, including better sleep, more energy, and improved ability to participate in physical activity. Additionally, catheter ablation may allow the patient to discontinue the use of antiarrhythmic medications, which can have significant side effects and may not always be effective in controlling AF.
- Finally, for patients with an impaired LVEF, catheter ablation may have a mortality benefit, as LV function can return to normal if sinus rhythm is maintained.
- **Overall, catheter ablation can offer significant benefits to patients with AF, including a reduction in symptoms, improved quality of life, and the potential to discontinue antiarrhythmic medications.**

Appendix B. Disclosures

Amerena JV Received travel support and honoraria for participating in advisory boards and consulting for BMS/Pfizer, Boehringer Ingelheim and Johnson and Johnson.

Chia KM Consultant for Medtronic; Received Honoraria from Medtronic and Biosense Webster.

Choo WK Received consultancy fees from Abbott Medical and educational honoraria from Medtronic and Biotronik.

Eslick AT Nil.

Hopper IK Advisory Board – Boehringer Ingelheim Jardiance; Speaker fees – Novartis, Boehringer Ingelheim, Eli Lilly, Astra Zeneca, HealthEd.

Hall T CEO of Hearts4Hearts

Kalman JM Fellowship/grant support from Medtronic and Biosense Webster

Kistler PM Recipient of an Investigatorship from the National Health and Medical Research (NHMRC) Council of Australia; Received funding from Abbott Medical for consultancy and speaking engagements and has served on the

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advisory board with fellowship support from Biosense Webster.

Kotschet E Speaker fees from Abbott, Medtronic, Biotronik, Boston Scientific.

Lim HS Received research funding from St Jude Medical (now Abbott) and Medtronic.

Ling L-H Received consultation and speaker fees from Abbott Medical Australia; The Alfred Hospital has received research support on behalf of Dr Ling from Abbott Medical Australia.

Mahajan R Served on the advisory board of Abbott and Medtronic; The University of Adelaide reports receiving on behalf of Dr Mahajan lecture and/or consulting fees from Abbott, Bayer, Biotronik, Medtronic, and Pfizer; The University of Adelaide reports receiving on behalf of Dr Mahajan research funding from Abbott, Bayer, and Medtronic.

Marasco SF Nil.

McLellan AJ Fellowship and educational support from Abbott Medical; Speaker and advisory fees from Abbott Medical.

Pathak RK Served on the advisory board of Medtronic, Abbott Medical, Boston Scientific; Canberra Heart Rhythm Foundation/Australian National University has received on his behalf lecture and/or consulting fees from Medtronic, Abbott Medical, Boston Scientific and Biotronik; Canberra Heart Rhythm Foundation/Australian National University has received research funding on behalf of Dr Pathak from Medtronic, Abbott Medical, Boston Scientific, and Biotronik.

Phillips KP Consultancy / Clinical Proctor and Presentations for Boston Scientific;

Consultancy / Clinical Proctor and Presentations for Abbott Medical.

Prabhu S Early investigator fellowship from National Health and Medical Research Council (NHMRC) and National Heart Foundation (NHF); Received fellowship and educational support from Boston Scientific and Abbott Medical; Speaker and advisory fees from Abbott Medical and Biosense Webster.

Sanders P Supported by an Investigator Grant from the National Health and Medical Research (NHMRC) Council of Australia; Has served on the advisory board of Medtronic, Abbott Medical, Boston Scientific, CathRx and PaceMate; The University of Adelaide has received on his behalf lecture and/or consulting fees from Medtronic, Abbott Medical, Boston Scientific and Pfizer; The University of Adelaide has received on his behalf research funding from Medtronic, Abbott Medical, Boston Scientific, and Becton Dickinson.

Stiles MK Speaker fees from Medtronic; Advisory Board, Ceryx Medical.

Thomas SP Consulting fees from Johnson & Johnson; Participating in clinical trials with Biotronik.

Watts TW Received speaker fees from Abbott Medical.

Weerasooriya R Biosense Webster, consultant fees; Abbott, consultant fees; Biotronik, consultant fees.

Director and owner - Heart Rhythm Clinic WA, Cardiac Rhythm Diagnostics Pty Ltd.

Wilsmore BR Received speaker and consultancy fees from Boston Scientific and Medtronic.

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