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GUIDELINES

2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS

The Task Force for the management of atrial fibrillation of the European Society of Cardiology (ESC)

Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC

Endorsed by the European Stroke Organisation (ESO)

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Keywords: Guidelines • Atrial fibrillation • Anticoagulation • Vitamin K antagonists • Non-vitamin K antagonist oral anticoagulants • Left atrial appendage occlusion • Rate control • Cardioversion • Rhythm control • Antiarrhythmic drugs • Upstream therapy • Catheter ablation • AF surgery • Valve repair • Pulmonary vein isolation • Left atrial ablation

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

ABC	age, biomarkers, clinical history
ACE	angiotensin-converting enzyme

ACS	acute coronary syndromes
AF	atrial fibrillation
AFFIRM	Atrial Fibrillation Follow-up Investigation of Rhythm Management
AFNET	German Competence NETwork on Atrial Fibrillation
AngII	angiotensin II
AHRE	atrial high rate episodes
APACHE-AF	Apixaban versus Antiplatelet drugs or no antithrombotic drugs after anticoagulation-associated intraCerebral HaEmorrhage in patients with Atrial Fibrillation
ARB	angiotensin receptor blocker
ARISTOTLE	Apixaban for Reduction in Stroke and Other Thromboembolic Events in Atrial Fibrillation
ARNI	angiotensin receptor neprilysin inhibition
ARTESiA	Apixaban for the Reduction of Thrombo-Embolism in Patients With Device-Detected Sub-Clinical Atrial Fibrillation
ATRIA	AnTicoagulation and Risk factors In Atrial fibrillation
AV	Atrioventricular
AXAFA	Anticoagulation using the direct factor Xa inhibitor apixaban during Atrial Fibrillation catheter Ablation: Comparison to vitamin K antagonist therapy
BAFTA	Birmingham Atrial Fibrillation Treatment of the Aged Study
BMI	body mass index
b.p.m.	beats per minute
CABANA	Catheter Ablation versus Antiarrhythmic Drug Therapy for Atrial Fibrillation Trial
CABG	coronary artery bypass graft
CAD	coronary artery disease
CHA_2DS_2-VASc	Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female)
$CHADS_2$	Cardiac failure, Hypertension, Age, Diabetes, Stroke (Doubled)
CI	confidence interval
CKD	chronic kidney disease
CPG	Committee for Practice Guidelines
CrCl	creatinine clearance
CT	computed tomography
CV	cardiovascular
CYP2D6	cytochrome P450 2D6
CYP3A4	cytochrome P450 3A4
DIG	Digitalis Investigation Group
EACTS	European Association for Cardio-Thoracic Surgery
EAST	Early treatment of Atrial fibrillation for Stroke prevention Trial
ECG	electrocardiogram/ electrocardiography
EHRA	European Heart Rhythm Association
ENGAGE AF-TIMI 48	Effective Anticoagulation with Factor Xa Next Generation in Atrial Fibrillation–Thrombolysis in Myocardial Infarction 48
EORP	EURObservational Research Programme
ESC	European Society of Cardiology
ESO	European stroke Organisation
FAST	Atrial Fibrillation Catheter Ablation vs. Surgical Ablation Treatment
FEV1	forced expiratory volume in 1 s
FFP	four-factor prothrombin complex concentrates
FXII	factor XII
GDF-15	growth differentiation factor 15
GFR	glomerular filtration rate
GUCH	grown-up congenital heart disease
HARMONY	A Study to Evaluate the Effect of Ranolazine and Dronedarone When Given Alone and in Combination in Patients With Paroxysmal Atrial Fibrillation
HAS-BLED	hypertension, abnormal renal/liver function (1 point each), stroke, bleeding history or predisposition, labile INR, elderly (>65 years), drugs/alcohol concomitantly (1 point each)
$HEMORR_2HAGES$	Hepatic or renal disease, ethanol abuse, malignancy history, older age >75, reduced platelet count/function/ antiplatelet, rebleeding risk (scores double), hypertension (uncontrolled), anaemia, genetic factors, excessive fall risk, stroke history
HF	heart failure
HFmrEF	heart failure with mid-range ejection fraction
HFpEF	heart failure with preserved ejection fraction
HFrEF	heart failure with reduced ejection fraction
HR	hazard ratio
ICD	implantable cardioverter defibrillator
IHD	ischaemic heart disease
IL-6	interleukin 6
INR	international normalized ratio
i.v.	intravenous
LA	left atrium/atrial
LAA	left atrial appendage
LAAOS	Left Atrial Appendage Occlusion Study
LV	left ventricular
LVEF	left ventricular ejection fraction
LVH	left ventricular hypertrophy
MANTRA-PAF	Medical ANtiarrhythmic Treatment or Radiofrequency

	Ablation in Paroxysmal Atrial Fibrillation
MERLIN	Metabolic Efficiency With Ranolazine for Less Ischemia in Non ST-Elevation Acute Coronary Syndromes
MRA	Mineralocorticoid receptor antagonist
MRI	magnetic resonance imaging
NIHSS	National Institutes of Health stroke severity scale
NOAC	non-vitamin K antagonist oral anticoagulant
NOAH	Non vitamin K antagonist Oral anticoagulants in patients with Atrial High rate episodes (NOAH)
NYHA	New York Heart Association
OAC	oral anticoagulation/oral anticoagulant
OR	odds ratio
ORBIT	Outcomes Registry for Better Informed Treatment of Atrial Fibrillation
PAFAC	Prevention of Atrial Fibrillation After Cardioversion trial
PAI-1	plasminogen activator inhibitor 1
PCI	percutaneous coronary intervention
PCC	prothrombin complex concentrates
PICOT	Population, Intervention, Comparison, Outcome, Time
PREVAIL	Prospective Randomized Evaluation of the Watchman LAA Closure Device In Patients with AF Versus Long Term Warfarin Therapy trial
PROTECT AF	Watchman Left Atrial Appendage System for Embolic Protection in Patients With AF trial
PUFA	polyunsaturated fatty acid
PVI	pulmonary vein isolation
QoL	quality of life
RACE	Rate Control Efficacy in Permanent Atrial Fibrillation
RATE-AF	Rate Control Therapy Evaluation in Permanent Atrial Fibrillation
RCT	randomized controlled trial
RE-CIRCUIT	Randomized Evaluation of Dabigatran Etexilate Compared to warfarIn in pulmonaRy Vein Ablation: Assessment of an Uninterrupted periproCedUral antIcoagulation sTrategy
RE-LY	Randomized Evaluation of Long-Term Anticoagulation Therapy
RF	radiofrequency
ROCKET-AF	Rivaroxaban Once Daily Oral Direct Factor Xa Inhibition Compared with Vitamin K Antagonism for Prevention of Stroke and Embolism Trial in Atrial Fibrillation
RR	risk ratio
rtPA	recombinant tissue plasminogen activator
SAMe-TT_2R_2	Sex (female), age (<60 years), medical history (two of the following: hypertension, diabetes, mi, pad, congestive heart failure, history of stroke, pulmonary disease, hepatic or renal disease), treatment (interacting medications e.g. amiodarone), tobacco use (within 2 years; scores double), race (non-Caucasian; scores double)
SD	standard deviation
SPAF	Stroke Prevention in Atrial Fibrillation
SR	sinus rhythm
TF	tissue factor
TIA	transient ischaemic attack
TIMI	Thrombolysis in Myocardial Infarction
TOE	transoesophageal echocardiography
TTR	time in therapeutic range
UFH	unfractionated heparin
VKA	vitamin K antagonist
VT	Ventricular tachycardia
VVI	Ventricular pacing, ventricular sensing, inhibited response pacemaker
WOEST	What is the Optimal antiplatElet and anticoagulant therapy in patients with oral anticoagulation and coronary StenTing
WPW	Wolff-Parkinson-White syndrome

1. PREAMBLE

Guidelines summarize and evaluate all available evidence on a particular issue at the time of the writing process, with the aim of assisting health professionals in selecting the best management strategies for an individual patient with a given condition, taking into account the impact on outcome, as well as the risk–benefit ratio of particular diagnostic or therapeutic means. Guidelines and recommendations should help health professionals to make decisions in their daily practice. However, the final decisions concerning an individual patient must be made by the responsible health professional(s) in consultation with the patient and caregiver as appropriate.

A great number of Guidelines have been issued in recent years by the European Society of Cardiology (ESC) and by the European Association for Cardio-Thoracic Surgery (EACTS), as well as by other societies and organisations. Because of the impact on clinical practice, quality criteria for the development of guidelines have been established in order to make all decisions transparent to the user. The recommendations for formulating and issuing ESC Guidelines can be found on the ESC website (http://www.escardio.org/Guidelines-&-Education/Clinical-Practice-Guidelines/Guidelines-development/Writing-ESC-Guidelines). ESC Guidelines represent the official position of the ESC on a given topic and are regularly updated.

Members of this Task Force were selected by the ESC, including representation from the European Heart Rhythm Association (EHRA), and EACTS as well as by the European Stroke Organisation (ESO) to represent professionals involved with the

Table 1: Classes of recommendations

Classes of recommendations	Definition	Suggested wording to use
Class I	**Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective.**	**Is recommended/is indicated**
Class II	**Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.**	
Class IIa	***Weight of evidence/opinion is in favour of usefulness/efficacy.***	**Should be considered**
Class IIb	***Usefulness/efficacy is less well established by evidence/opinion.***	**May be considered**
Class III	**Evidence or general agreement that the given treatment or procedure is not useful/effective and in some cases may be harmful.**	**Is not recommended**

Table 2: Levels of evidence

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

medical care of patients with this pathology. Selected experts in the field undertook a comprehensive review of the published evidence for management (including diagnosis, treatment, prevention and rehabilitation) of a given condition according to ESC Committee for Practice Guidelines (CPG) policy and approved by the EACTS and ESO. A critical evaluation of diagnostic and therapeutic procedures was performed, including assessment of the risk–benefit ratio. Estimates of expected health outcomes for larger populations were included, where data exist. The level of evidence and the strength of the recommendation of particular management options were weighed and graded according to predefined scales, as outlined in Tables 1 and 2.

The experts of the writing and reviewing panels provided declaration of interest forms for all relationships that might be perceived as real or potential sources of conflicts of interest. These forms were compiled into one file and can be found on the ESC website (http://www.escardio.org/guidelines). Any changes in declarations of interest that arise during the writing period must be notified to the ESC and EACTS and updated. The Task Force received its entire financial support from the ESC and EACTS without any involvement from the healthcare industry.

The ESC CPG supervises and co-ordinates the preparation of new Guidelines produced by task forces, expert groups or consensus panels. The Committee is also responsible for the endorsement process of these Guidelines. The ESC Guidelines undergo extensive review by the CPG and external experts, and in this case by EACTS and ESO-appointed experts. After appropriate revisions the Guidelines are approved by all the experts involved in the Task Force. The finalized document is approved by the CPG, EACTS and ESO for publication in the European Heart Journal, Europace, and in the European Journal of Cardio-Thoracic Surgery. The Guidelines were developed after careful consideration of the scientific and medical knowledge and the evidence available at the time of their dating.

The task of developing ESC and EACTS Guidelines covers not only integration of the most recent research, but also the creation of educational tools and implementation programmes for the recommendations. To implement the guidelines, condensed pocket guideline versions, summary slides, booklets with essential messages, summary cards for non-specialists and an electronic version for digital applications (smartphones, etc.) are produced. These versions are abridged and thus, if needed, one should always refer to the full text version, which is freely available on the ESC website. The National Societies of the ESC are encouraged to endorse, translate and implement all ESC Guidelines. Implementation programmes are needed because it has been shown that the outcome of disease may be favourably influenced by the thorough application of clinical recommendations.

Surveys and registries are needed to verify that real-life daily practice is in keeping with what is recommended in the guidelines, thus completing the loop between clinical research, writing of guidelines, disseminating them and implementing them into clinical practice.

Health professionals are encouraged to take the ESC and EACTS Guidelines fully into account when exercising their clinical judgment, as well as in the determination and the implementation of preventive, diagnostic or therapeutic medical strategies. However, the ESC and EACTS Guidelines do not override in any way whatsoever the individual responsibility of health professionals to make appropriate and accurate decisions in consideration of each patient's health condition and in consultation with that patient and the patient's caregiver where appropriate and/or necessary. It is also the health professional's responsibility to verify the rules and regulations applicable to drugs and devices at the time of prescription.

2. INTRODUCTION

Despite good progress in the management of patients with atrial fibrillation (AF), this arrhythmia remains one of the major causes of stroke, heart failure, sudden death, and cardiovascular morbidity in the world. Furthermore, the number of patients with AF is predicted to rise steeply in the coming years. To meet the growing demand for effective care of patients with AF, new information is continually generated and published, and the last few years have seen substantial progress. Therefore, it seems timely to publish this 2nd edition of the ESC guidelines on AF.

Reflecting the multidisciplinary input into the management of patients with AF, the Task Force includes cardiologists with varying subspecialty expertise, cardiac surgeons, stroke neurologists, and specialist nurses amongst its members. Supplementing the evidence review as outlined in the preamble, this Task Force defined three Population, Intervention, Comparison, Outcome, Time (PICOT) questions on relevant topics for the guidelines. The ESC commissioned external systematic reviews to answer these questions, and these reviews have informed specific recommendations.

Further to adhering to the standards for generating recommendations that are common to all ESC guidelines (see preamble), this Task Force discussed each draft recommendation during web-based conference calls dedicated to specific chapters, followed by consensus modifications and an online vote on each recommendation. Only recommendations that were supported by at least 75% of the Task Force members were included in the guidelines.

We hope that these guidelines will help to deliver good care to all patients with AF based on the current state-of-the-art evidence in 2016.

3. EPIDEMIOLOGY AND IMPACT FOR PATIENTS

3.1 Incidence and prevalence of atrial fibrillation

In 2010, the estimated numbers of men and women with AF worldwide were 20.9 million and 12.6 million, respectively, with higher incidence and prevalence rates in developed countries [1, 2]. One in four middle-aged adults in Europe and the US will develop AF [3–5]. By 2030, 14–17 million AF patients are anticipated in the European Union, with 120 000–215 000 newly diagnosed patients per year [2, 6, 7]. Estimates suggest an AF prevalence of approximately 3% in adults aged 20 years or older [8, 9], with greater prevalence in older persons [1] and in patients with conditions such as hypertension, heart failure, coronary artery disease (CAD), valvular heart disease, obesity, diabetes mellitus, or chronic kidney disease (CKD) [7, 10–15]. The increase in AF prevalence can be attributed both to better detection of silent AF [16–18], alongside increasing age and conditions predisposing to AF [19].

Table 3: Cardiovascular morbidity and mortality associated with atrial fibrillation

Event	Association with AF
Death	Increased mortality, especially cardiovascular mortality due to sudden death, heart failure or stroke.
Stroke	20–30% of all strokes are due to AF. A growing number of patients with stroke are diagnosed with 'silent', paroxysmal AF.
Hospitalizations	10–40% of AF patients are hospitalized every year.
Quality of life	Quality of life is impaired in AF patients independent of other cardiovascular conditions.
Left ventricular dysfunction and heart failure	Left ventricular dysfunction is found in 20–30% of all AF patients. AF causes or aggravates LV dysfunction in many AF patients, while others have completely preserved LV function despite long-standing AF.
Cognitive decline and vascular dementia	Cognitive decline and vascular dementia can develop even in anticoagulated AF patients. Brain white matter lesions are more common in AF patients than in patients without AF.

AF = atrial fibrillation; LV = left ventricular.

3.2 Morbidity, mortality, and healthcare burden of atrial fibrillation

AF is independently associated with a two-fold increased risk of all-cause mortality in women and a 1.5-fold increase in men [20–22] (Table 3). Death due to stroke can largely be mitigated by anticoagulation, while other cardiovascular deaths, for example due to heart failure and sudden death, remain common even in AF patients treated according to the current evidence base [23]. AF is also associated with increased morbidity, such as heart failure and stroke [21, 24, 25]. Contemporary studies show that 20–30% of patients with an ischaemic stroke have AF diagnosed before, during, or after the initial event [17, 26, 27]. White matter lesions in the brain, cognitive impairment [28–30], decreased quality of life [31, 32], and depressed mood [33] are common in AF patients, and between 10–40% of AF patients are hospitalized each year [23, 34, 35].

The direct costs of AF already amount to approximately 1% of total healthcare spending in the UK, and between 6.0–26.0 billion US dollars in the US for 2008 [36, 37], driven by AF-related complications (e.g. stroke) and treatment costs (e.g. hospitalizations). These costs will increase dramatically unless AF is prevented and treated in a timely and effective manner.

3.3 Impact of evidence-based management on outcomes in atrial fibrillation patients

Figure 1 depicts the major milestones in the management of AF. Despite these advances, substantial morbidity remains. Oral

ACE-I = angiotensin-converting enzyme inhibitor; AF = atrial fibrillation; ARB = angiotensin receptor blocker; HF = heart failure; HFrEF = heart failure with reduced ejection fraction; LVH = left ventricular hypertrophy; NOAC = non-vitamin K antagonist oral anticoagulant; PUFA = polyunsaturated fatty acid; PVI = pulmonary vein isolation; QoL = quality of life; RF = radiofrequency; SR = sinus rhythm; VKA = vitamin K antagonist.

Figure 1: Timeline of findings from landmark trials in atrial fibrillation management, including treatment of concomitant conditions and prevention (green), anticoagulation (blue), rate control therapy (orange), rhythm control therapy (red), and atrial fibrillation surgery (purple).

anticoagulation (OAC) with vitamin K antagonists (VKAs) or non-VKA oral anticoagulants (NOACs) markedly reduces stroke and mortality in AF patients [38, 39]. Other interventions such as rhythm control and rate control improve AF-related symptoms and may preserve cardiac function, but have not demonstrated a reduction in long-term morbidity or mortality [40, 41].

In contemporary, well-controlled, randomized clinical trials in AF, the average annual stroke rate is about 1.5% and the annualized death rate is around 3% in anticoagulated AF patients [40]. In real life, the annual mortality can be different (both higher and lower) [42]. A minority of these deaths are related to stroke, while sudden cardiac death and death from progressive heart failure are more frequent, emphasizing the need for interventions beyond anticoagulation [43, 44]. Furthermore, AF is also associated with high rates of hospitalization, commonly for AF management, but often also for heart failure, myocardial infarction, and treatment-associated complications [34, 45].

Recommendations relating to gender

Recommendations	Class[a]	Level[b]	Ref[c]
AF clinicians must offer effective diagnostic tools and therapeutic management to women and men equally to prevent stroke and death.	I	A	39,46,57
Catheter or surgical ablation techniques should be regarded as equally effective in women and men.	IIa	B	55,56

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

3.4 Gender

In both developed and developing countries, the age-adjusted incidence and prevalence of AF are lower in women, while the risk of death in women with AF is similar to or higher than that in men with AF [1, 46, 47]. Female AF patients who have additional stroke risk factors (particularly older age) are also at greater risk than men of having a stroke [48, 49], even those anticoagulated with warfarin

[50] (see Chapter 9 for details). Women with diagnosed AF can be more symptomatic than men and are typically older with more comorbidities [51, 52]. Bleeding risk on anticoagulation is similar in both sexes [49, 50, 53], but women appear less likely to receive specialist care and rhythm control therapy [54], while the outcomes of catheter ablation or AF surgery are comparable to those in men [55, 56]. These observations highlight the need to offer effective diagnostic tools and therapeutic management equally to women and men.

4. PATHOPHYSIOLOGICAL AND GENETIC ASPECTS THAT GUIDE MANAGEMENT

4.1 Genetic predisposition

AF, especially early-onset AF, has a strong heritable component that is independent of concomitant cardiovascular conditions [58, 59]. A few young AF patients suffer from inherited cardiomyopathies or channelopathies mediated by disease-causing mutations. These monogenic diseases also convey a risk for sudden death (see Chapter 6). Up to one-third of AF patients carry common genetic variants that predispose to AF, albeit with a relatively low added risk. At least 14 of these common variants, often single nucleotide polymorphisms, are known to increase the risk of prevalent AF in populations [60–62]. The most important variants are located close to the *paired-like homeodomain transcription factor 2* (Pitx2) gene on chromosome 4q25 [63, 64]. These variants modify the risk of AF up to seven-fold [64]. Several of the AF risk variants are also associated with cardioembolic or ischaemic stroke, possibly due to silent AF (see section 5.1) [62, 65, 66]. Changes in atrial action potential characteristics [67–70], atrial remodelling, and modified penetration of rare gene defects [61] have been suggested as potential mechanisms mediating increased AF risk in carriers of common gene variants. Genetic variants could, in the future, become useful for patient selection of rhythm or rate control [71–74]. While genomic analysis may provide an opportunity to improve the diagnosis and management of AF in the future [75, 76], routine genetic testing for common gene variants associated with AF cannot be recommended at present [77].

4.2 Mechanisms leading to atrial fibrillation

4.2.1 Remodelling of atrial structure and ion channel function. External stressors such as structural heart disease, hypertension, possibly diabetes, but also AF itself induce a slow but progressive process of structural remodelling in the atria (Figure 2). Activation of fibroblasts, enhanced connective tissue deposition, and fibrosis are the hallmarks of this process [78–80]. In addition, atrial fatty infiltration, inflammatory infiltrates, myocyte hypertrophy, necrosis, and amyloidosis are found in AF patients with concomitant conditions predisposing to AF [81–84]. Structural remodelling results in electrical dissociation between muscle bundles and local conduction heterogeneities [85], favouring re-entry and perpetuation of the arrhythmia [86]. In many patients, the structural remodelling process occurs before the onset of AF [78]. As some of the structural remodelling will be irreversible, early initiation of treatment seems desirable [87]. Table 4 gives an overview of the most relevant pathophysiological alterations in atrial tissue associated with AF, and lists corresponding clinical conditions that can contribute to these changes.

The functional and structural changes in atrial myocardium and stasis of blood, especially in the left atrial appendage (LAA), generate a prothrombotic milieu. Furthermore, even short episodes of AF lead to atrial myocardial damage and the expression of prothrombotic factors on the atrial endothelial surface, alongside activation of platelets and inflammatory cells, and contribute to a generalized prothrombotic state [88, 89]. The atrial and systemic activation of the coagulation system can partially explain why short episodes of AF convey a long-term stroke risk.

4.2.2 Electrophysiological mechanisms of atrial fibrillation. AF provokes a shortening of the atrial refractory period and AF cycle length during the first days of the arrhythmia, largely due to downregulation of the Ca^{2+}-inward current and upregulation of inward rectifier K^{+} currents [94, 95]. Structural heart disease, in contrast, tends to prolong the atrial refractory period, illustrating the heterogeneous nature of mechanisms that cause AF in different patients [96]. Hyperphosphorylation of various Ca^{2+}-handling proteins may contribute to enhanced spontaneous Ca^{2+} release events and triggered activity [97, 98], thus causing ectopy and promoting AF. Although the concept of Ca^{2+}-handling instability has been challenged recently [106, 107], it may mediate AF in structurally remodelled atria and explain how altered autonomic tone can generate AF [80, 105].

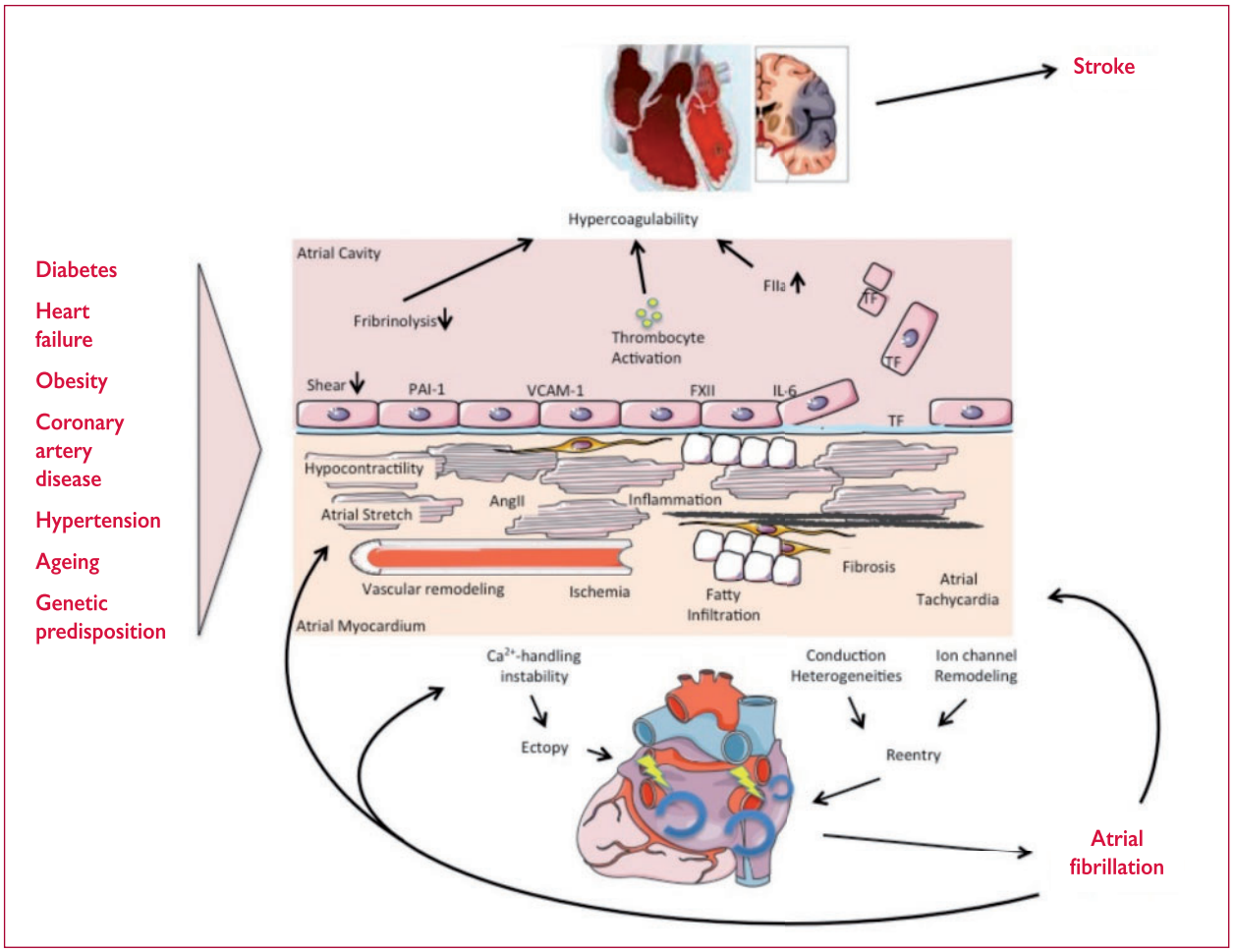
4.2.2.1 *Focal initiation and maintenance of atrial fibrillation*. The seminal observation by Haissaguerre *et al.* [108]. was that a focal source in the pulmonary veins can trigger AF, and ablation of this source can suppress recurrent AF. The mechanism of focal activity might involve both triggered activity and localized reentry [109, 110]. Hierarchic organization of AF with rapidly activated areas driving the arrhythmia has been documented in patients with paroxysmal AF [111, 112], but is less obvious in unselected patients with persistent AF [113].

4.2.2.2 *The multiple wavelet hypothesis and rotors as sources of atrial fibrillation*. Moe and Abildskov [114] proposed that AF can be perpetuated by continuous conduction of several independent wavelets propagating through the atrial musculature in a seemingly chaotic manner. As long as the number of wavefronts does not decline below a critical level, they will be capable of sustaining the arrhythmia. Numerous experimental and clinical observations can be reconciled with the multiple wavelet hypothesis [115]. All localized sources of AF (ectopic foci, rotors, or other stable re-entry circuits) cause fibrillatory conduction remote from the source, which is difficult to distinguish from propagation sustaining AF by multiple wavelets, and either of these phenomena may generate 'rotors' picked up by intracardiac [116, 117] or body surface [117] recordings.

5. DIAGNOSIS AND TIMELY DETECTION OF ATRIAL FIBRILLATION

5.1 Overt and silent atrial fibrillation

The diagnosis of AF requires rhythm documentation using an electrocardiogram (ECG) showing the typical pattern of AF: Absolutely irregular RR intervals and no discernible, distinct P waves. ECG-documented AF was the entry criterion in trials forming the



AngII = angiotensin II; TF = tissue factor; FXII = factor XII; IL-6 = interleukin 6; PAI-1 = plasminogen activator inhibitor 1; VCAM-1 = vascular cell adhesion molecule 1.

Figure 2: Major mechanisms causing atrial fibrillation that can be considered when choosing therapy. The various aetiological factors (left) cause a complex array of pathophysiological changes in the atria, including stretch-induced atrial fibrosis, hypocontractility, fatty infiltration, inflammation, vascular remodelling, ischaemia, ion channel dysfunction, and Ca^{2+}-instability. These changes enhance both ectopy and conduction disturbances, increasing the propensity of the atria to develop or maintain AF. At the same time, some of these alterations are involved in the occurrence of the hypercoagulable state associated with AF. For example, hypocontractility reduces local endothelial shear stress, which increases PAI-1 expression, and ischaemia-induced inflammation enhances the expression of endothelial adhesion molecules or promotes shedding of endothelial cells, resulting in tissue factor exposure to the blood stream. These changes contribute to the thrombogenic milieu in the atria of AF patients. AF in itself can aggravate many of the mechanisms shown, which may explain the progressive nature of the arrhythmia.

evidence for these guidelines. By accepted convention, an episode lasting at least 30 s is diagnostic. Individuals with AF may be symptomatic or asymptomatic ('silent AF'). Many AF patients have both symptomatic and asymptomatic episodes of AF [118–121].

Silent, undetected AF is common [120, 122], with severe consequences such as stroke and death [123–125]. Prompt recording of an ECG is an effective and cost-effective method to document chronic forms of AF [126]. The technology to detect paroxysmal, self-terminating AF episodes is rapidly evolving (see section 6.1 for a definition of AF patterns). There is good evidence that prolonged ECG monitoring enhances the detection of undiagnosed AF, e.g. monitoring for 72 h after a stroke [27, 127], or even longer periods [18, 128]. Daily short-term ECG recordings increase AF detection in populations over 75 years of age [129] (Web Figure 1). Ongoing studies will determine whether such early detection alters management (e.g. initiation of anticoagulation) and improves outcomes.

Once the ECG diagnosis of AF has been established, further ECG monitoring can inform management in the context of: (1) a change in symptoms or new symptoms; (2) suspected progression of AF; (3) monitoring of drug effects on ventricular rate; and (4) monitoring of antiarrhythmic drug effects or catheter ablation for rhythm control.

5.2 Screening for silent atrial fibrillation

5.2.1 Screening for atrial fibrillation by electrocardiogram in the community. Undiagnosed AF is common, especially in older populations and in patients with heart failure [130]. Opportunistic screening for silent AF seems cost-effective in elderly populations (e.g. >65 years) [131], and similar effects have been reported using single-lead ECG screening in other at-risk populations [132, 133]. Screening of older populations (mean age 64 years) yielded a prevalence of 2.3% for chronic forms of AF in 122,571 participants using either short-term ECG or pulse palpation (followed by ECG in those with an irregular pulse) [134]. Previously undiagnosed AF was found in 1.4% of

Table 4: Pathophysiological alterations in atrial tissue associated with atrial fibrillation and clinical conditions that could contribute to such alterations

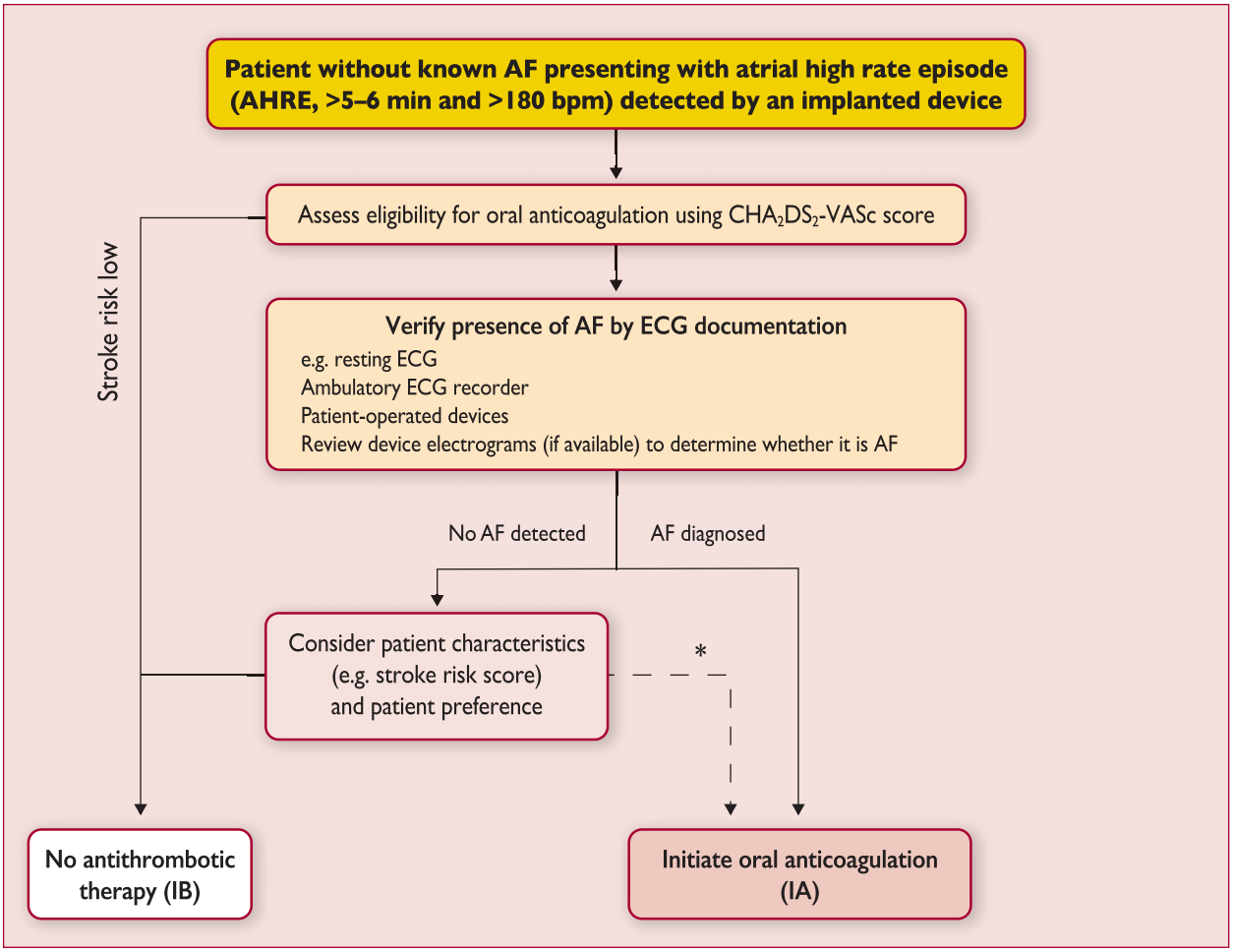
Pathophysiological alteration	Clinical conditions contributing to the alteration	Pro-arrhythmic mechanism/ functional consequence	References
Changes of the extracellular matrix, fibroblast function and fat cells			
Interstitial and replacement fibrosis	AF (especially forms with a high AF burden), hypertension, heart failure, valvular heart disease (via pressure and volume overload).	Electrical dissociation, conduction block, enhanced AF complexity.	78, 79, 90, 91
Inflammatory infiltration		Profibrotic responses, enhanced AF complexity.	81
Fatty infiltration	Obesity.	Profibrotic / proinflammatory responses, localized conduction block.	82, 92
Amyloid deposition	Aging, heart failure, coronary artery disease (via atrial scarring), genetic factors.	Conduction disturbances.	83, 93
Ion channel alterations			
Ion channel remodelling	AF (especially forms with a high AF burden), genetic predisposition to AF.	AF cycle shortening (if due to atrial tachycardia), AF cycle length prolongation (if due to heart failure), enhanced heterogeneity of atrial repolarization.	94–96
Ca^{2+} handling instability	AF (especially forms with a high AF burden), heart failure and hypertension (possibly through increased sympathetic activation).	Enhanced propensity to ectopy.	97, 98
Gap-junction redistribution	AF	Conduction disturbances.	99
Myocyte alterations			
Apoptosis and necrosis	Coronary artery disease, heart failure (through cardiomyocyte death and atrial scarring).	May induce replacement fibrosis.	100
Myocyte hypertrophy	Atrial dilatation, AF.	Aggravates conduction disturbances.	84, 101
Endothelial and vascular alterations			
Microvascular changes	Atherosclerosis, coronary and peripheral artery disease, possibly atrial fibrillation.	Aggravation of atrial ischaemia, heterogeneity of electrical function, structural remodelling.	102
Endocardial remodelling		Enhanced risk for thrombus formation.	103,104
Changes of the autonomic nervous system			
Sympathetic hyperinnervation	Heart failure, hypertension.	Enhanced propensity to ectopy.	80, 105

AF = atrial fibrillation; CAD = coronary artery disease.

those aged >65 years, suggesting a number needed to screen of 70. These findings encourage the further evaluation of systematic AF screening programmes in at-risk populations.

5.2.2 Prolonged monitoring for paroxysmal atrial fibrillation. Paroxysmal AF is often missed [120]. Repeated daily ECG recordings increased the detection of silent, asymptomatic paroxysmal AF in an unselected Swedish population aged >75 years [120, 135]. Several patient-operated devices [136, 137] and extended continuous ECG monitoring using skin patch recorders [138] have been validated for the detection of paroxysmal AF (Web Figure 1) [139]. The detection of asymptomatic AF by new technologies, such as smartphone cases with ECG electrodes, smart watches, and blood pressure machines with AF detection algorithms, has not yet been formally evaluated against an established arrhythmia detection method [140].

5.2.3 Patients with pacemakers and implanted devices. Implanted pacemakers or defibrillators with an atrial lead allow continuous monitoring of atrial rhythm. Using this technology, patients with atrial high rate episodes (AHRE) can be identified. Depending on the risk profile of the population studied, such AHRE are detected in 10–15% of pacemaker patients [141]. AHRE are associated with an increased risk of overt AF [hazard ratio (HR) 5.56; 95% confidence interval (CI) 3.78–8.17; $P < 0.001$] and ischaemic stroke or systemic embolism (HR 2.49; 95% CI 1.28–4.85; $P = 0.007$). The stroke risk in AHRE patients seems lower than the stroke risk in patients with diagnosed AF, and not all AHRE represent AF [142]. Strokes often occur without AHRE detected within 30 days before the event [143–147]. Consequently, it is unclear whether AHRE imply the same therapeutic requirements as overt AF [148], and the benefit of OAC in patients with AHRE is tested in ongoing clinical trials [e.g. Apixaban for the Reduction of Thrombo-Embolism in Patients



AF = atrial fibrillation; AFNET = German Competence NETwork on Atrial Fibrillation; AHRE = atrial high rate episodes; bpm = beats per minute; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female); ECG = electrocardiogram; EHRA = European Heart Rhythm Association.

*In rare individual circumstances, oral anticoagulation may be considered in patients with AHRE, but without diagnosed AF. This clearly needs discussion with the patient and careful evaluation of perceived benefit and risk.

[a]Adapted from the report of the 3rd AFNET/EHRA consensus conference [150].

Figure 3: Management of AHRE detected by an implanted device.

With Device-Detected Sub-Clinical Atrial Fibrillation (ARTESiA) (NCT01938248) and *N*on vitamin K antagonist *O*ral anticoagulants in patients with *A*trial *H*igh rate episodes (NOAH – AFNET 6) (NCT02618577)]. At present, pacemakers and implanted devices should be interrogated on a regular basis for AHRE, and patients with AHRE should undergo further assessment of stroke risk factors and for overt AF, including ECG monitoring (Figure 3) [149].

5.2.4 Detection of atrial fibrillation in stroke survivors. Sequential stratified ECG monitoring detected AF in 24% (95% CI 17–31) of stroke survivors [151], and in 11.5% (95% CI 8.9%–14.3%) in another meta-analysis [17], with large variations depending on the timing, duration, and method of monitoring. AF detection is not uncommon in unselected stroke patients (6.2%, 95% CI 4.4–8.3) [128], but is more likely in patients with cryptogenic stroke implanted with loop recorders or who have had ECG monitors for several weeks [18, 128, 152]. Cryptogenic stroke is defined as a stroke in which the cause could not be identified after extensive investigations [153]. A broader definition is embolic stroke of undetermined source [154]. Several studies have also found AF in patients in whom another competing cause for stroke has been identified clinically (e.g. hypertension or carotid artery stenosis) [27, 127]. Hence, prolonged ECG monitoring seems reasonable in all survivors of an ischaemic stroke without an established diagnosis of AF.

5.3 Electrocardiogram detection of atrial flutter

Right atrial isthmus-dependent flutter has a typical ECG pattern and ventricular rate [158]. The prevalence of atrial flutter is less than one-tenth of the prevalence of AF [159]. Atrial flutter often coexists with or precedes AF [160]. In typical, isthmus-dependent flutter, P waves will often show a 'saw tooth' morphology, especially in the inferior leads (II, III, aVF). The ventricular rate can be variable (usual ratio of atrial to ventricular contraction 4:1 to 2:1, in rare cases 1:1) and macro re-entrant tachycardias may be missed in stable 2:1 conduction. Vagal stimulation or intravenous adenosine can therefore be helpful to unmask atrial flutter. The management of atrial flutter is discussed in section 13.7. Left or

Recommendations for screening for atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
Opportunistic screening for AF is recommended by pulse taking or ECG rhythm strip in patients >65 years of age.	I	B	130,134, 155
In patients with TIA or ischaemic stroke, screening for AF is recommended by short-term ECG recording followed by continuous ECG monitoring for at least 72 hours.	I	B	27,127
It is recommended to interrogate pacemakers and ICDs on a regular basis for atrial high rate episodes (AHRE). Patients with AHRE should undergo further ECG monitoring to document AF before initiating AF therapy.	I	B	141,156
In stroke patients, additional ECG monitoring by long-term non-invasive ECG monitors or implanted loop recorders should be considered to document silent atrial fibrillation.	IIa	B	18,128
Systematic ECG screening may be considered to detect AF in patients aged >75 years, or those at high stroke risk.	IIb	B	130,135, 157

AF = atrial fibrillation; AHRE = atrial high rate episodes; ECG = electrocardiogram; ICD = implantable cardioverter defibrillator; TIA = transient ischaemic attack.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

Table 5: Patterns of atrial fibrillation

AF pattern	Definition
First diagnosed AF	AF that has not been diagnosed before, irrespective of the duration of the arrhythmia or the presence and severity of AF-related symptoms.
Paroxysmal AF	Self-terminating, in most cases within 48 hours. Some AF paroxysms may continue for up to 7 days.[a] AF episodes that are cardioverted within 7 days should be considered paroxysmal.[a]
Persistent AF	AF that lasts longer than 7 days, including episodes that are terminated by cardioversion, either with drugs or by direct current cardioversion, after 7 days or more.
Long-standing persistent AF	Continuous AF lasting for ≥1 year when it is decided to adopt a rhythm control strategy.
Permanent AF	AF that is accepted by the patient (and physician). Hence, rhythm control interventions are, by definition, not pursued in patients with permanent AF. Should a rhythm control strategy be adopted, the arrhythmia would be re-classified as 'long-standing persistent AF'.

AF = atrial fibrillation.
[a]The distinction between paroxysmal and persistent AF is often not made correctly without access to long-term monitoring [163]. Hence, this classification alone is often insufficient to select specific therapies. If both persistent and paroxysmal episodes are present, the predominant pattern should guide the classification.

right atrial macro re-entrant tachycardia is mainly found in patients after catheter ablation for AF, AF surgery, or after open heart surgery [158].

6. CLASSIFICATION OF ATRIAL FIBRILLATION

6.1 Atrial fibrillation pattern

In many patients, AF progresses from short, infrequent episodes to longer and more frequent attacks. Over time, many patients will develop sustained forms of AF. In a small proportion of patients, AF will remain paroxysmal over several decades (2–3% of AF patients) [161]. The distribution of paroxysmal AF recurrences is not random, but clustered [162]. AF may also regress from persistent to paroxysmal AF. Furthermore, asymptomatic recurrences of AF are common in patients with symptomatic AF [120].

Based on the presentation, duration, and spontaneous termination of AF episodes, five types of AF are traditionally distinguished: first diagnosed, paroxysmal, persistent, long-standing persistent, and permanent AF (Table 5). If patients suffer from both paroxysmal and persistent AF episodes, the more common type should be used for classification. Clinically determined AF patterns do not correspond well to the AF burden measured by long-term ECG monitoring [163]. Even less is known about the response to therapy in patients with long-standing persistent AF or long-standing paroxysmal AF. Despite these inaccuracies, the distinction between paroxysmal and persistent AF has been used in many trials and therefore still forms the basis of some recommendations.

There is some evidence suggesting that AF burden may influence stroke risk [44, 124, 164] and could modify the response to rhythm control therapy [76, 165]. The evidence for this is weak. Therefore, AF burden should not be a major factor in deciding on the usefulness of an intervention that is deemed suitable for other reasons.

6.2 Atrial fibrillation types reflecting different causes of the arrhythmia

The risk of developing AF is increased in a variety of physiological and disease states (Figure 2), and the historic term 'lone AF' is probably misleading and should be avoided [166]. Although the pattern of AF may be the same, the mechanisms underpinning AF vary substantially between patients [167] (Table 6). This suggests that stratifying AF patients by underlying drivers of AF could inform management, for example, considering cardiac and systemic comorbidity (e.g. diabetes and obesity [168]), lifestyle factors (e.g. activity level, smoking, alcohol intake [169, 170]), markers of cardiac structural

Table 6: Clinical types of atrial fibrillation[a]

AF type	Clinical presentation	Possible pathophysiology
AF secondary to structural heart disease	AF in patients with LV systolic or diastolic dysfunction, long-standing hypertension with LVH, and/or other structural heart disease. The onset of AF in these patients is a common cause of hospitalization and a predictor of poor outcome.	Increased atrial pressure and atrial structural remodelling, together with activation of the sympathetic and renin-angiotensin system.
Focal AF	Patients with repetitive atrial runs and frequent, short episodes of paroxysmal atrial fibrillation. Often highly symptomatic, younger patients with distinguishable atrial waves (coarse AF), atrial ectopy, and/or atrial tachycardia deteriorating in AF.	Localized triggers, in most cases originating from the pulmonary veins, initiate AF. AF due to one or a few re-entrant drivers is also considered to be part of this type of AF.
Polygenic AF	AF in carriers of common gene variants that have been associated with early onset AF.	Currently under study. The presence of selected gene variants may also influence treatment outcomes.
Postoperative AF	New onset of AF (usually self-terminating) after major (typically cardiac) surgery in patients who were in sinus rhythm before surgery and had no prior history of AF.	Acute factors: inflammation, atrial oxidative stress, high sympathetic tone, electrolyte changes, and volume overload, possibly interacting with a pre-existing substrate.
AF in patients with mitral stenosis or prosthetic heart valves	AF in patients with mitral stenosis, after mitral valve surgery and in some cases other valvular disease.	Left atrial pressure (stenosis) and volume (regurgitation) load are the main drivers of atrial enlargement and structural atrial remodelling in these patients.
AF in athletes	Usually paroxysmal, related to duration and intensity of training.	Increased vagal tone and atrial volume.
Monogenic AF	AF in patients with inherited cardiomyopathies, including channelopathies.	The arrhythmogenic mechanisms responsible for sudden death are likely to contribute to the occurrence of AF in these patients.

AF = atrial fibrillation; LV = left ventricular; LVH = left ventricular hypertrophy.
[a]It is recognized that these types of AF will overlap in clinical practice, and that their impact for management needs to be evaluated systematically; modified from the report on the fourth AFNET/EHRA Consensus Conference [76].

remodelling (e.g. fibrosis [171–173] or electrocardiographic parameters of AF complexity [174]), or genetic background. Table 6 provides such a taxonomy, informed by expert consensus [76, 120, 175], but without much evidence to underpin its clinical use [176]. Systematic research defining the major drivers of AF is clearly needed to better define different types of AF [176].

6.3 Symptom burden in atrial fibrillation

Patients with AF have significantly poorer quality of life than healthy controls, experiencing a variety of symptoms including lethargy, palpitations, dyspnoea, chest tightness, sleeping difficulties, and psychosocial distress [32, 177–180]. Improved quality of life has been noted with both pharmacological and interventional therapies [181–185], but there are limited data to compare the benefit of different treatments [32, 186]. Assessment of quality of life is further constrained by a lack of cross-validation of the several AF-specific quality of life tools [187–191]. With regard to symptom assessment, EHRA suggested the EHRA symptom scale (Table 7) to describe symptom severity in AF patients [192]. A similar scale (the Canadian Cardiovascular Society Severity of Atrial Fibrillation Scale) is used in Canada [193]. The EHRA scale has been used and validated [194–199]. A modification was proposed in 2014, subdividing EHRA class 2 into mild (2a) or moderate (2b) impact [199]. As symptoms in class 2b ('troubling' symptoms) identified patients with a health utility benefit of rhythm control in that study, this modification may provide a threshold for potential treatment decisions, pending independent validation. While some AF patients had no or minimal symptoms (25–40%), many (15–30%) report severe or disabling symptoms [194, 196]. The modified EHRA scale should be used to guide symptom-orientated treatment decisions and for longitudinal patient profiling.

Table 7: Modified European Heart Rhythm Association symptom scale (modified from Wynn *et al*. [199])

Modified EHRA score	Symptoms	Description
I	None	AF does not cause any symptoms
2a	Mild	Normal daily activity not affected by symptoms related to AF[a]
2b	Moderate	Normal daily activity not affected by symptoms related to AF, but patient troubled by symptoms[a]
3	Severe	Normal daily activity affected by symptoms related to AF
4	Disabling	Normal daily activity discontinued

AF = atrial fibrillation; EHRA = European Heart Rhythm Association.
[a]EHRA class 2a and 2b can be differentiated by evaluating whether patients are functionally affected by their AF symptoms. AF-related symptoms are most commonly fatigue/tiredness and exertional shortness of breath, or less frequently palpitations and chest pain [42, 194, 200–202].

Recommendation on use of the modified European Heart Rhythm Association symptom scale

Recommendation	Class[a]	Level[b]	Ref[c]
Use of the modified EHRA symptom scale is recommended in clinical practice and research studies to quantify AF-related symptoms.	I	C	192,199

AF = atrial fibrillation; EHRA = European Heart Rhythm Association.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

7. DETECTION AND MANAGEMENT OF RISK FACTORS AND CONCOMITANT CARDIOVASCULAR DISEASES

Many cardiovascular diseases and concomitant conditions increase the risk of developing AF (Table 8), recurrent AF, and AF-associated complications. The identification of such conditions, their prevention and treatment is an important leverage to prevent AF and its disease burden. Knowledge of these factors and their management is hence important for optimal management of AF patients [203, 204].

7.1 Heart failure

Heart failure and AF coincide in many patients [215–217]. They are linked by similar risk factors and share a common pathophysiology [218]. Heart failure and AF can cause and exacerbate each other through mechanisms such as structural cardiac remodelling, activation of neurohormonal mechanisms, and rate-related impairment of left ventricular (LV) function. Patients with AF and concomitant heart failure, both with preserved ejection fraction [LV ejection fraction (LVEF) ≥50%] and reduced ejection fraction (LVEF <40%) [219, 220], suffer from a worse prognosis, including increased mortality [16, 221]. The recent ESC Guidelines on heart failure [222] have also introduced a new category of heart failure with mid-range ejection fraction (HFmrEF; LVEF 40–49%), although data on AF patients in this group are limited. Prevention of adverse outcomes and maintenance of a good quality of life are the aims of management in all patients with AF and concomitant heart failure, regardless of LVEF [223]. The general approach to AF management does not differ between heart failure patients and others, but a few considerations are worthwhile. Of note, the only therapy with proven prognostic value in these patients is anticoagulation, and appropriate OAC should be prescribed in all patients at risk of stroke (see Chapter 9).

7.1.1 Patients with atrial fibrillation and heart failure with reduced ejection fraction. In addition to OAC, standard heart failure therapy should be used in patients with heart failure with reduced ejection fraction (HFrEF), as detailed in the ESC

Table 8: Cardiovascular and other conditions independently associated with atrial fibrillation

Characteristic/comorbidity	Association with AF
Genetic predisposition (based on multiple common gene variants associated with AF)[64]	HR range 0.4–3.2
Older age[19] 50–59 years 60–69 years 70–79 years 80–89 years	HR: 1.00 (reference) 4.98 (95% CI 3.49–7.10) 7.35 (95% CI 5.28–10.2) 9.33 (95% CI 6.68–13.0)
Hypertension (treated) vs. none[19]	HR 1.32 (95% CI 1.08–1.60)
Heart failure vs. none[19]	HR 1.43 (95% CI 0.85–2.40)
Valvular heart disease vs. none[205]	RR 2.42 (95% CI 1.62–3.60)
Myocardial infarction vs. none[19]	HR 1.46 (95% CI 1.07–1.98)
Thyroid dysfunction[206,207] Hypothyroidism Subclinical hyperthyroidism Overt hyperthyroidism	(reference: euthyroid) HR 1.23 (95% CI 0.77–1.97) RR 1.31 (95% CI 1.19–1.44) RR 1.42 (95% CI 1.22–1.63)
Obesity[19,208] None (BMI <25 kg/m²) Overweight (BMI 25–30 kg/m²) Obese (BMI ≥31 kg/m²)	HR: 1.00 (reference) 1.13 (95% CI 0.87–1.46) 1.37 (95% CI 1.05–1.78)
Diabetes mellitus vs. none[19]	HR 1.25 (95% CI 0.98–1.60)
Chronic obstructive pulmonary disease[209] FEV1 ≥80% FEV1 60–80% FEV1 <60%	RR: 1.00 (reference) 1.28 (95% CI 0.79–2.06) 2.53 (95% CI 1.45–4.42)
Obstructive sleep apnoea vs. none[210]	HR 2.18 (95% CI 1.34–3.54)
Chronic kidney disease[211] None Stage 1 or 2 Stage 3 Stage 4 or 5	OR: 1.00 (reference) 2.67 (95% CI 2.04–3.48) 1.68 (95% CI 1.26–2.24) 3.52 (95% CI 1.73–7.15)
Smoking[212] Never Former Current	HR: 1.00 (reference) 1.32 (95% CI 1.10–1.57) 2.05 (95% CI 1.71–2.47)
Alcohol consumption[213] None 1– 6 drinks/week 7–14 drinks/week 15–21 drinks/week >21 drinks/week	RR: 1.00 (reference) 1.01 (95% CI 0.94–1.09) 1.07 (95% CI 0.98–1.17) 1.14 (95% CI 1.01–1.28) 1.39 (95% CI 1.22–1.58)
Habitual vigorous exercise[214] Non-exercisers <1 day/week 1−2 days/week 3−4 days/week 5−7 days/week	RR: 1.00 (reference) 0.90 (95% CI 0.68−1.20) 1.09 (95% CI 0.95−1.26) 1.04 (95% CI 0.91−1.19) 1.20 (95% CI 1.02−1.41)

AF = atrial fibrillation; BMI = body mass index; CI = confidence interval; FEV1 = forced expiratory volume in 1 second; HR = hazard ratio; OR = odds ratio; RR = risk ratio.

Guidelines [222]. This includes angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs), mineralocorticoid antagonists, defibrillators, cardiac resynchronization therapy [218], and combined angiotensin receptor neprilysin inhibition (ARNI) in patients able to tolerate an ACE inhibitor or ARB with ongoing symptoms [224].

Rate control of AF is discussed in detail in Chapter 9. In brief, only beta-blockers and digoxin are suitable in HFrEF because of the negative inotropic potential of verapamil and diltiazem. Beta-blockers are usually the first-line option in patients with clinically stable HFrEF, although a meta-analysis using individual patient data from randomized controlled trials (RCTs) found no reduction in mortality from beta-blockers vs. placebo in those with AF at baseline (HR 0.97, 95% CI 0.83–1.14) [23]. Digoxin is commonly prescribed in clinical practice, but no head-to-head RCTs in AF patients have been performed. In a meta-analysis of observational studies, digoxin had a neutral effect on mortality in patients with AF and concomitant heart failure (adjusted observational studies HR 0.90, 95% CI 0.70–1.16; propensity-matched observational studies RR 1.08, 95% CI 0.93–1.26) [225]. Therefore, initial and combination rate control therapy for AF in HFrEF should take account of individual patient characteristics and symptoms; beta-blocker initiation should be delayed in patients with acute decompensated heart failure, and digoxin can accumulate and provoke adverse effects in patients with kidney dysfunction (see Chapter 10).

Patients with AF and HFrEF who present with severe symptoms may require rhythm control therapy in addition to rate control therapy. For patients who develop HFrEF as a result of rapid AF (tachycardiomyopathy), a rhythm control strategy is preferred, based on several relatively small patient cohorts and trials reporting improved LV function after restoration of sinus rhythm [185, 226–228]. The diagnosis of tachycardiomyopathy can be challenging, and at times requires the restoration of sinus rhythm [229]. Catheter ablation may be a useful method to restore LV function and quality of life in AF patients with HFrEF [185, 226–228], but further data are needed. Figure 4 summarizes the approach to patients with AF and heart failure.

7.1.2 Atrial fibrillation patients with heart failure with preserved ejection fraction. The diagnosis of heart failure with preserved ejection fraction (HFpEF) in patients with AF is problematic because of the difficulty in separating symptoms that are due to HF from those due to AF. Although diagnostic differentiation can be achieved by cardioversion and clinical reassessment but should be reserved for symptomatic improvement as a specific therapy that improves prognosis in HFpEF is currently lacking. Echocardiography can support the detection of HFpEF in patients with symptomatic AF by providing evidence of relevant structural heart disease [e.g. LV hypertrophy (LVH)] and/or measurement of diastolic dysfunction. Reduced early diastolic myocardial velocity e′ by tissue Doppler reflects impaired LV relaxation, while the ratio of E/e′ is correlated with invasive measurement of LV filling pressures [230–234]. Natriuretic peptide levels are part of the diagnostic assessment of HFpEF [222], although natriuretic peptide levels are elevated in AF patients and the optimum diagnostic cut-off is still unknown [235]. The management of patients with AF and concomitant HFpEF should focus on the control of fluid balance and concomitant conditions such as hypertension and myocardial ischaemia.

7.1.3 Atrial fibrillation patients with heart failure with mid-range ejection fraction. HFmrEF is a recently defined entity, describing patients with symptoms and signs of heart failure, LVEF 40–49%, elevated levels of natriuretic peptides, and either LV hypertrophy, left atrial (LA) enlargement, or evidence of diastolic dysfunction [222]. However, diagnosis is more difficult in patients with AF, as natriuretic peptides are elevated in AF and LA dilatation is common, regardless of concomitant heart failure. LVEF is also variable and difficult to assess in AF patients because of AF-induced reduction in systolic LV function and variable cardiac cycle length. Further study of this group is required before particular treatment strategies in AF patients with HFmrEF can be recommended.

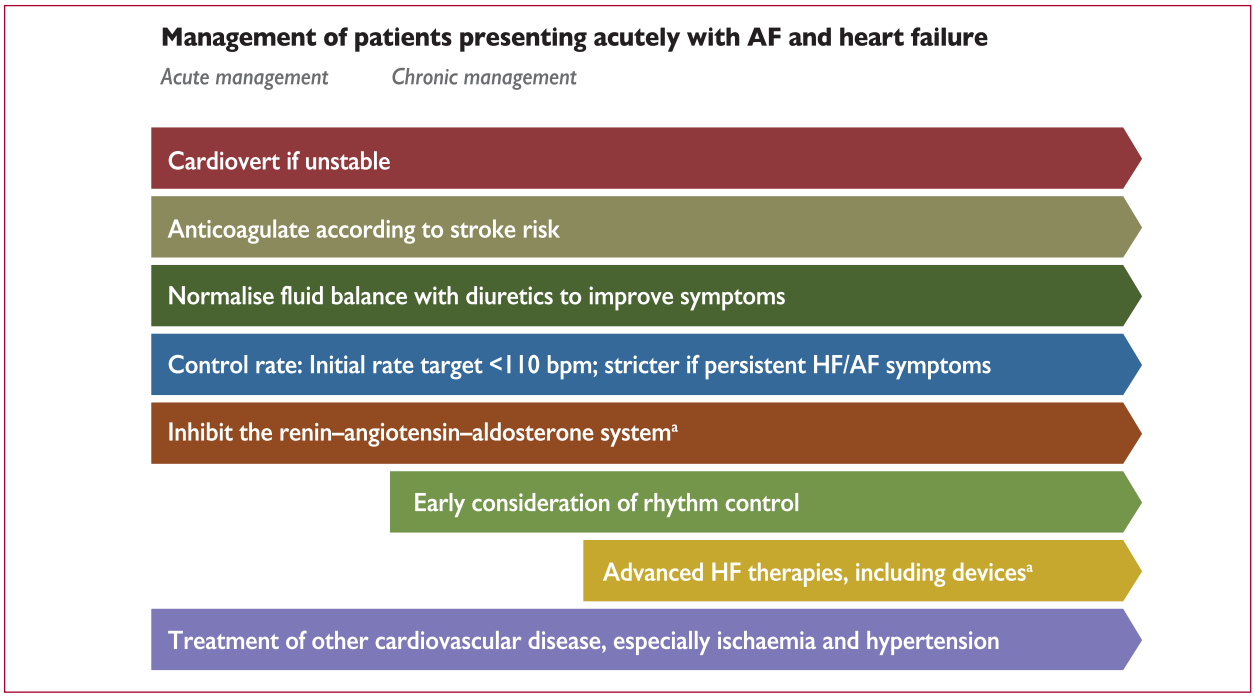
7.1.4 Prevention of atrial fibrillation in heart failure. Retrospective analyses from large randomized trials have reported a lower incidence of new-onset AF in patients treated with ACE inhibitors/ARBs compared with placebo [236–238]. The reduced incidence of AF with ACE inhibitors/ARBs is less evident in patients with HFpEF [239] and is lost in patients without heart failure [240–242]. Neprilysin inhibition does not seem to add to this effect [224]. Beta-blocker therapy was associated with a 33% reduction in the adjusted odds of incident AF in HFrEF patients pre-treated with ACE inhibitors/ARBs, reinforcing the importance of beta-blocker therapy in HFrEF patients in sinus rhythm [23]. Eplerenone, a mineralocorticoid receptor antagonist, also reduced the risk of new-onset AF in patients with LVEF ≤35%, New York Heart Association (NYHA) Class II, when added to ACE inhibitors/ARBs and beta-blockers [243].

7.2 Hypertension

Hypertension is a stroke risk factor in AF; uncontrolled high blood pressure enhances the risk of stroke and bleeding events and may lead to recurrent AF. Therefore, good blood pressure control should form an integral part of the management of AF patients [247]. Inhibition of the renin–angiotensin–aldosterone system can prevent structural remodelling and recurrent AF [236, 244]. A recent analysis of the Danish healthcare database with long-term monitoring of the effect of different antihypertensive agents on the occurrence of overt AF suggests a beneficial effect of ACE inhibitors or ARBs [245]. Secondary analyses of ACE inhibitors or ARBs in patients with heart failure or LVH show a lower incidence of new-onset AF [238, 246]. In patients with established AF, but without LV dysfunction or heart failure, ARBs do not prevent recurrent AF better than placebo [240, 241]. ACE inhibitors or ARBs may reduce recurrent AF after cardioversion when co-administered with antiarrhythmic drug therapy compared with an antiarrhythmic drug alone [248, 249]. Meta-analyses driven by these studies suggested a lower risk of recurrent AF [236–238, 250], but at least one controlled trial failed to demonstrate benefit [240, 251].

7.3 Valvular heart disease

Valvular heart disease is independently associated with incident AF [252]. Approximately 30% of patients with AF have some form of valvular heart disease, often detected only by



ACE = angiotensin-converting enzyme; AF = atrial fibrillation; ARB = angiotensin receptor blocker; ARNI = angiotensin receptor neprilysin inhibition; b.p.m = beats per minute; HF = heart failure.
[a]In patients with heart failure and reduced ejection fraction. Also consider combined ARNI in patients able to tolerate an ACE inhibitor or ARB with ongoing symptoms.

Figure 4: Initial management of patients presenting acutely with atrial fibrillation and heart failure. (Adapted from Kotecha and Piccini [218].)

echocardiogram [201, 253–255]. AF worsens prognosis in patients with severe valvular heart disease [256], including those undergoing surgery or transcatheter interventions for aortic or mitral valve disease [257–262]. Valvular heart disease can be associated with an increased thrombo-embolic risk, which probably also adds to the stroke risk in AF patients [263]. Similar to heart failure, valvular disease and AF interact with and sustain each other through volume and pressure overload, tachycardiomyopathy, and neurohumoral factors [264–270]. When valve dysfunction is severe, AF can be regarded as a marker for progressive disease, thus favouring valve repair or replacement [271].

Traditionally, patients with AF have been dichotomized into 'valvular' and 'non-valvular' AF [272]. Although slightly different definitions have been used, valvular AF mainly refers to AF patients that have either rheumatic valvular disease (predominantly mitral stenosis) or mechanical heart valves. In fact, while AF implies an incremental risk for thrombo-embolism in patients with mitral valve stenosis [263, 273, 274], there is no clear evidence that other valvular diseases, including mitral regurgitation or aortic valve disease, need to be considered when choosing an anticoagulant or indeed to estimate stroke risk in AF [275]. Therefore, we have decided to replace the historic term 'non-valvular' AF with reference to the specific underlying conditions.

Recommendations for patients with valvular heart disease and atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
Early mitral valve surgery should be considered in severe mitral regurgitation, preserved LV function, and new-onset AF, even in the absence of symptoms, particularly when valve repair is feasible.	IIa	C	276
Mitral valvulotomy should be considered for asymptomatic patients with severe mitral stenosis and suitable valve anatomy who have new-onset AF.	IIa	C	

AF = atrial fibrillation; LV = left ventricular.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

7.4 Diabetes mellitus

Diabetes and AF frequently coexist because of associations with other risk factors [277–283]. Diabetes is a risk factor for stroke and other complications in AF [284]. In patients with AF, a longer duration of diabetes appears to confer a higher risk of thrombo-embolism, albeit without greater risk of OAC-related bleeding [285]. Unfortunately, intensive glycaemic control does not affect the rate of new-onset AF [284], while treatment with metformin seems to be associated with a decreased long-term risk of AF in diabetic patients [286] and may even

be associated with a lower long-term stroke risk [13]. Diabetic retinopathy, a measure of disease severity, does not increase the risk of ocular bleeding in anticoagulated patients [287].

7.5 Obesity and weight loss

7.5.1 Obesity as a risk factor. Obesity increases the risk for AF (Table 8) [288–291] with a progressive increase according to body mass index (BMI) [288, 290–292]. Obese patients may have more LV diastolic dysfunction, increased sympathetic activity and inflammation, and increased fatty infiltration of the atria [293–295]. Obesity may also be a risk factor for ischaemic stroke, thrombo-embolism, and death in AF patients [292].

7.5.2 Weight reduction in obese patients with atrial fibrillation. Intensive weight reduction in addition to the management of other cardiovascular risk factors (in the range of 10–15 kg weight loss achieved), led to fewer AF recurrences and symptoms compared with an approach based on general advice in obese patients with AF [203, 204, 296]. Improved cardiorespiratory fitness can further decrease AF burden in obese patients with AF [297]. Although the findings in these studies have to be confirmed, they underpin the positive effect of weight reduction in obese AF patients.

7.5.3 Catheter ablation in obese patients. Obesity may increase the rate of AF recurrence after catheter ablation [298–301], with obstructive sleep apnoea as an important potential confounder. Obesity has also been linked to a higher radiation dose and complication rate during AF ablation [302, 303]. Notably, the symptomatic improvement after catheter ablation of AF in obese patients seems comparable to the improvement in normal-weight patients [298]. In view of the potential to reduce AF episodes by weight reduction (see section 7.5.2.), AF ablation should be offered to obese patients in conjunction with lifestyle modifications that lead to weight reduction.

7.6 Chronic obstructive pulmonary disease, sleep apnoea, and other respiratory diseases

AF has been associated with obstructive sleep apnoea [304, 305]. Multiple pathophysiological mechanisms can contribute to AF in obstructive sleep apnoea, including autonomic dysfunction, hypoxia, hypercapnia, and inflammation [96, 304–307]. Obstructive sleep apnoea exaggerates intrathoracic pressure changes, which in itself and via vagal activation can provoke shortening of the atrial action potential and induce AF. Risk factor reduction and continuous positive airway pressure ventilation can reduce AF recurrence [308–312]. It seems reasonable to consider obstructive sleep apnoea screening in AF patients with risk factors. Obstructive sleep apnoea treatment should be optimized to improve AF treatment results in appropriate patients. Servo-controlled pressure support therapy should not be used in HFrEF patients with predominantly central sleep apnoea (of which 25% had concomitant AF) [313].

Patients with chronic obstructive pulmonary disease often suffer from atrial tachycardias, which need to be differentiated from AF by ECG. Agents used to relieve bronchospasm, notably theophyllines and beta-adrenergic agonists, may precipitate AF and make control of the ventricular response rate difficult. Non-selective beta-blockers, sotalol, propafenone, and adenosine should be used with caution in patients with significant bronchospasm, while they can safely be used in patients with chronic obstructive pulmonary disease. Beta-1 selective blockers (e.g. bisoprolol, metoprolol, and nebivolol), diltiazem, and verapamil are often tolerated and effective (see Chapter 10).

7.7 Chronic kidney disease

AF is present in 15–20% of patients with CKD [316]. The definition of CKD in most AF trials is relatively strict. Although an estimated creatinine clearance (CrCl) rate of <60 mL/min is indicative of CKD, a number of trials in AF patients have used CrCl <50 mL/min to adapt NOAC dosage, usually estimated using the Cockroft–Gault formula. CrCl in AF patients can deteriorate over

Recommendation for obese patients with atrial fibrillation

Recommendation	Class[a]	Level[b]	Ref[c]
In obese patients with AF, weight loss together with management of other risk factors should be considered to reduce AF burden and symptoms.	IIa	B	204,288, 296

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendation.

Recommendations for patients with atrial fibrillation and respiratory diseases

Recommendations	Class[a]	Level[b]	Ref[c]
Correction of hypoxaemia and acidosis should be considered as initial management for patients who develop AF during an acute pulmonary illness or exacerbation of chronic pulmonary disease.	IIa	C	
Interrogation for clinical signs of obstructive sleep apnoea should be considered in all AF patients.	IIa	B	304,305, 314,315
Obstructive sleep apnoea treatment should be optimized to reduce AF recurrences and improve AF treatment results.	IIa	B	307–311

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

Recommendations for patients with kidney disease and atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
The assessment of kidney function by serum creatinine or creatinine clearance is recommended in all AF patients to detect kidney disease and to support correct dosing of AF therapy.	I	A	316, 318–321
All AF patients treated with oral anticoagulation should be considered for at least yearly renal function evaluation to detect chronic kidney disease.	IIa	B	

AF = atrial fibrillation
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

time [317]. The management of OAC in patients with CKD is discussed in section 9.2.4.

8. INTEGRATED MANAGEMENT OF PATIENTS WITH ATRIAL FIBRILLATION

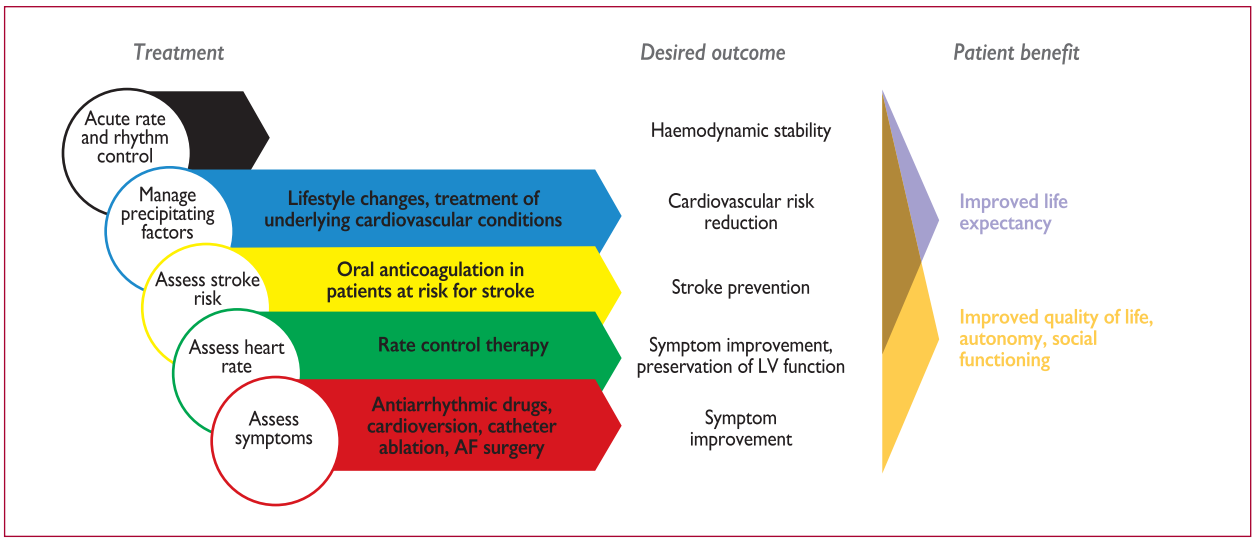
Most patients initially access the healthcare system through pharmacists, community health workers, or primary care physicians. As AF is often asymptomatic ("silent AF"), these healthcare professionals are important stakeholders to enable the adequate detection of AF and to ensure consistent management. The initial assessment should be performed at the point of first contact with the healthcare system, and is feasible in most healthcare settings (when an ECG is available). We propose to consider five domains in the initial assessment of patients presenting with newly diagnosed AF (Figure 5). These domains are:

1. Haemodynamic instability or limiting, severe symptoms;
2. Presence of precipitating factors (e.g. thyrotoxicosis, sepsis, or post-operative AF) and underlying cardiovascular conditions;
3. Stroke risk and need for anticoagulation;
4. Heart rate and need for rate control;
5. Symptom assessment and decision for rhythm control.

An integrated, structured approach to AF care, as applied successfully to other domains of medicine [322–324], will facilitate consistent, guideline-adherent AF management for all patients [325] (Figure 6), with the potential to improve outcomes [42, 326, 327]. Such approaches are consistent with the Innovative Care for Chronic Conditions Framework proposal put forward by the World Health Organization [328]. Review by an AF service, or at least referral to a cardiologist, will usually be required after the initial assessment to fully evaluate the effect of AF on cardiovascular health [329]. There may also be reasons for early or urgent referral (Table 9). Integrated care of all patients with newly diagnosed AF should help to overcome the current shortcomings of AF management, such as underuse of anticoagulation, access to rate and rhythm control therapy, and inconsistent approaches to cardiovascular risk reduction. Integrated AF care requires the cooperation of primary care physicians, cardiologists, cardiac surgeons, AF specialists, stroke specialists, allied health practitioners, and patients, encompassing lifestyle interventions, treatment of underlying cardiovascular diseases, and AF-specific therapy (Figure 7).

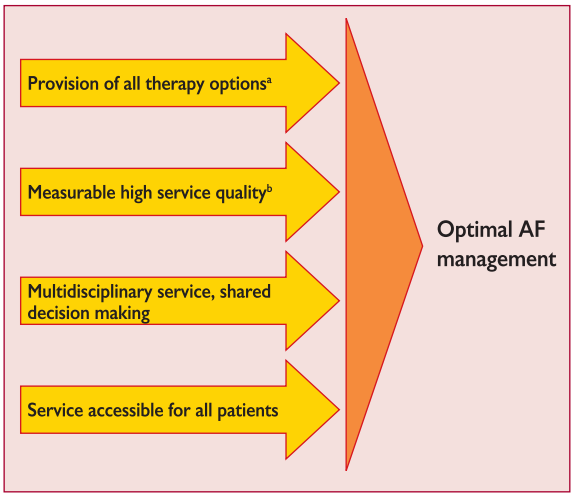
8.1 Evidence supporting integrated atrial fibrillation care

Several structured approaches to AF care have been developed. Some evidence underpins their use, while more research is needed into the best way of delivering integrated AF care.



AF = atrial fibrillation; LV = left ventricular.

Figure 5: Acute and chronic management of atrial fibrillation patients, desired cardiovascular outcomes, and patient benefits. Adapted from the report on the 4th AFNET/EHRA consensus conference [76].



AF = atrial fibrillation.
[a]On-site or through institutionalized cooperation.
[b]Safety outcomes should be collected in published and monitored central databases.

Figure 6: Achieving optimal management of atrial fibrillation patients.

Table 9: Clinical signs calling for urgent involvement of a specialized atrial fibrillation service[a]

Clinical conditions
Haemodynamic instability
Uncontrollable rate
Symptomatic bradycardia not amenable to reduction of rate control agents
Severe angina or worsening left ventricular function
Transient ischaemic attack or stroke

[a]Anticoagulation should be initiated early in all suitable patients and will not routinely require specialist input.

Integrated AF management in an RCT increased the use of evidence-based care, and reduced by approximately one-third the composite outcome of cardiovascular hospitalization and cardiovascular death over a mean follow-up of 22 months (14.3% vs. 20.8%, HR 0.65; 95% CI 0.45–0.93; $P = 0.017$) compared with usual care in a large tertiary care centre [330]. Integrated AF management appeared cost-effective in that study [331]. However, an Australian RCT showed only a marginal effect on unplanned admissions and death using integrated AF care limited to the initial care period, possibly emphasizing the need for sustained integration of AF care [332]. Two observational studies of integrated AF care found fewer hospitalizations [333, 334], one study showed fewer cases of stroke [333], and a further non-randomized study identified a trend for a lower rate of the composite outcome of death, cardiovascular hospitalization, and AF-related emergency visits [335]. More research is needed, and integrated AF care is likely to require different designs in different healthcare settings.

8.2 Components of integrated atrial fibrillation care

8.2.1 Patient involvement. Patients should have a central role in the care process. As treatment of AF requires patients to change their lifestyles and adhere to chronic therapy, at times without an immediately tangible benefit, they need to understand their responsibilities in the care process. Physicians and healthcare professionals are responsible for providing access to evidence-based therapy, but adherence to therapy is ultimately the responsibility of informed and autonomous patients, best described as 'shared accountability' [336]. Hence, information and the education of patients, and often of their partners and relatives, is indispensable to encourage a self-management role and to empower patients to participate in shared decision-making [326, 328], and to support understanding of the disease and the suggested treatments [337].

8.2.2 Multidisciplinary atrial fibrillation teams. Delegation of tasks from specialists to general physicians and from physicians to allied health professionals is a fundamental concept of

Integrated AF management			
Patient involvement	**Multidisciplinary teams**	**Technology tools**	**Access to all treatment options for AF**
• Central role in care process • Patient education • Encouragement and empowerment for self-management • Advice and education on lifestyle and risk factor management • Shared decision making	• Phycisians (general physicians, cardiology and stroke AF specialists, surgeons) and allied health professionals work in a collaborative practice model • Efficient mix of communication skills, education, and experience	• Information on AF • Clinical decision support • Checklist and communication tools • Used by healthcare professionals and patients • Monitoring of therapy adherence and effectiveness	• Structured support for lifestyle changes • Anticoagulation • Rate control • Antiarrhythmic drugs • Catheter and surgical interventions (ablation, LAA occluder, AF surgery, etc.)
• ***Informed, involved, empowered patient***	• ***Working together in a multidisciplinary chronic AF care team***	• ***Navigation system to support decision making in treatment team***	• ***Complex management decisions underpinned by an AF Heart Team***

AF = atrial fibrillation; LAA = left atrial appendage.

Figure 7: Fundamentals of integrated care in atrial fibrillation patients.

integrated care models. A multidisciplinary AF team approach includes an efficient mix of interpersonal and communication skills, education, and expertise in AF management, as well as the use of dedicated technology. This approach underlines the importance of redesigning daily practice in a way that encourages non-specialists and allied professionals to have an important role in educating patients and co-ordinating care, while the specialist remains medically responsible. Cultural and regional differences will determine the composition of AF teams.

8.2.3 Role of non-specialists. Some non-specialist health care professionals, e.g. physicians in primary care have extensive expertise in stroke prevention and initial management of AF patients. Others may seek training to acquire such knowledge. Other components of AF management (e.g. assessment of concomitant cardiovascular conditions, antiarrhythmic drug therapy, or interventional treatment) often require specialist input. Integrated AF care structures should support treatment initiation by non-specialists where appropriate, and provide ready access to specialist knowledge to optimize AF care.

8.2.4 Technology use to support atrial fibrillation care. Technology, such as decision support software, has the potential to enhance the implementation of evidence-based care and improve outcomes, when used to enhance expert advice [338]. Electronic tools can also ensure coherent communication within the AF team. With a view to support the wider use of such technology, this Task Force is providing digital decision tools, in the form of freely accessible smartphone apps, to AF healthcare professionals and to AF patients.

8.3 Diagnostic workup of atrial fibrillation patients

AF is often found in patients with other, at times undiagnosed, cardiovascular conditions. Thus, all AF patients will benefit from a comprehensive cardiovascular assessment [339].

Recommendations for an integrated approach to care

Recommendations	Class[a]	Level[b]	Ref[c]
An integrated approach with structured organization of care and follow-up should be considered in all patients with AF, aiming to improve guidelines adherence and to reduce hospitalizations and mortality.	IIa	B	330–332
Placing patients in a central role in decision-making should be considered in order to tailor management to patient preferences and improve adherence to long-term therapy.	IIa	C	330, 332, 334

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

8.3.1 Recommended evaluation in all atrial fibrillation patients. A complete medical history should be taken and all patients should undergo clinical evaluation that includes thorough assessment for concomitant conditions, establishing the AF pattern, estimation of stroke risk and AF-related symptoms, and assessment of arrhythmia-related complications such as thrombo-embolism or LV dysfunction. A 12-lead ECG is recommended to establish a suspected diagnosis of AF, to determine rate in AF, and to screen for conduction defects, ischaemia, and signs of structural heart disease. Initial blood tests should evaluate thyroid and kidney function, as well as serum electrolytes and full blood count. Transthoracic echocardiography is recommended in all AF patients to guide treatment decisions. Transthoracic echocardiography should be used to identify structural disease (e.g. valvular disease) and assess LV size and function (systolic and diastolic), atrial size, and right heart function [339, 340]. Although biomarkers such as natriuretic peptides are elevated in AF patients, there is insufficient data to suggest that blood-based parameters are independent markers for AF [341–343].

8.3.2 Additional investigations in selected patients with atrial fibrillation. Ambulatory ECG monitoring in AF patients can assess the adequacy of rate control, relate symptoms with AF recurrences, and detect focal induction of bouts of paroxysmal AF. Transoesophageal echocardiography (TOE) is useful to further assess valvular heart disease and to exclude intracardiac thrombi, especially in the LAA, to facilitate early cardioversion or catheter ablation [344]. Patients with symptoms or signs of myocardial ischaemia should undergo coronary angiography or stress testing as appropriate. In patients with AF and signs of cerebral ischaemia or stroke, computed tomography (CT) or magnetic resonance

Recommendations for diagnostic workup of atrial fibrillation patients

Recommendations	Class[a]	Level[b]	Ref[c]
ECG documentation is required to establish the diagnosis of AF.	I	B	349
A full cardiovascular evaluation, including an accurate history, careful clinical examination, and assessment of concomitant conditions, is recommended in all AF patients.	I	C	
Transthoracic echocardiography is recommended in all AF patients to guide management.	I	C	339
Long-term ECG monitoring should be considered in selected patients to assess the adequacy of rate control in symptomatic patients and to relate symptoms with AF episodes.	IIa	C	

AF = atrial fibrillation; ECG = electrocardiogram.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

imaging (MRI) of the brain is recommended to detect stroke and support decisions regarding acute management and long-term anticoagulation. Delayed-enhancement MRI of the left atrium using gadolinium contrast [345–347], T1 mapping using cardiac MRI [347], and intracardiac echo [348] may help to guide treatment decisions in AF, but require external validation in multicentre studies.

8.4 Structured follow-up

Most AF patients need regular follow-up to ensure continued optimal management. Follow-up may be undertaken in primary care, by specially trained nurses, by cardiologists, or by AF specialists [325, 330]. A specialist should co-ordinate care and follow-up. Follow-up should ensure implementation of the management plan, continued engagement of the patient, and therapy adaptation where needed.

8.5 Defining goals of atrial fibrillation management

AF management comprises therapies with prognostic impact (anticoagulation and treatment of cardiovascular conditions) and therapies predominantly providing symptomatic benefit (rate control and rhythm control, Table 10). Therapies with prognostic benefit need careful explanation to patients when their benefits are not directly felt. Rhythm control therapy can be successful if symptoms are controlled, even when AF recurs. Explaining the expected benefits to each patient at the start of AF management will prevent unfounded expectations and has the potential to optimize quality of life.

9. STROKE PREVENTION THERAPY IN ATRIAL FIBRILLATION PATIENTS

OAC therapy can prevent the majority of ischaemic strokes in AF patients and can prolong life [38, 39, 42, 194, 201, 329, 350–352]. It is superior to no treatment or aspirin in patients with different profiles for stroke risk [353, 354]. The net clinical benefit is almost universal, with the exception of patients at very low stroke risk, and OAC should therefore be used in most patients with AF (Figure 8). Despite this evidence, underuse or premature termination of OAC therapy is still common. Bleeding events, both severe and nuisance bleeds, a perceived 'high risk of bleeding' on anticoagulation, and the efforts required to monitor and dose-adjust VKA therapy are among the most common reasons for withholding or ending OAC [352, 355–359]. However, the considerable stroke risk without OAC often exceeds the bleeding risk on OAC, even in the elderly, in patients with cognitive dysfunction, or in patients with frequent falls or frailty [360, 361]. The bleeding risk on aspirin is not different to the bleeding risk on VKA [362] or NOAC therapy [354, 363], while VKA and NOACs, but not aspirin, effectively prevent strokes in AF patients [38, 354, 362, 363].

Table 10: Goal-based follow-up

Category	Intervention	Follow-up aspects	Performance indicator (examples)
Prognostic	Comorbidity control (relevant examples given)	Obesity Arterial hypertension Heart failure Coronary artery disease Diabetes Valvular heart disease	Weight loss Blood pressure control Heart failure therapy and hospitalizations Statin and antiplatelet therapy; revascularization Glycaemic control Valve repair or replacement
Prognostic	Anticoagulation	Indication (risk profile; timing, e.g. post-cardioversion). Adherence (NOAC or VKA) and INR (if VKA). NOAC dosing (co-medications; age; weight; renal function).	Stroke Bleeding Mortality
Mainly symptomatic Partly prognostic	Rate control	Symptoms Average resting heart rate <110 b.p.m.	Modified EHRA score Heart failure status LV function Exercise capacity Hospitalization Therapy complications
Symptomatic at present	Rhythm control	Symptoms vs. side effects Exclusion of pro-arrhythmia (PR; QRS; QTc interval)	
Relevant for implementation of therapy and adherence	Patient education and self-care capabilities	Knowledge (about disease; about treatment; about management goals) Capabilities (what to do if…)	Adherence to therapy Directed evaluation, preferably based on systematic checklists
Relevant for chronic care management	Caregiver involvement	Who? (spouse; GP; home nurse; pharmacist) Clearly spelling out participation roles Knowledge and capabilities	Directed evaluation of task performance (e.g. via patient card) Dispensed medication Log of follow-up visits

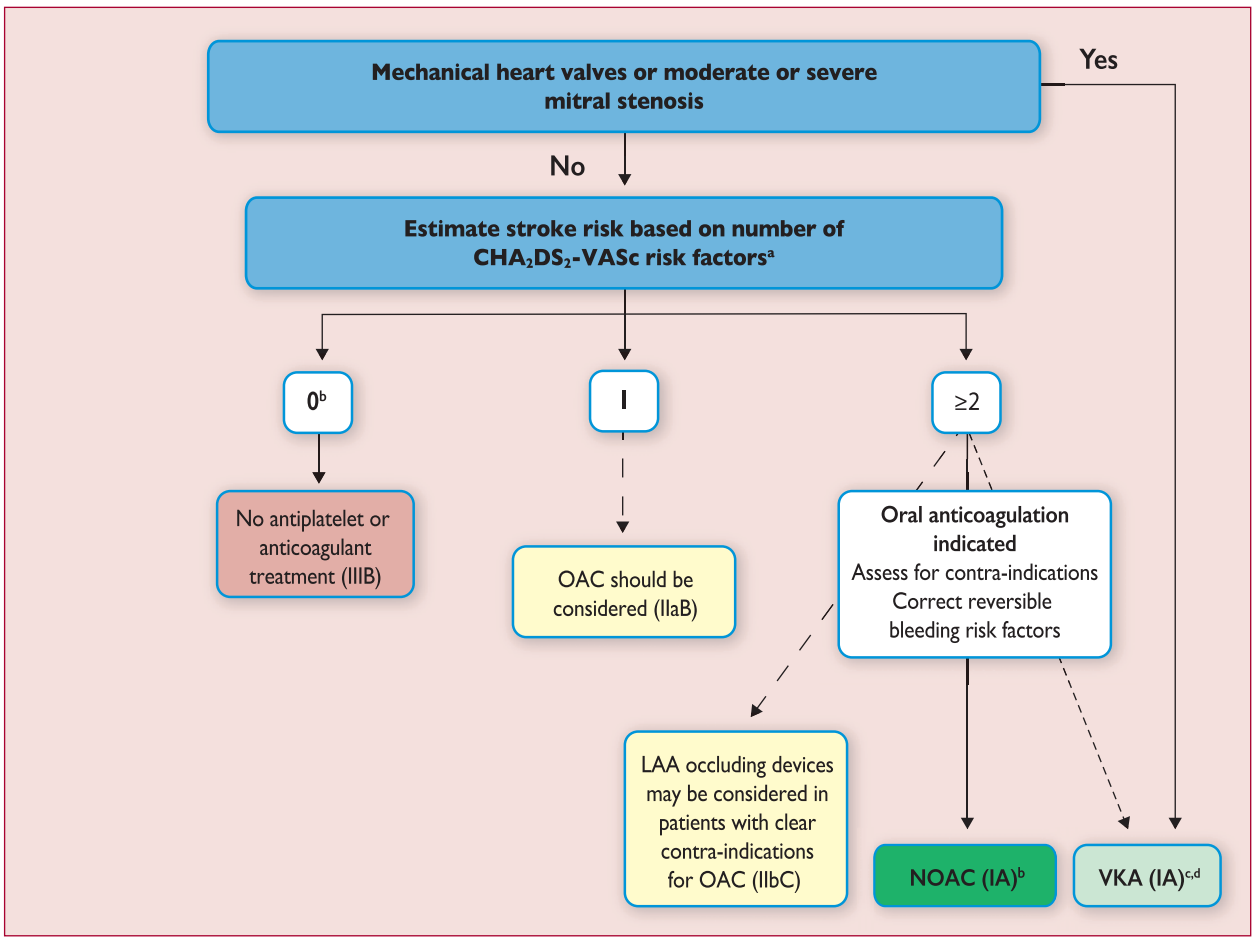
b.p.m. = beats per minute; mEHRA symptoms scale = modified European Heart Rhythm Association symptoms scale; GP = general practitioner; INR = international normalized ratio; LV = left ventricular; NOAC = non-vitamin K antagonist oral anticoagulant; VKA = vitamin K antagonist.

9.1 Prediction of stroke and bleeding risk

9.1.1 Clinical risk scores for stroke and systemic embolism. Simple, clinically applicable stroke risk-stratification schemes in AF patients were developed in the late 1990s in small cohort studies, and have later been refined and validated in larger populations [364–368]. The introduction of the CHA_2DS_2-VASc score (Table 11) has simplified the initial decision for OAC in AF patients. Since its first incorporation in the ESC guidelines in 2010 [369], it has been widely used [370]. We recommend estimating stroke risk in AF patients based on the CHA_2DS_2-VASc score [368]. In general, patients without clinical stroke risk factors do not need antithrombotic therapy, while patients with stroke risk factors (i.e. CHA_2DS_2-VASc score of 1 or more for men, and 2 or more for women) are likely to benefit from OAC.

Other, less established risk factors for stroke include unstable international normalized ratio (INR) and low time in therapeutic range (TTR) in patients treated with VKAs; previous bleed or anaemia; alcohol excess and other markers for decreased therapy adherence; CKD; elevated high-sensitivity troponin; and elevated N-terminal pro-B-type natriuretic peptide.

9.1.2 Anticoagulation in patients with a CHA_2DS_2-VASc score of 1 in men and 2 in women. Controlled trials studying OAC in AF patients have been enriched for patients at high risk of stroke [38, 39, 42, 194, 201, 329, 351, 352], and hence there is strong evidence that patients with a CHA_2DS_2-VASc risk score of 2 or more in men, and 3 or more in women, benefit from OAC. Fortunately, we now have a growing evidence base regarding stroke risk in patients with one clinical risk factor (i.e. a CHA_2DS_2-VASc score of 1 for men, and 2 for women), although this relies largely on observed stroke rates in patients not receiving OAC. In many of these patients, anticoagulation seems to provide a clinical benefit [371–375]. The rates of stroke and thrombo-embolism vary considerably in patients with CHA_2DS_2-VASc scores of 1 or 2 due to differences in outcomes, populations, and anticoagulation status (Web Table 1) [371, 376, 377, 1041]. We therefore commissioned an analysis of stroke risk in men and women with one additional stroke risk factor to inform these guidelines (Web Table 1, last line). OAC should be considered for men with a CHA_2DS_2-VASc score of 1 and women with a score of 2, balancing the expected stroke reduction, bleeding risk, and patient preference. Importantly, age (65 years and older) conveys a relatively high and continuously increasing stroke risk that also potentiates



AF = atrial fibrillation; LAA = left atrial appendage; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; VKA = vitamin K antagonist.
[a]Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes, prior stroke/TIA/embolus (2 points), Vascular disease, age 65–74 years, female Sex.
[b]Includes women without other stroke risk factors.
[c]IIaB for women with only one additional stroke risk factor.
[d]IB for patients with mechanical heart valves or mitral stenosis.

Figure 8: Stroke prevention in atrial fibrillation.

Recommendations for prediction of stroke and bleeding risk

Recommendations	Class[a]	Level[b]	Ref[c]
The CHA_2DS_2-VASc score is recommended for stroke risk prediction in patients with AF.	I	A	368, 371, 386
Bleeding risk scores should be considered in AF patients on oral anticoagulation to identify modifiable risk factors for major bleeding.	IIa	B	384, 386, 387, 389–392
Biomarkers such as high-sensitivity troponin and natriuretic peptide may be considered to further refine stroke and bleeding risk in AF patients.	IIb	B	380–382, 387, 393

AF = atrial fibrillation; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female).
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

other risk factors (such as heart failure and sex). Hence, an individualized weighing of risk, as well as patient preferences, should inform the decision to anticoagulate patients with only one CHA_2DS_2-VASc risk factor, apart from female sex. Female sex does not appear to increase stroke risk in the absence of other stroke risk factors (Web Table 1) [378, 379].

Measurement of cardiac troponin (high-sensitivity troponin T or I) and N-terminal pro-B-type natriuretic peptide may provide additional prognostic information in selected AF patients [380–382]. Biomarker-based risk scores may, in the future, prove helpful to better stratify patients (e.g. those at a truly low risk of stroke) [75, 382].

9.1.3 Clinical risk scores for bleeding. Several bleeding risk scores have been developed, mainly in patients on VKAs. These include HAS-BLED [hypertension, abnormal renal/liver function (1 point each), stroke, bleeding history or predisposition, labile INR, elderly (>65 years), drugs/alcohol concomitantly (1 point each)], ORBIT (Outcomes Registry for Better Informed Treatment of Atrial Fibrillation), and more recently, the ABC (age, biomarkers, clinical history) bleeding score, which also makes use of selected biomarkers [383–385]. Stroke and bleeding risk factors overlap (compare Tables 11 and 12). For example, older age is one of the most important predictors of both ischaemic stroke and bleeding in AF patients [386, 387]. A high bleeding risk score should generally not result in withholding OAC. Rather, bleeding risk factors should be identified and treatable factors corrected (see section 9.5). Table 12 provides details of modifiable bleeding risk factors.

9.2 Stroke prevention

9.2.1 Vitamin K antagonists. Warfarin and other VKAs were the first anticoagulants used in AF patients. VKA therapy reduces the risk of stroke by two-thirds and mortality by one-quarter compared with control (aspirin or no therapy) [38]. VKAs have been used in many patients throughout the world with good outcomes [394–396], and this is reflected in the warfarin arms of the NOAC trials (see section 9.2.2.). The use of VKAs is limited by the narrow therapeutic interval, necessitating frequent monitoring and dose adjustments, but VKAs, when delivered with adequate time in therapeutic range (TTR), are effective for stroke prevention in AF patients. Clinical parameters can help to identify patients who are likely to achieve a decent TTR on VKA therapy [397]. These have been summarized in the SAMe-TT_2R_2 score. Patients who fare well on this score, when treated with a VKA, have on average a higher TTR than patients who do not fare well on the score [398, 399]. VKAs are currently the only treatment with established safety in AF patients with rheumatic mitral valve disease and/or a mechanical heart valve prosthesis [400].

9.2.2 Non-vitamin K antagonist oral anticoagulants. NOACs, including the direct thrombin inhibitor dabigatran and the factor Xa inhibitors apixaban, edoxaban, and rivaroxaban, are suitable alternatives to VKAs for stroke prevention in AF (Table 13). Their use in clinical practice is increasing rapidly [401]. All NOACs have a predictable effect (onset and offset) without need for regular anticoagulation monitoring. The phase III trials have been conducted with carefully selected doses of the NOACs, including clear rules for dose reduction that should be followed in clinical practice (Table 13).

9.2.2.1 *Apixaban*. In the ARISTOTLE (Apixaban for Reduction in Stroke and Other Thrombo-embolic Events in Atrial Fibrillation) trial [319], apixaban 5 mg twice daily reduced stroke or systemic embolism by 21% compared with warfarin, combined with a 31% reduction in major bleeding and an 11% reduction in all-cause mortality (all statistically significant). Rates of haemorrhagic stroke and intracranial haemorrhage, but not of ischaemic stroke, were lower on apixaban. Rates of gastrointestinal bleeding were similar between the two treatment arms [402].

Apixaban is the only NOAC that has been compared with aspirin in AF patients; apixaban significantly reduced stroke or systemic embolism by 55% compared with aspirin, with no or only a small difference in rates of major bleeding or intracranial haemorrhage [354, 403].

9.2.2.2 *Dabigatran*. In the RE-LY (Randomized Evaluation of Long-Term Anticoagulation Therapy) study [318, 404], dabigatran 150 mg twice daily reduced stroke and systemic embolism by 35% compared with warfarin without a significant difference in major bleeding events. Dabigatran 110 mg twice daily was non-inferior to warfarin for prevention of stroke and systemic embolism, with 20% fewer major bleeding events. Both dabigatran doses significantly reduced haemorrhagic stroke and intracranial haemorrhage. Dabigatran 150 mg twice daily significantly reduced ischaemic stroke by 24% and vascular mortality by 12%, while gastrointestinal bleeding was significantly increased by 50%. There was a non-significant numerical increase in the rate of myocardial infarction with both dabigatran doses [318, 404], which has not been replicated in large post-authorization analyses [396]. These observational data have also replicated the benefit of dabigatran over VKA found in the RE-LY trial in patients who were mainly treated with the higher dabigatran dose (150 mg twice daily) [396].

Table 11: Clinical risk factors for stroke, transient ischaemic attack, and systemic embolism in the CHA_2DS_2-VASc score

CHA_2DS_2-VASc risk factor	Points
Congestive heart failure Signs/symptoms of heart failure or objective evidence of reduced left ventricular ejection fraction	+1
Hypertension Resting blood pressure >140/90 mmHg on at least two occasions or current antihypertensive treatment	+1
Age 75 years or older	+2
Diabetes mellitus Fasting glucose >125 mg/dL (7 mmol/L) or treatment with oral hypoglycaemic agent and/or insulin	+1
Previous stroke, transient ischaemic attack, or thromboembolism	+2
Vascular disease Previous myocardial infarction, peripheral artery disease, or aortic plaque	+1
Age 65–74 years	+1
Sex category (female)	+1

CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female).

Table 12: Modifiable and non-modifiable risk factors for bleeding in anticoagulated patients based on bleeding risk scores

Modifiable bleeding risk factors
Hypertension (especially when systolic blood pressure is >160 mmHg)[a,b,c]
Labile INR or time in therapeutic range <60%[a] in patients on vitamin K antagonists
Medication predisposing to bleeding, such as antiplatelet drugs and non-steroidal anti-inflammatory drugs[a,d]
Excess alcohol (≥8 drinks/week)[a,b]
Potentially modifiable bleeding risk factors
Anaemia[b,c,d]
Impaired renal function[a,b,c,d]
Impaired liver function[a,b]
Reduced platelet count or function[b]
Non-modifiable bleeding risk factors
Age[e] (>65 years)[a] (≥75 years)[b,c,d]
History of major bleeding[a,b,c,d]
Previous stroke[a,b]
Dialysis-dependent kidney disease or renal transplant[a,c]
Cirrhotic liver disease[a]
Malignancy[b]
Genetic factors[b]
Biomarker-based bleeding risk factors
High-sensitivity troponin[e]
Growth differentiation factor-15[e]
Serum creatinine/estimated CrCl[e]

ABC = age, biomarkers, clinical history; ATRIA = AnTicoagulation and Risk factors In Atrial fibrillation; CKD = chronic kidney disease; CrCl = creatinine clearance; HAS-BLED = hypertension, abnormal renal/liver function (1 point each), stroke, bleeding history or predisposition, labile INR, elderly (>65 years), drugs/alcohol concomitantly (1 point each); $HEMORR_2HAGES$ = hepatic or renal disease, ethanol abuse, malignancy, older (age >75), reduced platelet count or function, rebleeding risk (prior bleed; 2 points), hypertension (uncontrolled), anaemia, genetic factors (CYP 2C9 polymorphisms), excessive fall risk (including neuropsychiatric disease), and stroke; INR = international normalized ratio; ORBIT = Outcomes Registry for Better Informed Treatment of Atrial Fibrillation; TTR = time in therapeutic range; VKA = vitamin K antagonist.
[a]Derived from the HAS-BLED score [384].
[b]Derived from the $HEMORR_2HAGES$ score [383].
[c]Derived from the ATRIA score [385].
[d]Derived from the ORBIT score [388].
[e]Derived from the ABC bleeding score [387].

9.2.2.3 *Edoxaban*. In the ENGAGE AF-TIMI 48 (Effective Anticoagulation with Factor Xa Next Generation in Atrial Fibrillation–Thrombolysis in Myocardial Infarction 48) trial [321], edoxaban 60 mg once daily and edoxaban 30 mg once daily (with dose reductions in certain patients, Table 13), were compared with adjusted-dose warfarin [405]. Edoxaban 60 mg once daily was non-inferior to warfarin (Table 13). In an on-treatment analysis, edoxaban 60 mg once daily significantly reduced stroke or systemic embolism by 21% and significantly reduced major bleeding events by 20% compared with warfarin, while edoxaban 30 mg once daily was non-inferior to warfarin for prevention of stroke and systemic embolism but significantly reduced major bleeding events by 53%. Cardiovascular death was reduced in patients randomized to edoxaban 60 mg once daily or edoxaban 30 mg once daily compared with warfarin. Only the higher dose regimen has been approved for stroke prevention in AF.

9.2.2.4 *Rivaroxaban*. In the ROCKET-AF (Rivaroxaban Once Daily Oral Direct Factor Xa Inhibition Compared with Vitamin K Antagonism for Prevention of Stroke and Embolism Trial in Atrial Fibrillation) trial [320], patients were randomized to rivaroxaban 20 mg once daily or VKA, with a dose adjustment to 15 mg daily for those with estimated CrCl 30–49 mL/min by the Cockroft–Gault formula (Table 13). Rivaroxaban was non-inferior to warfarin for the prevention of stroke and systemic embolism in the intent-to-treat analysis, while the per-protocol on-treatment analysis achieved statistical superiority with a 21% reduction in stroke or systemic embolism compared with warfarin. Rivaroxaban did not reduce the rates of mortality, ischaemic stroke, or major bleeding events compared to VKA. There was an increase in gastrointestinal bleeding events, but a significant reduction in haemorrhagic stroke and intracranial haemorrhage with rivaroxaban compared with warfarin. Comparable event rates have been reported in post-authorization analyses, which are part of the post-approval risk management process [406, 407].

Table 13: Characteristics of approved non-vitamin K antagonist oral anticoagulants compared

	Dabigatran (RE-LY)			**Rivaroxaban (ROCKET-AF)**		**Apixaban (ARISTOTLE)**		**Edoxaban (ENGAGE AF-TIMI 48)**		
Mechanism	Oral direct thrombin inhibitor			Oral direct factor Xa inhibitor		Oral direct factor Xa inhibitor		Oral direct factor Xa inhibitor		
Bioavailability, %	6			66 fasting, 80–100 with food		50		62		
Time to peak levels, hours	3			2–4		3		1–2		
Half-life, hours	12–17			5–13		9–14		10–14		
Excretion	80% renal			66% liver, 33% renal		27% renal		50% renal		
Dose	150 mg twice daily or 110 mg twice daily			20 mg once daily		5 mg twice daily.		60 mg once daily or 30 mg once daily		
Dose reduction in selected patients				Rivaroxaban 15 mg once daily if CrCl 30-49 mL/min		Apixaban 2.5 mg twice daily if at least 2 of age ≥80 years, body weight ≤60 kg or serum creatinine level ≥1.5 mg/dL (133 μmol/L)		Edoxaban 60 mg reduced to 30 mg once daily, and edoxaban 30 mg reduced to 15 mg once daily, if any of the following: creatinine clearance of 30–50 mL/min, body weight ≤60 kg, concomitant use of verapamil or quinidine or dronedarone		
Study design	Randomized, open-label			Randomized, double-blind		Randomized, double-blind		Randomized, double-blind		
Number of patients	18 113			14 264		18 201		21 105		
Follow-up period, years	2			1.9		1.8		2.8		
Randomized groups	Dose-adjusted warfarin vs. blinded doses of dabigatran (150 mg twice daily, 110 mg twice daily)			Dose-adjusted warfarin vs. rivaroxaban 20 mg once daily		Dose-adjusted warfarin vs. apixaban 5 mg twice daily		Dose-adjusted warfarin vs. edoxaban (60 mg once daily, 30 mg once daily)		
Age, years	71.5 ± 8.7 (mean ± SD)			73 (65–78) [median (interquartile range)]		70 (63–76) [median (interquartile range)]		72 (64–78) [median (interquartile range)]		
Male sex, %	63.6			60.3		64.5		61.9		
$CHADS_2$ score (mean)	2.1			3.5		2.1		2.8		
	Warfarin	Dabigatran 150	Dabigatran 110	Warfarin	Rivaroxaban	Warfarin	Apixaban	Warfarin	Edoxaban 60	Edoxaban 30
	n = 6022	*n* = 6076	*n* = 6015	*n* = 7133	*n* = 7131	*n* = 9081	*n* = 9120	*n* = 7036	n = 7035	*n* = 7034
	Event rate, %/year	Event rate, %/year (RR vs. warfarin)	Event rate, %/ year (RR vs. warfarin)	Event rate, %/year	Event rate, %/year (HR vs. warfarin)	Event rate, %/year	Event rate, %/year (HR vs. warfarin)	Event rate, %/year	Event rate, %/year (HR vs. warfarin)	Event rate, %/year (HR vs. warfarin)
Stroke/systemic embolism	1.72	1.12 (0.65, 0.52–0.81; *P* for non-inferiority and superiority <0.001)	1.54 (0.89, 0.73–1.09; *P* for non-inferiority <0.001)	2.4	2.1 (0.88, 0.75–1.03; *P* for non-inferiority <0.001, *P* for superiority = 0.12)	1.60	1.27 (0.79, 0.66–0.95; *P* <0.001 for non-inferiority, *P* = 0.01 for superiority)	1.80	1.57 (0.87, 0.73–1.04; *P* <0.001 for non-inferiority, *P* = 0.08 for superiority)	2.04 (1.13, 0.96–1.34; *P* = 0.005 for non-inferiority, *P* = 0.10 for superiority)
Ischaemic stroke	1.22	0.93 (0.76, 0.59–0.97; *P* = 0.03)	1.34 (1.10, 0.88–1.37; *P* = 0.42)	1.42	1.34 (0.94; 0.75–1.17; *P* = 0.581)	1.05	0.97 (0.92, 0.74–1.13; *P* = 0.42)	1.25	1.25 (1.00, 0.83–1.19; *P* = 0.97)	1.77 (1.41, 1.19–1.67; *P* <0.001)
Haemorrhagic stroke	0.38	0.10 (0.26, 0.14–0.49; *P* <0.001)	0.12 (0.31, 0.17–0.56; *P* <0.001)	0.44	0.26 (0.59; 0.37–0.93; *P* = 0.024)	0.47	0.24 (0.51, 0.35–0.75; *P* <0.001)	0.47	0.26 (0.54, 0.38–0.77; *P* <0.001)	0.16 (0.33, 0.22–0.50; *P* <0.001)
Major bleeding	3.61	3.40 (0.94, 0.82–1.08; *P* = 0.41)	2.92 (0.80, 0.70–0.93; *P* = 0.003)	3.45	3.60 (1.04; 0.90-2.30; *P* = 0.58)	3.09	2.13 (0.69, 0.60–0.80; *P* <0.001)	3.43	2.75 (0.80, 0.71–0.91; *P* <0.001)	1.61 (0.47, 0.41–0.55; *P* <0.001)
Intracranial bleeding	0.77	0.32 (0.42, 0.29–0.61; *P* <0.001)	0.23 (0.29 0.19–0.45; *P* <0.001)	0.74	0.49 (0.67; 0.47–0.93; *P* = 0.02)	0.80	0.33 (0.42, 0.30–0.58; *P* <0.001)	0.85	0.39 (0.47, 0.34–0.63; *P* <0.001)	0.26 (0.30, 0.21–0.43; *P* <0.001)
Gastrointestinal major bleeding	1.09	1.60 (1.48, 1.19–1.86; *P* <0.001)	1.13 (1.04, 0.82–1.33; *P* = 0.74)	1.24	2.00 (1.61; 1.30-1.99; *P* < 0.001)	0.86	0.76 (0.89, 0.70–1.15; *P* = 0.37)	1.23	1.51 (1.23, 1.02–1.50; *P* = 0.03)	0.82 (0.67, 0.53–0.83; *P* <0.001)
Myocardial infarction	0.64	0.81 (1.27, 0.94–1.71; *P* = 0.12)	0.82 (1.29, 0.96–1.75; *P* = 0.09)	1.12	0.91 (0.81; 0.63–1.06; *P* = 0.12)	0.61	0.53 (0.88, 0.66–1.17; *P* = 0.37)	0.75	0.70 (0.94, 0.74–1.19; *P* = 0.60)	0.89 (1.19, 0.95–1.49; *P* = 0.13)
Death from any cause	4.13	3.64 (0.88, 0.77–1.00; *P* = 0.051)	3.75 (0.91, 0.80–1.03; *P* = 0.13)	2.21	1.87 (0.85; 0.70–1.02; *P* = 0.07)	3.94	3.52 (0.89, 0.80–0.99; *P* = 0.047)	4.35	3.99 (0.92, 0.83–1.01; *P* = 0.08)	3.80 (0.87, 0.79–0.96; *P* = 0.006)

9.2.3 Non-vitamin K antagonist oral anticoagulants or vitamin K antagonists. Both VKAs and NOACs are effective for the prevention of stroke in AF. A meta-analysis [39] based on the high-dose treatment groups of the pivotal studies of warfarin vs. NOACs included 42 411 patients receiving a NOAC and 29 272 receiving warfarin. NOACs in these dosages significantly reduced stroke or systemic embolic events by 19% compared with warfarin (RR 0.81; 95% CI 0.73–0.91; $P < 0.0001$), mainly driven by a reduction in haemorrhagic stroke (RR 0.49; 95% CI 0.38–0.64; $P < 0.0001$). Mortality was 10% lower in patients randomized to NOAC therapy (RR 0.90; 95% CI 0.85–0.95; $P = 0.0003$) and intracranial haemorrhage was halved (RR 0.48; 95% CI 0.39–0.59; $P < 0.0001$), while gastrointestinal bleeding events were more frequent (RR 1.25; 95% CI 1.01–1.55; $P = 0.04$) [39]. The stroke reduction with NOACs was consistent in all evaluated subgroups, while there was a suggestion of greater relative reduction in bleeding with NOACs at centres with poor INR control (interaction $P = 0.022$). Notably, the substantial reduction in intracranial haemorrhage by NOACs compared with warfarin seems unrelated to the quality of INR control [408, 409].

9.2.4 Oral anticoagulation in atrial fibrillation patients with chronic kidney disease. CKD is associated with stroke and bleeding in large data sets [410, 411]. Anticoagulation can be safely used in AF patients with moderate or moderate-to-severe CKD [glomerular filtration rate (GFR) ≥15 mL/min]: the SPAF (Stroke Prevention in Atrial Fibrillation) III trial randomized 805/1936 participants with stage 3 CKD (estimated GFR <59 mL/min/1.73 m^2), and reported good outcomes on warfarin (INR 2–3) [412]. This finding is supported by a large Swedish database, in which stroke risk was lower in CKD patients with AF treated with warfarin (adjusted HR 0.76; 95% CI 0.72–0.80) [413], while bleeding was also slightly increased, especially during therapy initiation [414]. In a meta-analysis of the major NOAC trials, patients with mild or moderate CKD suffered fewer strokes, systemic emboli, or major bleeding events on NOACs than on warfarin [415]. Kidney function should be regularly monitored in AF patients on OACs to allow dose adaptation for those on NOACs (Table 14) and to refine risk estimation [416].

9.2.5 Oral anticoagulation in atrial fibrillation patients on dialysis. Approximately one in eight dialysis patients suffer from AF, with an incidence rate of 2.7/100 patient-years [417]. AF is associated with increased mortality in patients on dialysis [417]. There are no randomized trials assessing OAC in haemodialysis patients [418], and no controlled trials of NOACs in patients with severe CKD (CrCl <25–30 mL/min) [318–321]. Warfarin use was associated either with a neutral or increased risk of stroke in database analyses of patients on dialysis [419–421], including a population-based analysis in Canada (adjusted HR for stroke 1.14; 95% CI 0.78–1.67, adjusted HR for bleeding 1.44; 95% CI 1.13–1.85) [422]. In contrast, data from Denmark suggest a benefit of OAC in patients on renal replacement therapy [423]. Hence, controlled studies of anticoagulants (both VKAs and NOACs) in AF patients on dialysis are needed [424].

9.2.6 Patients with atrial fibrillation requiring kidney transplantation. There are no randomized trials assessing OAC in patients after kidney transplantation. The prescription of NOAC therapy should be guided by the estimated GFR of the

Table 14: Dose adjustment for NOACs as evaluated in the PHASE III trials (adapted from Hart *et al.* [316])

	Dabigatran (RE-LY) [318,425]	Rivaroxaban (ROCKET-AF) [320,426]	Apixaban (ARISTOTLE) [319,427]	Edoxaban (ENGAGE AF-TIMI 48) [321]
Renal clearance	80%	35%	25%	50%
Number of patients	18 113	14 264	18 201	21 105
Dose	150 mg or 110 mg twice daily	20 mg once daily	5 mg twice daily	60 mg (or 30 mg) once daily
Exclusion criteria for CKD	CrCl <30 mL/min	CrCl <30 mL/min	Serum creatinine >2.5 mg/dL or CrCl <25 mL/min	CrCl <30 mL/min
Dose adjustment with CKD	None	15 mg once daily if CrCl <30–49 mL/min	2.5 mg twice daily if serum creatinine ≥1.5 mg/dL (133 μmol/L) plus age ≥80 years or weight ≤60 kg	30 mg (or 15 mg) once daily if CrCl <50 mL/min
Percentage of patients with CKD	20% with CrCl 30–49 mL/min	21% with CrCl 30–49 mL/min	15% with CrCl 30–50 mL/dL	19% with CrCl <50 mL/min
Reduction of stroke and systemic embolism	No interaction with CKD status	No interaction with CKD status	No interaction with CKD status	NA
Reduction in major haemorrhages compared to warfarin	Reduction in major haemorrhage with dabigatran was greater in patients with eGFR >80 mL/min with either dose	Major haemorrhage similar	Reduction in major haemorrhage with apixaban	NA

CKD = chronic kidney disease; CrCl = creatinine clearance; GFR = glomerular filtration rate; NA = not available.

transplanted kidney. Potential pharmacokinetic interactions of OAC with immunosuppressive agents should be considered.

9.2.7 Antiplatelet therapy as an alternative to oral anticoagulants. The evidence supporting antiplatelet monotherapy for stroke prevention in AF is very limited [38, 428–430]. VKA therapy prevents stroke, systemic embolism, myocardial infarction, and vascular death better than single or dual antiplatelet therapy with aspirin and clopidogrel (annual risk of 5.6% for aspirin and clopidogrel vs. 3.9% with VKA therapy) [431]. Even greater benefits were seen in VKA-treated patients with a high TTR [432]. Antiplatelet therapy increases bleeding risk, especially dual antiplatelet therapy (2.0% vs. 1.3% with antiplatelet monotherapy; $P < 0.001$) [433], with bleeding rates that are similar to those on OAC [354, 362, 431, 434]. Thus, antiplatelet therapy cannot be recommended for stroke prevention in AF patients.

9.3 Left atrial appendage occlusion and exclusion

9.3.1 Left atrial appendage occlusion devices. Interventional LAA occlusion [446–449], and limited experience with percutaneous LAA ligation, has mainly been reported in observational studies and registries. Only one device (Watchman®) has been compared with VKA therapy in randomized trials [PROTECT AF (Watchman Left Atrial Appendage System for Embolic Protection in Patients With AF trial), see Web Table 2; and PREVAIL (Prospective Randomized Evaluation of the Watchman LAA Closure Device In Patients with AF Versus Long Term Warfarin Therapy trial)] [449–451]. In these data sets, LAA occlusion was non-inferior to VKA treatment for the prevention of stroke in AF patients with moderate stroke risk, with a possibility of lower bleeding rates in the patients who continued follow-up [452, 453]. These data were confirmed in a patient-level meta-analysis of the two trials and their associated registries [453]. LAA occlusion may also reduce stroke risk in patients with

Recommendations for stroke prevention in patients with atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
Oral anticoagulation therapy to prevent thromboembolism is recommended for all male AF patients with a CHA_2DS_2-VASc score of 2 or more.	I	A	38, 318–321, 354, 404
Oral anticoagulation therapy to prevent thromboembolism is recommended in all female AF patients with a CHA_2DS_2-VASc score of 3 or more.	I	A	38, 318–321, 354, 404
Oral anticoagulation therapy to prevent thromboembolism should be considered in male AF patients with a CHA_2DS_2-VASc score of 1, considering individual characteristics and patient preferences.	IIa	B	371, 375–377
Oral anticoagulation therapy to prevent thromboembolism should be considered in female AF patients with a CHA_2DS_2-VASc score of 2, considering individual characteristics and patient preferences.	IIa	B	371, 376, 377
Vitamin K antagonist therapy (INR 2.0–3.0 or higher) is recommended for stroke prevention in AF patients with moderate-to-severe mitral stenosis or mechanical heart valves.	I	B	274, 435–440
When oral anticoagulation is initiated in a patient with AF who is eligible for a NOAC (apixaban, dabigatran, edoxaban, or rivaroxaban), a NOAC is recommended in preference to a vitamin K antagonist.	I	A	39, 318–321, 404
When patients are treated with a vitamin K antagonist, time in therapeutic range (TTR) should be kept as high as possible and closely monitored.	I	A	395, 432, 441-444
AF patients already on treatment with a vitamin K antagonist may be considered for NOAC treatment if TTR is not well controlled despite good adherence, or if patient preference without contra-indications to NOAC (e.g. prosthetic valve).	IIb	A	39, 318, 319, 404, 408
Combinations of oral anticoagulants and platelet inhibitors increase bleeding risk and should be avoided in AF patients without another indication for platelet inhibition.	III (harm)	B	429, 445
In male or female AF patients without additional stroke risk factors, anticoagulant or antiplatelet therapy is not recommended for stroke prevention.	III (harm)	B	368, 371, 376, 377
Antiplatelet monotherapy is not recommended for stroke prevention in AF patients, regardless of stroke risk.	III (harm)	A	38, 429, 430
NOACs (apixaban, dabigatran, edoxaban, and rivaroxaban) are not recommended in patients with mechanical heart valves (Level of evidence B) or moderate-to-severe mitral stenosis (Level of evidence C).	III (harm)	B C	318–321, 400, 404

AF = atrial fibrillation; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female); INR = international normalized ratio; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; TTR = time in therapeutic range; VKA = vitamin K antagonist.

[a]Class of recommendation.

[b]Level of evidence.

[c]Reference(s) supporting recommendations.

contraindications to OAC [454, 455]. The implantation procedure can cause serious complications [446, 456–458], with high event rates reported in analyses from insurance databases and systematic reviews, possibly identifying a certain degree of reporting bias [446, 456]. A large recent European registry reported a high rate of implantation success (98%), with an acceptable procedure-related complication rate of 4% at 30 days [459]. Most patients who historically would be considered unsuitable for OAC therapy seem to do relatively well on contemporarily managed OAC [396, 407, 460]. Adequately powered controlled trials are urgently needed to inform the best use of these devices, including LAA occluders in patients who are truly unsuitable for OAC or in patients who suffer a stroke on OAC, randomized comparisons of LAA occluders with NOACs, and assessment of the minimal antiplatelet therapy acceptable after LAA occlusion.

9.3.2 Surgical left atrial appendage occlusion or exclusion. Surgical LAA occlusion or exclusion concomitant to cardiac surgery has been performed for many decades and with various techniques. Multiple observational studies indicate the feasibility and safety of surgical LAA occlusion/exclusion, but only limited controlled trial data are available [461–464]. Residual LAA flow or incomplete LAA exclusion can increase stroke risk [465]. In most studies, LAA occlusion/exclusion was performed during other open heart surgery, and more recently in combination with surgical ablation of AF [463] or as a stand-alone thoracoscopic procedure. One randomized trial evaluating the role of concomitant AF surgery and LAA occlusion reported in 2015, without a clear benefit of LAA exclusion for stroke prevention in the subgroup undergoing AF surgery [466]. A large randomized trial is currently underway [467].

Recommendations for occlusion or exclusion of the left atrial appendage

Recommendations	Class[a]	Level[b]	Ref[c]
After surgical occlusion or exclusion of the LAA, it is recommended to continue anticoagulation in at-risk patients with AF for stroke prevention.	I	B	461,462
LAA occlusion may be considered for stroke prevention in patients with AF and contra-indications for long-term anticoagulant treatment (e.g. those with a previous life-threatening bleed without a reversible cause).	IIb	B	449,453, 454
Surgical occlusion or exclusion of the LAA may be considered for stroke prevention in patients with AF undergoing cardiac surgery.	IIb	B	463
Surgical occlusion or exclusion of the LAA may be considered for stroke prevention in patients undergoing thoracoscopic AF surgery.	IIb	B	468

AF = atrial fibrillation; LAA = left atrial appendage.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

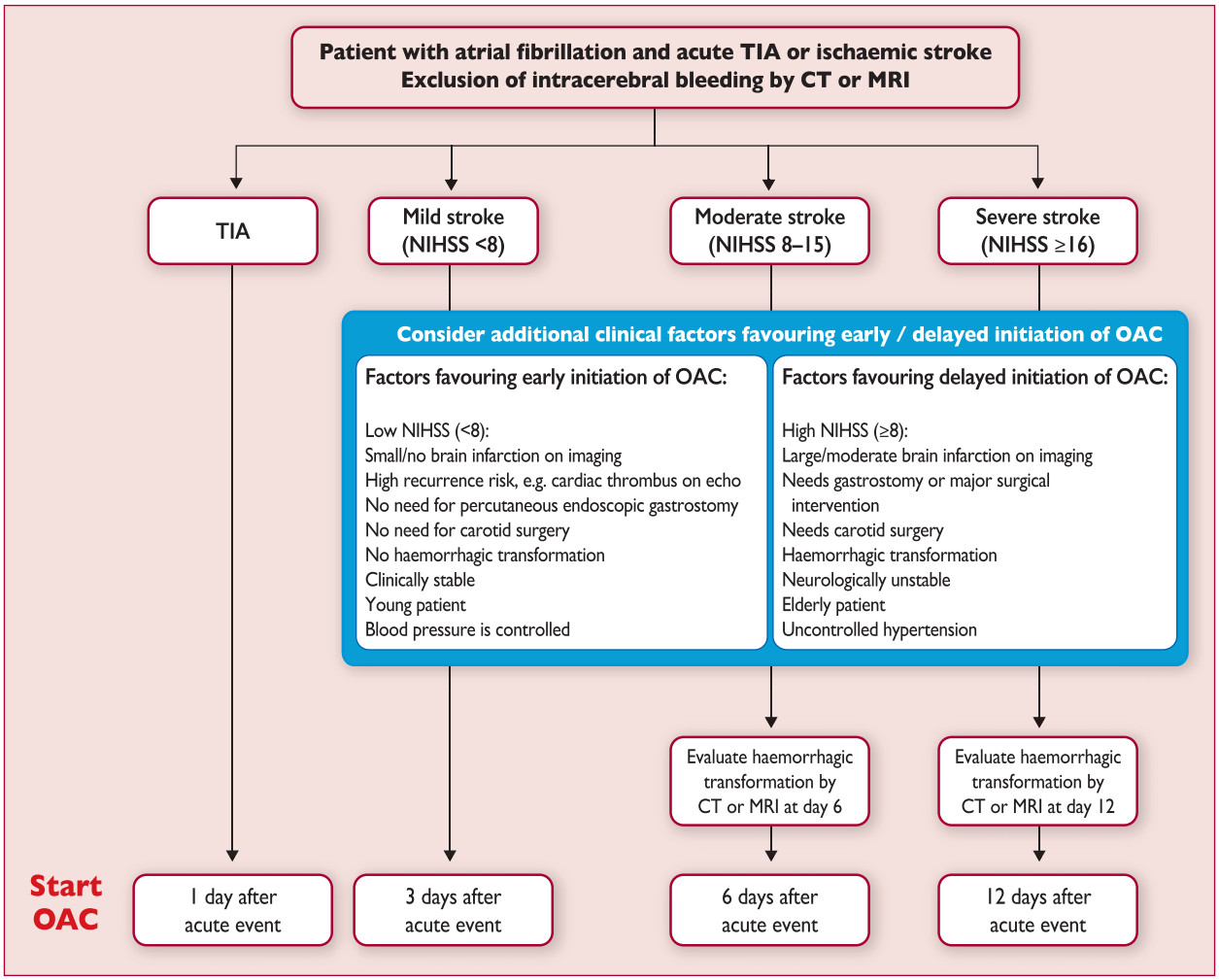
9.4 Secondary stroke prevention

The most important risk factors for stroke in patients with AF are advanced age and previous cardioembolic stroke or TIA [382], emphasizing the need for OAC in these patients. The highest risk of recurrent stroke is in the early phase after a first stroke or TIA [469, 470].

9.4.1 Treatment of acute ischaemic stroke. Systemic thrombolysis with recombinant tissue plasminogen activator (rtPA) is an effective and approved medical treatment for acute ischaemic stroke in patients presenting within 4.5 h of symptom onset [471]. Systemic thrombolysis is contraindicated in patients on therapeutic OAC [472, 473]. Recombinant tissue plasminogen activator can be given in patients treated with a VKA if the INR is below 1.7 [474], or in dabigatran-treated patients with a normal activated partial thromboplastin time and last intake of drug >48 h previously (based on expert consensus) [472]. Whether specific NOAC antidotes [475] could be used followed by systemic thrombolysis needs to be investigated. Thrombectomy can be performed in anticoagulated patients with distal occlusion of the internal carotid artery or middle cerebral artery in a 6 h window [476].

9.4.2 Initiation of anticoagulation after transient ischaemic attack or ischaemic stroke. Data on the optimal use of anticoagulants (heparin, low-molecular-weight heparin, heparinoid, VKA, NOAC) in the first days after a stroke are scarce. Parenteral anticoagulants seem to be associated with a non-significant reduction in recurrent ischaemic stroke when administered 7–14 days after the acute stroke [odds ratio (OR) 0.68; 95% CI 0.44–1.06), with a significant increase in symptomatic intracranial bleeding (OR 2.89; 95% CI 1.19–7.01), and a similar rate of death or disability at final follow-up [477]. It seems likely that the bleeding risk on parenteral anticoagulation exceeds the stroke prevention benefit in the first days after a large stroke, whereas patients with a TIA or a small stroke may benefit from early (immediate) initiation or continuation of anticoagulation. Therefore, we propose to initiate anticoagulation in AF patients between 1 and 12 days after an ischaemic stroke, depending on stroke severity (Figure 9) [478]. We suggest repeat brain imaging to determine the optimal initiation of anticoagulation in patients with a large stroke at risk for haemorrhagic transformation. Long-term OAC with a VKA [363, 479–481] or NOAC [482] conveys benefits in AF patients who survived a stroke. NOACs seem to convey slightly better outcomes, mainly driven by fewer intracranial haemorrhages and haemorrhagic strokes (OR 0.44; 95% CI 0.32–0.62) [482]. Detailed data for edoxaban have not yet been published [321]. If a patient suffers a stroke or TIA whilst taking an anticoagulant, switching to another anticoagulant should be considered.

9.4.3 Initiation of anticoagulation after intracranial haemorrhage. No prospective studies have investigated the benefit or risk of the initiation of OAC after intracranial haemorrhage [483], and patients with a history of intracranial bleeding were



AF = atrial fibrillation; CT = computed tomography; NIHSS = National Institutes of Health stroke severity scale (available at http://www.strokecenter.org/wp-content/uploads/2011/08/NIH_Stroke_Scale.pdf); OAC = oral anticoagulation; TIA = transient ischaemic attack

Figure 9: Initiation or continuation of anticoagulation in atrial fibrillation patients after a stroke or transient ischaemic attack. This approach is based on consensus rather than prospective data.

excluded from the randomized trials comparing NOACs with VKAs. The available evidence indicates that anticoagulation in patients with AF can be reinitiated after 4–8 weeks, especially when the cause of bleeding or the relevant risk factor (e.g. uncontrolled hypertension, see Table 12) has been treated, and that such treatment leads to fewer recurrent (ischaemic) strokes and lower mortality [460, 484]. If anticoagulation is resumed, it seems reasonable to consider anticoagulants with a low bleeding risk [39]. Figure 10 depicts a consensus opinion on the initiation or resumption of OAC after an intracranial haemorrhage. We recommend a multidisciplinary decision with input from stroke physicians/neurologists, cardiologists, neuroradiologists, and neurosurgeons.

9.5 Strategies to minimize bleeding on anticoagulant therapy

In a meta-analysis of 47 studies, the overall incidence of major bleeding with VKAs was 2.1 (range 0.9–3.4) per 100 patient-years in controlled trials and 2.0 (range 0.2–7.6) per 100 patient-years for observational data sets [488]. Minimizing treatable bleeding risk factors (see Table 12) seems paramount to reduce the bleeding rate on anticoagulants.

9.5.1 Uncontrolled hypertension. Uncontrolled hypertension increases the risk of bleeding on OAC [53]. Hence, keeping systolic blood pressure well controlled is of particular relevance in anticoagulated patients with AF. Treatment according to current guidelines is recommended in patients with known hypertension [489].

9.5.2 Previous bleeding event. History of bleeding events and the presence of anaemia are important parts of the assessment of all patients receiving OAC. The majority of bleeding events are gastrointestinal. Compared with warfarin, the risk of gastrointestinal bleeds was increased for dabigatran 150 mg twice daily [396, 490], rivaroxaban 20 mg once daily [491], and edoxaban 60 mg once daily [321]. The risk of gastrointestinal bleeds was comparable to warfarin on dabigatran 110 mg twice daily [490] and on apixaban 5 mg twice daily [319]. Recent observational analyses

Recommendations for secondary stroke prevention

Recommendations	Class[a]	Level[b]	Ref[c]
Anticoagulation with heparin or LMWH immediately after an ischaemic stroke is not recommended in AF patients.	III (harm)	A	477
In patients who suffer a TIA or stroke while on anticoagulation, adherence to therapy should be assessed and optimized.	IIa	C	
In patients who suffer a moderate-to-severe ischaemic stroke while on anticoagulation, anticoagulation should be interrupted for 3–12 days based on a multidisciplinary assessment of acute stroke and bleeding risk.	IIa	C	
In AF patients who suffer a stroke, aspirin should be considered for prevention of secondary stroke until the initiation or resumption of oral anticoagulation.	IIa	B	485
Systemic thrombolysis with rtPA is not recommended if the INR is above 1.7 (or, for patients on dabigatran, if aPTT is outside normal range).	III (harm)	C	472, 474
NOACs are recommended in preference to VKAs or aspirin in AF patients with a previous stroke.	I	B	363,482
After TIA or stroke, combination therapy of OAC and an antiplatelet is not recommended.	III (harm)	B	486
After intracranial haemorrhage, oral anticoagulation in patients with AF may be reinitiated after 4–8 weeks provided the cause of bleeding or the relevant risk factor has been treated or controlled.	IIb	B	483, 484, 487

AF = atrial fibrillation; INR = international normalized ratio; LMWH = low molecular weight heparin; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; TIA = transient ischaemic attack; VKA = vitamin K antagonist.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

do not replicate these findings, suggesting a smaller effect [396, 492, 493]. In patients in whom the source of bleeding has been identified and corrected, OAC can be reinitiated. This also appears true for patients who have had an intracranial haemorrhage, once modifiable bleeding risk factors (e.g. uncontrolled hypertension) have been corrected [460, 484].

9.5.3 Labile international normalized ratio and adequate non-vitamin K antagonist oral anticoagulant dosing. TTR on VKA therapy is an important predictor of major haemorrhage [432, 441, 494]. Therefore, we recommend targeting the INR between 2.0 and 3.0 in patients on VKAs, maintaining a high TTR (e.g. ≥70% [494]), and to consider switching to a NOAC when a high TTR cannot be sustained [444]. NOAC dosing should follow the dose-reduction criteria evaluated in the clinical trials, considering renal function, age, and weight. Patient information and empowerment, best delivered through integrated AF management, seem paramount to achieve this goal.

9.5.4 Alcohol abuse. Alcohol excess is a risk factor for bleeding in anticoagulated patients [384], mediated by poor adherence, liver disease, variceal bleeding, and risk of major trauma. Severe alcohol abuse and binge drinking habits should be corrected in patients eligible for OAC.

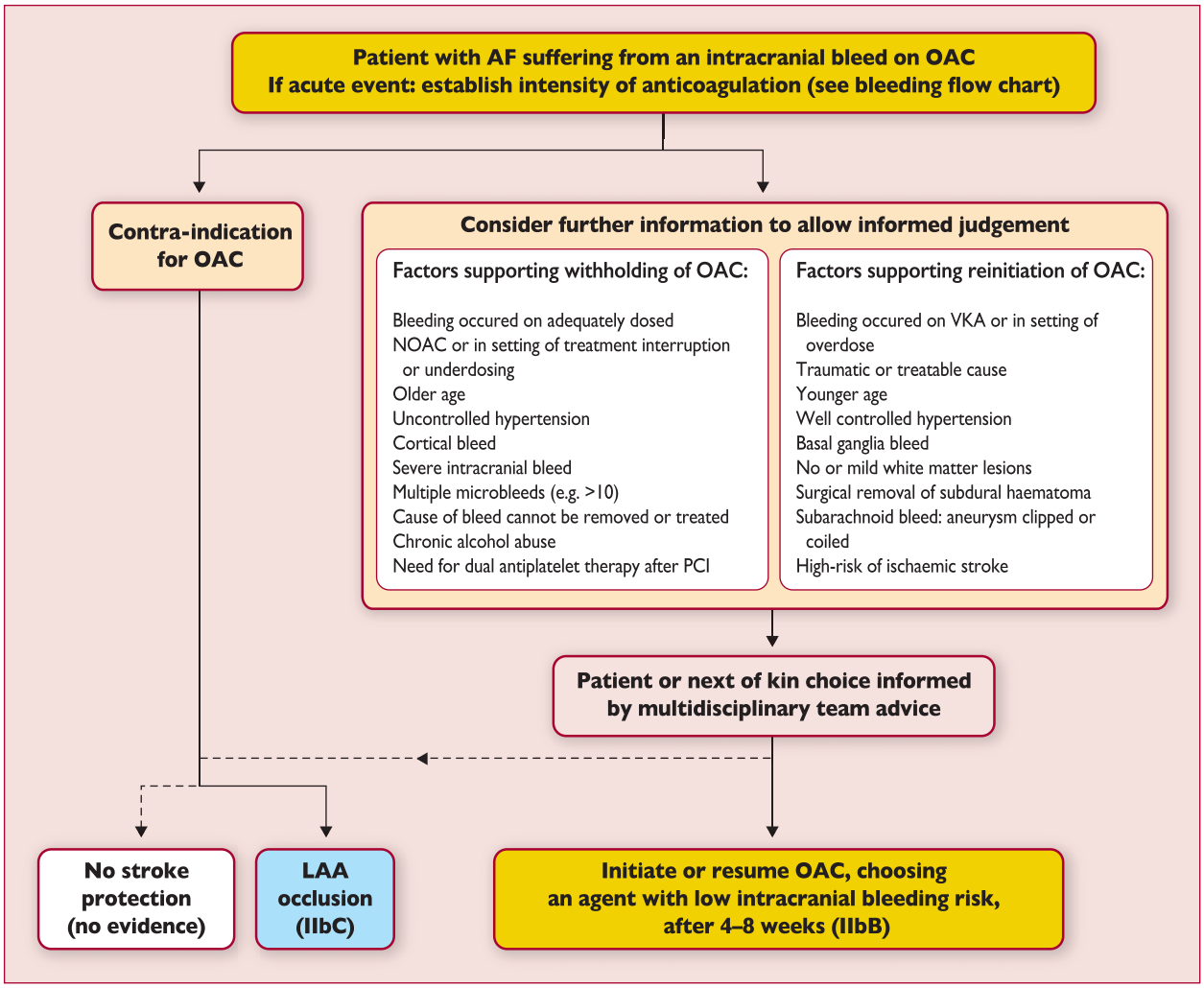
9.5.5 Falls and dementia. Falls and dementia are associated with increased mortality in AF patients [495], without evidence that these conditions markedly increase the risk of intracranial haemorrhage [495, 496]. Hence, anticoagulation should only be withheld from patients with severe uncontrolled falls (e.g. epilepsy or advanced multisystem atrophy with backwards falls), or in selected patients with dementia where compliance and adherence cannot be ensured by a caregiver.

9.5.6 Genetic testing. In addition to food and drug interactions, multiple genetic variations affect the metabolism of VKAs [497]. The systematic use of genetic information for adjustment of VKA dosage has been evaluated in several controlled clinical studies [498–500]. Genetic testing has little effect on TTR or bleeding risk on warfarin, and is not recommended for clinical use at present [501].

9.5.7 Bridging periods off oral anticoagulation. Most cardiovascular interventions (e.g. percutaneous coronary intervention or pacemaker implantation) can be performed safely on continued OAC. When interruption of OAC is required, bridging does not seem to be beneficial, except in patients with mechanical heart valves: In a randomized trial of 1884 patients with AF, interruption of anticoagulation was non-inferior to heparin bridging for the outcome of arterial thrombo-embolism (incidence of 0.4% and 0.3%, respectively) and resulted in a lower risk of major bleeding (1.3% and 3.2%, respectively) [502]. OAC interruptions should be minimized to prevent stroke.

9.6 Management of bleeding events in anticoagulated patients with atrial fibrillation

9.6.1 Management of minor, moderate, and severe bleeding. General assessment of an anticoagulated patient with AF experiencing a bleeding event should include the assessment of bleeding site, onset, and severity of the bleeding, the time-point of last intake of OAC and other antithrombotic drugs, and other factors influencing bleeding risk such as CKD, alcohol abuse, and concurrent medications. Laboratory tests should include haemoglobin, haematocrit, platelet count, renal function, and, for VKA patients, prothrombin time, activated partial thromboplastin time, and INR. Coagulation tests do not provide much information in patients on NOACs, except for activated partial thromboplastin time in the case of dabigatran. More specific coagulation tests do exist, including diluted thrombin time (HEMOCLOT) for dabigatran and calibrated quantitative anti-factor Xa assays for factor Xa inhibitors [503]. However, these tests are not always



AF = atrial fibrillation; LAA = left atrial appendage; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; PCI = percutaneous coronary intervention; VKA = vitamin K antagonist.

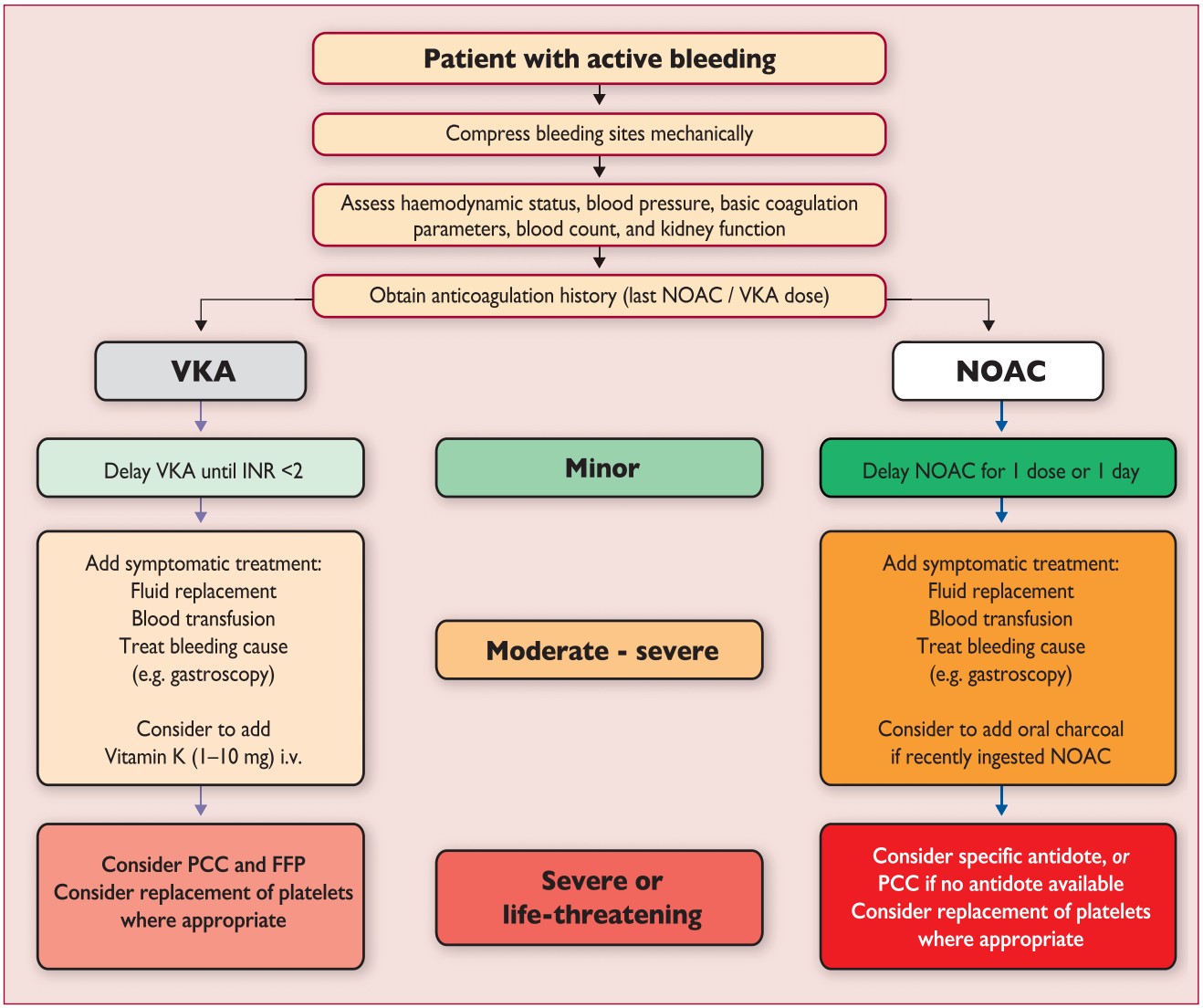
Figure 10: Initiation or resumption of anticoagulation in atrial fibrillation patients after an intracranial bleed. This approach is based on consensus opinion and retrospective data. In all patients, evaluation by a multidisciplinary panel is required before treatment (stroke physician/neurologist, cardiologist, neuroradiologist, and neurosurgeon).

readily available and are often unnecessary for bleeding management [504].

We propose a simple scheme to manage bleeding events in patients on OAC (Figure 11). Minor bleeding events should be treated with supportive measures such as mechanical compression or minor surgery to achieve haemostasis. In patients receiving VKAs, the next dose of VKA can be postponed. NOACs have a short plasma half-life of approximately 12 h, and improved haemostasis is expected within 12–24 h after a delayed or omitted dose. Treatment of moderate bleeding events may require blood transfusions and fluid replacement. Specific diagnostic and treatment interventions directed against the cause of the bleeding (e.g. gastroscopy) should be performed promptly. If the intake of NOAC was recent (<2–4 h), charcoal administration and/or gastric lavage will reduce further exposure. Dialysis clears dabigatran but is less effective for the other NOACs.

Immediate reversal of the antithrombotic effect is indicated in severe or life-threatening bleeding events. An agreed institutional procedure for the management of life-threatening bleeds should be documented and accessible at all times to ensure adequate initial management. For VKAs, administration of fresh frozen plasma restores coagulation more rapidly than vitamin K, and prothrombin complex concentrates achieve even faster blood coagulation [505]. Registry data suggest that the combination of plasma and prothrombin complex concentrates is associated with the lowest case fatality following intracranial haemorrhage on VKA treatment with an INR ≥1.3 [506]. In a multicentre randomized trial of 188 patients, four-factor prothrombin complex concentrates achieved more rapid INR reversal and effective haemostasis than plasma in patients undergoing urgent surgical or invasive procedures [507]. Administration of prothrombin complex concentrates may also be considered for severe bleeding on NOAC treatment if specific antidotes are not available.

Several antidotes to NOACs are under development. Idarucizumab (approved in 2015 by the US Food and Drug Administration and the European Medicines Agency) is a clinically available humanized antibody fragment that binds dabigatran and rapidly and dose-dependently reverses its effects



FFP = fresh frozen plasma; INR = international normalized ratio; i.v. = intravenous; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; PCC = prothrombin complex concentrates; VKA = vitamin K antagonist.

Figure 11: Management of active bleeding in patients receiving anticoagulation. Institutions should have an agreed procedure in place.

without over-correction or thrombin generation [475]. Andexanet alpha, a modified recombinant human factor Xa that lacks enzymatic activity, reverses the anticoagulant activity of factor Xa antagonists in healthy subjects within minutes after administration and for the duration of infusion, with a transient increase in markers of coagulation activity of uncertain clinical relevance [508]. Another agent under development is ciraparantag (PER977), an antidote designed to reverse both direct thrombin and factor Xa inhibitors as well as the indirect inhibitor enoxaparin [509]. The clinical usefulness of these specific antidotes needs further evaluation.

9.6.2 Oral anticoagulation in atrial fibrillation patients at risk of or having a bleeding event. While anticoagulation therapy should be paused to control active bleeding, absolute contraindications to long-term OAC after a bleeding episode are rare. When nuisance bleeds are the reason to stop OAC, a change from one anticoagulant to another seems reasonable. Many causes or triggers of major bleeding events can be treated and/or eliminated, including uncontrolled hypertension, gastrointestinal ulcers, and intracranial aneurysms. Reinitiation of anticoagulation after a bleeding event is often clinically justified [460, 510]. Difficult decisions, including the discontinuation and recommencement of OAC, should be taken by a multidisciplinary team, balancing the estimated risk of recurrent stroke and bleeding, and considering the bleeding risk of different stroke prevention therapies. LAA exclusion or occlusion might be an alternative in selected patients.

9.7 Combination therapy with oral anticoagulants and antiplatelets

Approximately 15% of AF patients in contemporary trials [513] and registries [514–516] have a history of myocardial infarction. Between 5–15% of AF patients will require stenting at some point

Recommendations for management of bleeding

Recommendations	Class[a]	Level[b]	Ref[c]
Blood pressure control in anticoagulated patients with hypertension should be considered to reduce the risk of bleeding	IIa	B	511
When dabigatran is used, a reduced dose (110 mg twice daily) may be considered in patients >75 years to reduce the risk of bleeding.	IIb	B	490
In patients at high-risk of gastrointestinal bleeding, a VKA or another NOAC preparation should be preferred over dabigatran 150 mg twice daily, rivaroxaban 20 mg once daily, or edoxaban 60 mg once daily.	IIa	B	321,396, 402,405, 490,492, 493,512
Advice and treatment to avoid alcohol excess should be considered in all AF patients considered for OAC.	IIa	C	
Genetic testing before the initiation of VKA therapy is not recommended.	III (no benefit)	B	497
Reinitiation of OAC after a bleeding event should be considered in all eligible patients by a multidisciplinary AF team, considering different anticoagulants and stroke prevention interventions, improved management of factors that contributed to bleeding, and stroke risk.	IIa	B	460
In AF patients with severe active bleeding events, it is recommended to interrupt OAC therapy until the cause of bleeding is resolved.	I	C	

AF = atrial fibrillation; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; VKA = vitamin K antagonist.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

in their lives. This scenario requires careful consideration of antithrombotic therapy, balancing bleeding risk, stroke risk, and risk of acute coronary syndromes (ACS) [516]. Co-prescription of OAC with antiplatelet therapy, in particular triple therapy, increases the absolute risk of major haemorrhage [445, 517, 518]. A recent meta-analysis involving 30 866 patients with a recent ACS evaluated the effects of adding NOAC therapy to single (4135 patients) or dual (26 731 patients) antiplatelet therapy [519]. The addition of a NOAC increased the bleeding risk by 79–134%, while reducing recurrent ischaemic events only marginally in patients without AF. OAC monotherapy, and not combination therapy with antiplatelets, is recommended in AF patients with stable CAD but without an ACS and/or coronary intervention in the previous 12 months. In patients treated for ACS, and in those receiving a coronary stent, short-term triple combination therapy of OAC, clopidogrel, and aspirin seems warranted (Figure 12).

9.7.1 Antithrombotic therapy after acute coronary syndromes and percutaneous coronary intervention in patients requiring oral anticoagulation. The optimal combination antithrombotic therapy or duration of combination therapy for AF patients undergoing percutaneous coronary intervention is not known, but the continued bleeding risk suggests a short duration. Expert consensus [520], reviewed and reconsidered by this Task Force, suggests the following principles: AF patients at risk for stroke, patients with mechanical valves, and patients with recent or recurrent deep vein thrombosis or pulmonary embolism should continue OAC during and after stenting. In general, a short period of triple therapy (OAC, aspirin, clopidogrel) is recommended, followed by a period of dual therapy (OAC plus a single antiplatelet) (Figure 13). When a NOAC is used, the consensus recommendation is that the lowest dose effective for stroke prevention in AF should be considered. Dose reduction beyond the approved dosing tested in phase III trials (see Table 13) is not currently recommended, and awaits assessment in ongoing controlled trials. The combination of aspirin, clopidogrel, and low-dose rivaroxaban (2.5 mg twice daily) is not recommended for stroke prevention in AF [521].

The use of prasugrel or ticagrelor as part of triple therapy should be avoided unless there is a clear need for these agents (e.g. stent thrombosis on aspirin plus clopidogrel), given the lack of evidence and the greater risk of major bleeding compared with clopidogrel [522, 523]. Ongoing trials will inform about such combination therapies in the future.

The omission of aspirin while maintaining clopidogrel and OAC has been evaluated in the WOEST (What is the Optimal antiplatElet and anticoagulant therapy in patients with oral anticoagulation and coronary StenTing) trial, in which 573 anticoagulated patients undergoing percutaneous coronary intervention (70% with AF) were randomized to either dual therapy with OAC and clopidogrel (75 mg once daily) or to triple therapy with OAC, clopidogrel, and aspirin [524]. Bleeding was lower in the dual vs. triple therapy arm, driven by fewer minor bleeding events. The rates of myocardial infarction, stroke, target vessel revascularization, and stent thrombosis did not differ (albeit with low event numbers), but all-cause mortality was lower in the dual therapy group at 1 year (2.5% vs. triple therapy 6.4%). Although the trial was too small to assess ischaemic outcomes, dual therapy with OAC and clopidogrel may emerge in the future as an alternative to triple therapy in patients with AF and ACS and/or coronary intervention [525].

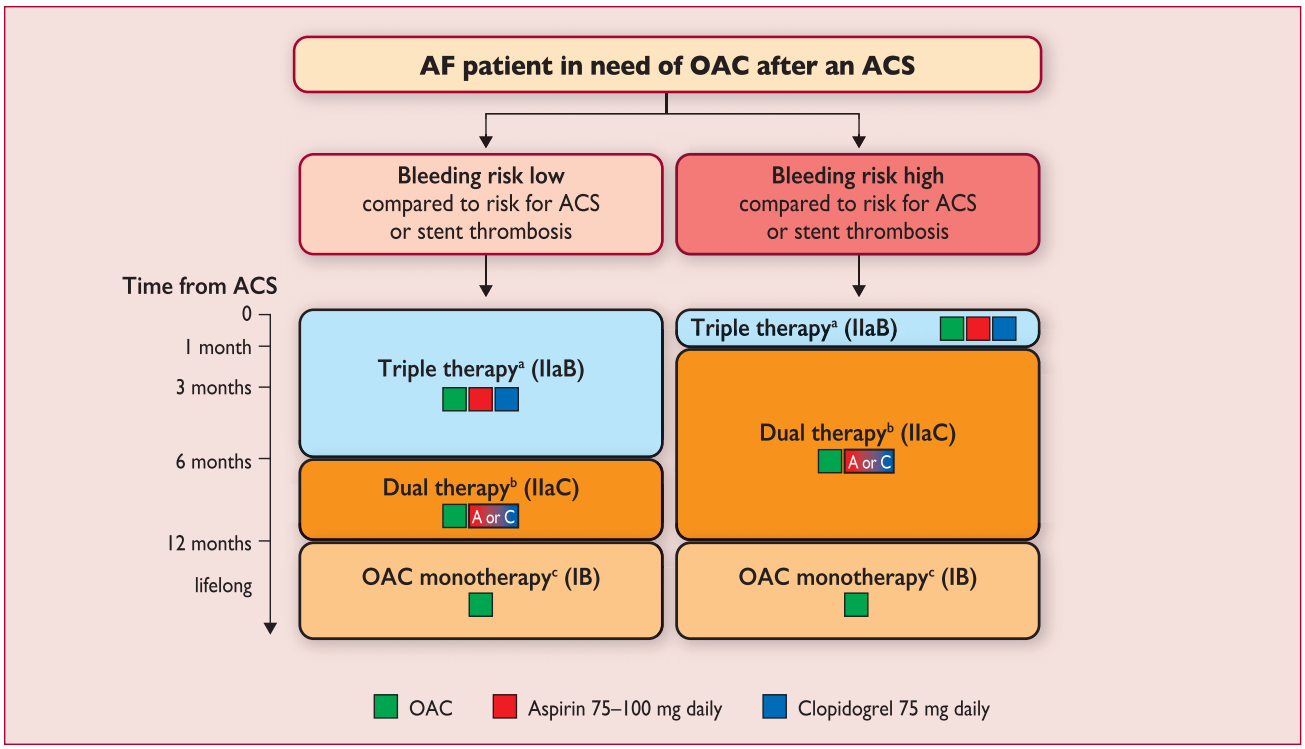
10. RATE CONTROL THERAPY IN ATRIAL FIBRILLATION

Rate control is an integral part of the management of AF patients, and is often sufficient to improve AF-related symptoms. Compared with stroke prevention and rhythm control, very little robust evidence exists to inform the best type and intensity of rate control treatment, with the majority of data derived from short-term crossover trials and observational studies [41, 526–528]. Pharmacological rate control can be achieved for acute or long-term rate control with beta-blockers, digoxin, the calcium channel blockers diltiazem and verapamil, or combination therapy (Table 15). A number of antiarrhythmic drugs also have rate-limiting properties (amiodarone, dronedarone, sotalol, and to some extent propafenone), but they should only be used in patients needing rhythm control therapy (see Chapter 11).

Recommendations for combination therapy with oral anticoagulants and antiplatelets

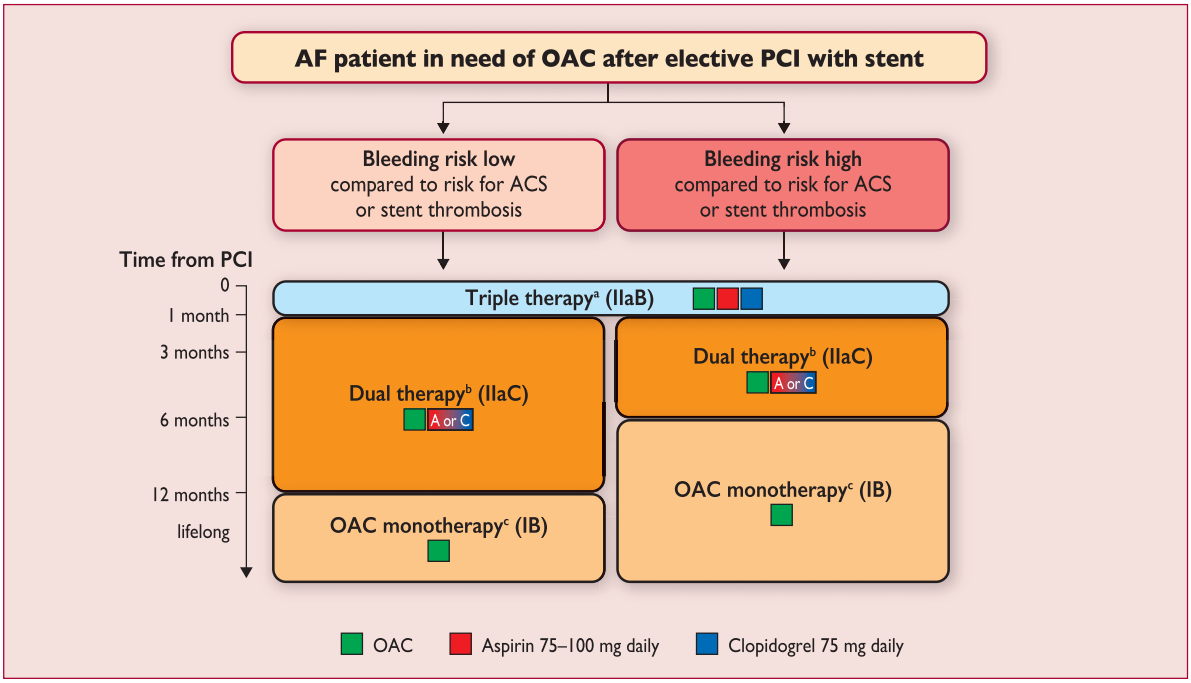
Recommendations	Class[a]	Level[b]	Ref[c]
After elective coronary stenting for stable coronary artery disease in AF patients at risk of stroke, combination triple therapy with aspirin, clopidogrel and an oral anticoagulant should be considered for 1 month to prevent recurrent coronary and cerebral ischaemic events.	IIa	B	522,524
After an ACS with stent implantation in AF patients at risk of stroke, combination triple therapy with aspirin, clopidogrel and an oral anticoagulant should be considered for 1–6 months to prevent recurrent coronary and cerebral ischaemic events.	IIa	C	520
After an ACS without stent implantation in AF patients at risk of stroke, dual treatment with an oral anticoagulant and aspirin or clopidogrel should be considered for up to 12 months to prevent recurrent coronary and cerebral ischaemic events.	IIa	C	
The duration of combination antithrombotic therapy, especially triple therapy, should be kept to a limited period, balancing the estimated risk of recurrent coronary events and bleeding.	IIa	B	520
Dual therapy with any oral anticoagulant plus clopidogrel 75 mg/day may be considered as an alternative to initial triple therapy in selected patients.	IIb	C	524,525

ACS = acute coronary syndromes; AF = atrial fibrillation; OAC = oral anticoagulant.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.



ACS = acute coronary syndrome; AF = atrial fibrillation; OAC = oral anticoagulation (using vitamin K antagonists or non-vitamin K antagonist oral anticoagulants); PCI = percutaneous coronary intervention.
[a]Dual therapy with OAC and aspirin or clopidogrel may be considered in selected patients, especially those not receiving a stent or patients at a longer time from the index event.
[b]OAC plus single antiplatelet.
[c]Dual therapy with OAC and an antiplatelet agent (aspirin or clopidogrel) may be considered in patients at high risk of coronary events.

Figure 12: Antithrombotic therapy after an acute coronary syndrome in atrial fibrillation patients requiring anticoagulation.



ACS = acute coronary syndrome; AF = atrial fibrillation; OAC = oral anticoagulation (using vitamin K antagonists or non-vitamin K antagonist oral anticoagulants); PCI = percutaneous coronary intervention.
[a]Dual therapy with OAC and aspirin or clopidogrel may be considered in selected patients.
[b]OAC plus single antiplatelet.
[c]Dual therapy with OAC and an antiplatelet agent (aspirin or clopidogrel) may be considered in patients at high risk of coronary events.

Figure 13: Antithrombotic therapy after elective percutaneous intervention in atrial fibrillation patients requiring anticoagulation.

10.1 Acute rate control

In the setting of acute new-onset AF, patients are often in need of heart rate control. Physicians should evaluate underlying causes of elevated heart rate, such as infection, endocrine imbalance, anaemia, and pulmonary embolism. For acute rate control, beta-blockers and diltiazem/verapamil are preferred over digoxin because of their rapid onset of action and effectiveness at high sympathetic tone [528–532]. The choice of drug (Table 15) and target heart rate will depend on patient characteristics, symptoms, LVEF and haemodynamics, but a lenient initial approach to heart rate seems acceptable. Combination therapy may be required (Figure 14). In patients with HFrEF, beta-blockers, digitalis (digoxin or digitoxin), or their combination should be used [218, 533], as diltiazem and verapamil can have negative inotropic effects in patients with LVEF <40% [222, 534, 535]. In critically ill patients and those with severely impaired LV systolic function, intravenous amiodarone can be used where excess heart rate is leading to haemodynamic instability [536–538]. Urgent cardioversion should be considered in unstable patients (see section 11.1).

10.2 Long-term pharmacological rate control

10.2.1 Beta-blockers. Beta-adrenoreceptor blocker monotherapy is often the first-line rate-controlling agent [539], largely based on observations of better acute heart rate control than digoxin. Interestingly, the prognostic benefit of beta-blockers seen in HFrEF patients with sinus rhythm is lost in those with AF. In an individual patient-level meta-analysis of RCTs, beta-blockers did not reduce all-cause mortality compared to placebo in those with AF at baseline (HR 0.97; 95% CI 0.83–1.14; $P = 0.73$), whereas there was a clear benefit in patients with sinus rhythm (HR 0.73; 95% CI 0.67–0.80; $P < 0.001$) [23]. The analysis, which included 3066 participants with HFrEF and AF, showed consistency across all subgroups and outcomes, with no heterogeneity between the 10 RCTs included (I^2 = 0%). Despite this lack of prognostic benefit in HFrEF, this Task Force still considers beta-blockers as a useful first-line rate control agent across all AF patients, based on the potential for symptomatic and functional improvement as a result of rate control, the lack of harm from published studies, and the good tolerability profile across all ages in sinus rhythm and in AF [23, 540].

10.2.2 Non-dihydropyridine calcium channel blockers. Verapamil or diltiazem provide reasonable rate control in AF patients [541]. They should be avoided in patients with HFrEF because of their negative inotropic effects [222, 534, 535]. Verapamil or diltiazem can improve arrhythmia-related symptoms [526], in comparison with beta-blockers, which reduced exercise capacity and increased B-type natriuretic peptide in one small trial of low-risk patients with preserved LVEF [542].

10.2.3 Digitalis. Cardiac glycosides such as digoxin and digitoxin have been in use for over two centuries, although prescriptions have been declining steadily over the past 15 years [543]. In the randomized Digitalis Investigation Group (DIG) trial, digoxin had no effect on mortality compared to placebo in HFrEF patients in sinus rhythm (RR 0.99; 95% CI 0.91–1.07), but reduced hospital admissions (RR 0.72; 95% CI 0.66–0.79) [544, 545]. There have been no head-to-head RCTs of digoxin in AF patients [546].

Table 15: Rate control therapy in atrial fibrillation

Therapy	Acute intravenous rate control	Long-term oral rate control	Side effect profile	Comments
Beta-blockers[a]				
Bisoprolol	Not available	1.25–20 mg once daily or split.	Most common reported adverse symptoms are lethargy, headache, peripheral oedema, upper respiratory tract symptoms, gastrointestinal upset and dizziness. Adverse effects include bradycardia, atrioventricular block and hypotension.	Bronchospasm is rare – in cases of asthma, recommend beta-1 selective agents (avoid carvedilol). Contra-indicated in acute cardiac failure and a history of severe bronchospasm.
Carvedilol	Not available	3.125–50 mg twice daily.		
Metoprolol	2.5–10 mg intravenous bolus (repeated as required).	100–200 mg total daily dose (according to preparation).		
Nebivolol	Not available	2.5–10 mg once daily or split.		
Esmolol	0.5 mg/kg intravenous bolus over 1 min; then 0.05–0.25 mg/kg/min.			
Calcium-channel blockers				
Diltiazem	15–25 mg intravenous bolus (repeated as required).	60 mg 3 times daily up to 360 mg total daily dose (120–360 mg once daily modified release).	Most common reported adverse symptoms are dizziness, malaise, lethargy, headache, hot flushes, gastrointestinal upset and oedema. Adverse effects include bradycardia, atrioventricular block and hypotension (prolonged hypotension possible with verapamil).	Use with caution in combination with beta-blockers. Reduce dose with hepatic impairment and start with smaller dose in renal impairment. Contra-indicated in LV failure with pulmonary congestion or LVEF <40%.
Verapamil	2.5–10 mg intravenous bolus (repeated as required).	40–120 mg 3 times daily (120–480 mg once daily modified release).		
Cardiac glycosides				
Digoxin	0.5 mg intravenous bolus (0.75–1.5 mg over 24 hours in divided doses).	0.0625–0.25 mg daily dose	Most common reported adverse symptoms are gastrointestinal upset, dizziness, blurred vision, headache and rash. In toxic states (serum levels >2 ng/mL), digoxin is proarrhythmic and can aggravate heart failure, particularly with co-existent hypokalaemia.	High plasma levels associated with increased risk of death. Check renal function before starting and adapt dose in patients with CKD. Contra-indicated in patients with accessory pathways, ventricular tachycardia and hypertrophic cardiomyopathy with outflow tract obstruction.
Digitoxin	0.4–0.6 mg intravenous bolus.	0.05–0.3 mg daily dose.		
Specific indications				
Amiodarone	300 mg intravenously diluted in 250 mL 5% dextrose over 30–60 minutes (preferably via central venous cannula).[b]	200 mg daily	Hypotension, bradycardia, nausea, QT prolongation, pulmonary toxicity, skin discolouration, thyroid dysfunction, corneal deposits and cutaneous reaction with extravasation.	Suggested as adjunctive therapy in patients where heart rate control cannot be achieved using combination therapy.

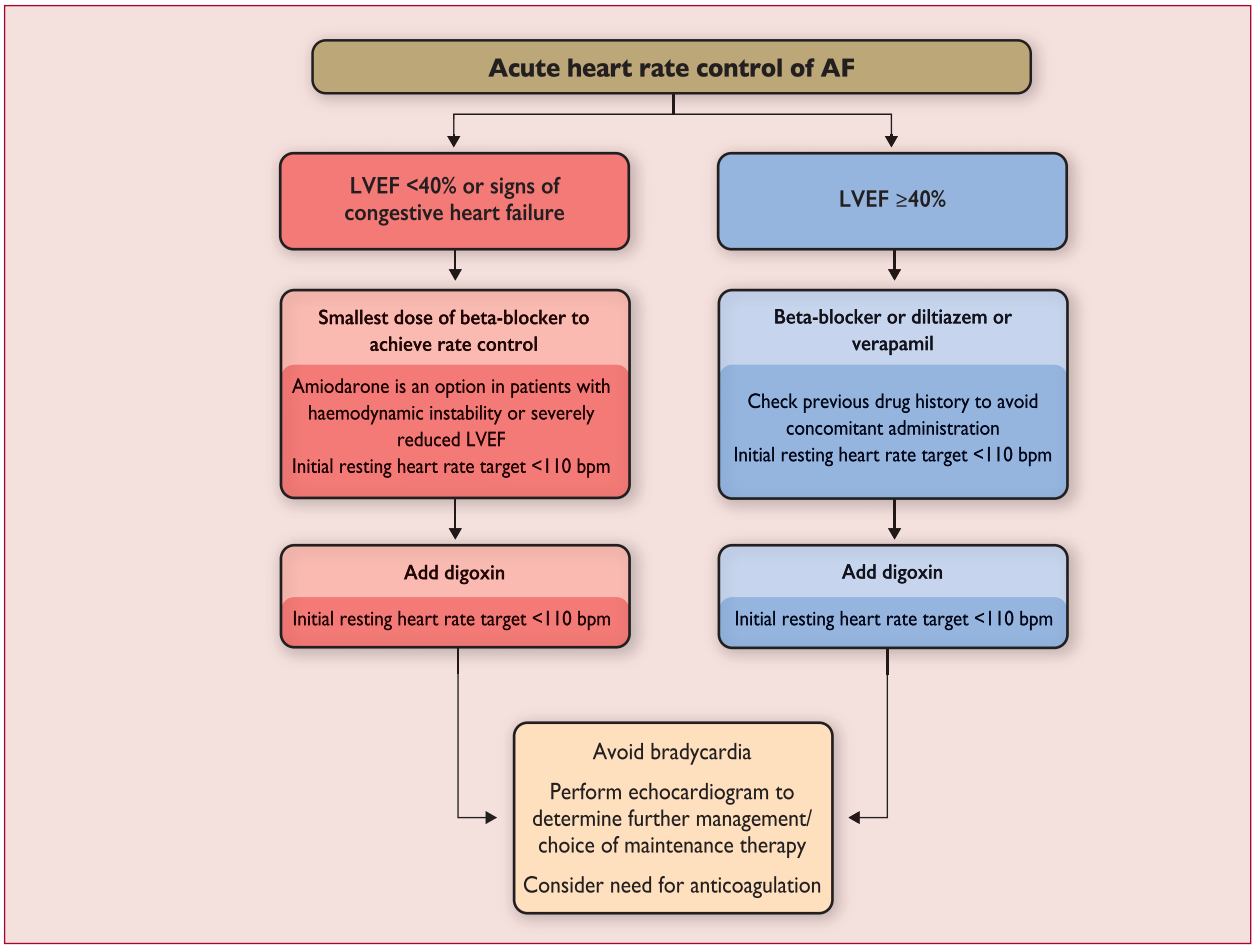
AF = atrial fibrillation; CKD = chronic kidney disease; i.v. = intravenous; LV = left ventricular; LVEF = left ventricular ejection fraction.

[a]A number of other beta-blockers are also available, but are not recommended as specific rate control therapy in AF. These include atenolol (25–100 mg once daily with a short biological half-life), propranolol [non-selective, 1 mg over 1 min and repeat up to 3 mg at 2-min intervals (acute) or 10–40 mg three times daily (long-term)], or labetalol [non-selective, 1–2 mg/min (acute)].

[b]If ongoing requirement for amiodarone, follow with 900 mg i.v. over 24 h diluted in 500–1000 mL via a central venous cannula.

Observational studies have associated digoxin use with excess mortality in AF patients [547–549], but this association is likely due to selection and prescription biases rather than harm caused by digoxin [550–553], particularly as digoxin is commonly prescribed to sicker patients [225]. In a crossover mechanistic trial of 47 patients with HFrEF and AF, there were no differences in heart rate, blood pressure, walking distance, or LVEF between carvedilol and digoxin, although beta-blockers did result in higher B-type natriuretic peptide levels, combination carvedilol/digoxin improved LVEF, and digoxin withdrawal reduced LVEF [554]. Comparisons with other rate control therapies are based on small, short-duration studies that identify no or marginal differences in exercise capacity, quality of life, or LVEF compared to digoxin [526, 554–558]. Lower doses of digoxin (≤250 μg once daily), corresponding to serum digoxin levels of 0.5–0.9 ng/mL, may be associated with better prognosis [225].

10.2.4 Amiodarone. Amiodarone can be useful for rate control as a last resort. The wide array of extracardiac adverse effects associated with amiodarone renders it a reserve agent in patients whose heart rate cannot be controlled with combination therapy (e.g. beta-blocker or verapamil/diltiazem combined with digoxin).



See Table 15 for medication dosage. Digitoxin is a suitable alternative to digoxin, where available.
AF = atrial fibrillation; bpm = beats per minute; LVEF = left ventricular ejection fraction.

Figure 14: Acute heart rate control in patients with atrial fibrillation.

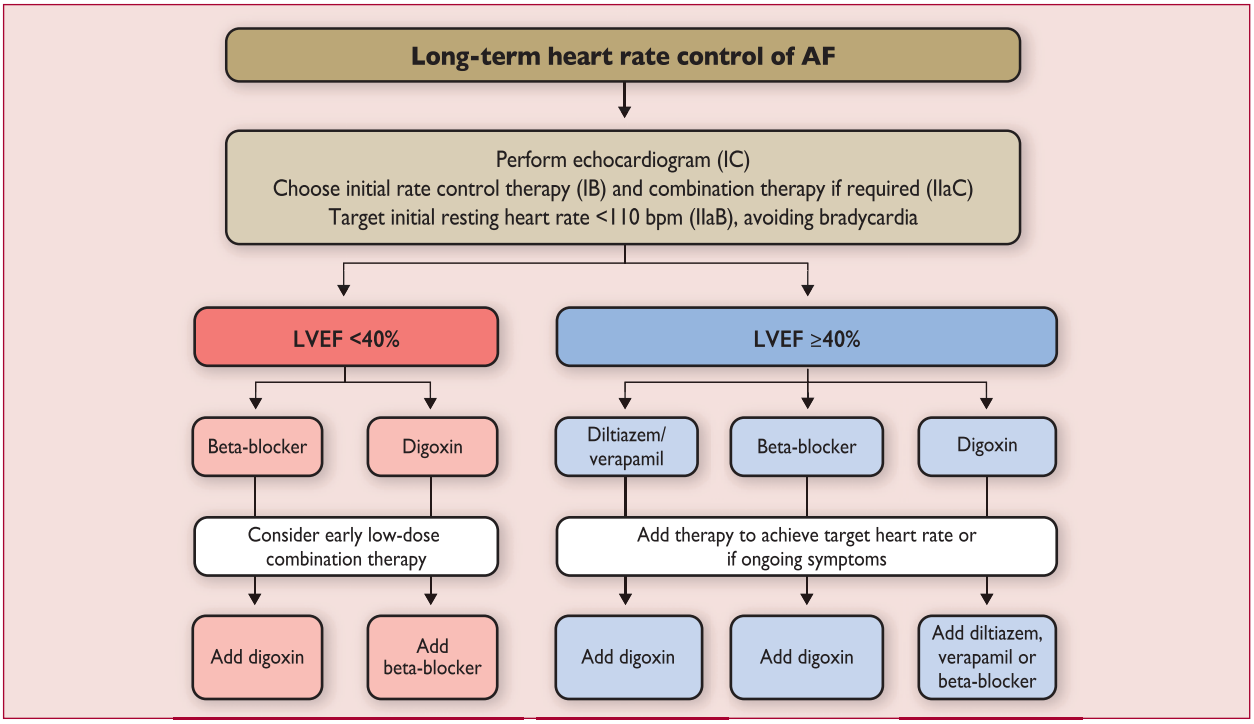
In summary, there is equipoise for the use of different rate control agents in AF. The choice of beta-blocker, diltiazem/verapamil, digoxin, or combination therapy should be made on an individual basis, after consideration of patient characteristics and patient preference. All available therapies have the potential for adverse effects and patients should initially be treated with a low dose and uptitrated to achieve symptom improvement. In practice, achieving a heart rate <110 b.p.m. will often require combination therapy (Figure 15). The benefit of different rate control strategies on symptoms, quality of life, and other intermediate outcomes is under investigation [559].

10.3 Heart rate targets in atrial fibrillation

The optimal heart rate target in AF patients is unclear. The RACE (Rate Control Efficacy in Permanent Atrial Fibrillation) II study randomized 614 patients with permanent AF to either a target heart rate <80 b.p.m. at rest and <110 b.p.m. during moderate exercise, or to a lenient heart rate target of <110 b.p.m. There was no difference in a composite of clinical events (14.9% in the strict rate control group, 12.9% in the lenient group) [560], NYHA class, or hospitalizations [560, 561]. Similar results were found in a pooled analysis of the AFFIRM (Atrial Fibrillation Follow-up Investigation of Rhythm Management) and RACE trials (1091 participants), albeit with smaller heart rate differences and without randomization [562]. It is worthwhile to note that many 'adequately rate-controlled' patients (resting heart rate 60–100 b.p.m.) are severely symptomatic, calling for additional management [194]. Nonetheless, lenient rate control is an acceptable initial approach, regardless of heart failure status, unless symptoms call for stricter rate control.

10.4 Atrioventricular node ablation and pacing

Ablation of the atrioventricular node/His bundle and implantation of a VVI pacemaker can control ventricular rate when medications fail to control rate and symptoms. It is a relatively simple procedure with a low complication rate and low long-term mortality risk [563, 564], especially when the pacemaker is implanted a few weeks before the AV nodal ablation and the initial pacing rate after ablation is set at 70–90 b.p.m [565, 566]. The procedure does not worsen LV function [567] and may even improve LVEF in selected patients [568–570]. In selected HFrEF patients treated with biventricular pacing (cardiac resynchronization therapy), AF can terminate [571], although such a 'rhythm control' effect of cardiac resynchronization therapy is likely to be small and clearly needs confirmation [572]. AV nodal ablation renders patients pacemaker-dependent for



See Table 15 for medication dosage. Digitoxin is a suitable alternative to digoxin, where available.
AF = atrial fibrillation; bpm = beats per minute; LVEF = left ventricular ejection fraction.

Figure 15: Long-term heart rate control in patients with atrial fibrillation.

the rest of their lives, limiting AV nodal ablation and pacing to patients whose symptoms cannot be managed by rate-controlling medication or by reasonable rhythm control interventions (see AF Heart Team, section 11.6). The choice of pacing therapy (right ventricular or biventricular pacing with or without an implantable defibrillator) will depend on individual patient characteristics, including LVEF [573, 574].

11. RHYTHM CONTROL THERAPY IN ATRIAL FIBRILLATION

Restoring and maintaining sinus rhythm is an integral part of AF management. Antiarrhythmic drugs approximately double the rate of sinus rhythm compared with placebo [580–584]. Catheter ablation or combination therapy is often effective when antiarrhythmic drugs fail [226, 585–587]. Although many clinicians believe that maintaining sinus rhythm can improve outcomes in AF patients [588], all trials that have compared rhythm control and rate control to rate control alone (with appropriate anticoagulation) have resulted in neutral outcomes [41, 578, 579, 582, 589–593]. Whether modern rhythm control management involving catheter ablation, combination therapy, and early therapy leads to a reduction in major cardiovascular events is currently under investigation, e.g. in the EAST – AFNET 4 (Early treatment of Atrial fibrillation for Stroke prevention Trial) [40] and CABANA (Catheter Ablation vs. Anti-arrhythmic Drug Therapy for Atrial Fibrillation Trial) [594] trials. For now, rhythm control therapy is indicated to improve symptoms in AF patients who remain symptomatic on adequate rate control therapy.

11.1 Acute restoration of sinus rhythm

11.1.1 Antiarrhythmic drugs for acute restoration of sinus rhythm ('pharmacological cardioversion'). Antiarrhythmic drugs can restore sinus rhythm in patients with AF (pharmacological cardioversion) as shown in small controlled trials, meta-analyses [41, 584, 595, 596], and in a few larger controlled trials [597–605]. Outside of Europe, dofetilide is available and can convert recent-onset AF [606]. Pharmacological cardioversion restores sinus rhythm in approximately 50% of patients with recent-onset AF (Table 16) [607–609]. In the short-term, electrical cardioversion restores sinus rhythm quicker and more effectively than pharmacological cardioversion and is associated with shorter hospitalization [609–613]. Pharmacological cardioversion, conversely, does not require sedation or fasting (Figure 16).

Flecainide and propafenone are effective for pharmacological cardioversion [595, 602–605, 614, 615], but their use is restricted to patients without structural heart disease. Ibutilide is an alternative where available, but carries a risk of torsades de pointes [615]. Vernakalant [602–605] can be given to patients with mild heart failure (NYHA Class I or II), including those with ischaemic heart disease, provided they do not present with hypotension or severe aortic stenosis [616–618]. Amiodarone can be used in patients with heart failure and in patients with ischaemic heart disease (although patients with severe heart failure were excluded from most of the AF cardioversion trials) [596]. Amiodarone also slows heart rate by 10–12 b.p.m. after 8–12 h when given intravenously [596]. Both amiodarone and flecainide appear more effective than sotalol in restoring sinus rhythm [600, 601, 619].

Recommendations for rate control

Recommendations	Class[a]	Level[b]	Ref[c]
Beta-blockers, digoxin, diltiazem, or verapamil are recommended to control heart rate in AF patients with LVEF ≥40%.	I	B	225,526, 528,531, 532,541, 555,575
Beta-blockers and/or digoxin are recommended to control heart rate in AF patients with LVEF <40%.	I	B	23,225, 526,533, 554,575, 576
Combination therapy comprising different rate controlling agents should be considered if a single agent does not achieve the necessary heart rate target.	IIa	C	23,554, 577
In patients with haemodynamic instability or severely depressed LVEF, amiodarone may be considered for acute control of heart rate.	IIb	B	536–538
In patients with permanent AF (i.e. where no attempt to restore sinus rhythm is planned), antiarrhythmic drugs should not routinely be used for rate control.	III (harm)	A	41,578, 579
A resting heart rate of <110 b.p.m. (i.e. lenient rate control) should be considered as the initial heart rate target for rate control therapy.	IIa	B	560
Rhythm rather than rate control strategies should be considered as the preferred management in pre-excited AF and AF during pregnancy.	IIa	C	
Atrioventricular node ablation should be considered to control heart rate in patients unresponsive or intolerant to intensive rate and rhythm control therapy, accepting that these patients will become pacemaker dependent.	IIa	B	184,564, 569

AF = atrial fibrillation; b.p.m. = beats per minute; LVEF = left ventricular ejection fraction.
Digitoxin is a suitable alternative to digoxin, where available. In patients with heart failure with reduced ejection fraction (LVEF <40%), recommended beta-blockers are bisoprolol, carvedilol, long-acting metoprolol, and nebivolol.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

11.1.2 'Pill in the pocket' cardioversion performed by patients. In selected patients with infrequent symptomatic episodes of paroxysmal AF, a single bolus of oral flecainide (200–300 mg) or propafenone (450–600 mg) can be self-administered by the patient at home ('pill in the pocket' therapy) to restore sinus rhythm, after safety has been established in the hospital setting [620]. This approach seems marginally less effective than hospital-based cardioversion [621], but is practical and provides control and reassurance to selected patients.

11.1.3 Electrical cardioversion. Synchronized direct current electrical cardioversion quickly and effectively converts AF to sinus rhythm, and is the method of choice in severely haemodynamically compromised patients with new-onset AF (Figure 16) [626–628]. Electrical cardioversion can be performed safely in sedated patients treated with intravenous midazolam and/or propofol. Continuous monitoring of blood pressure and oximetry during the procedure is important [629]. Skin burns may occasionally be observed. Intravenous atropine or isoproterenol, or temporary transcutaneous pacing, should be available to mitigate post-cardioversion bradycardia. Biphasic defibrillators are more effective than monophasic waveforms, and have become the industry standard [626, 628]. Anterior–posterior electrode positions generate a stronger shock field in the left atrium than anterolaterally positioned electrodes, and restore sinus rhythm more effectively [626, 627, 630].

Pre-treatment with amiodarone (requiring a few weeks of therapy) [631, 632], sotalol [631], ibutilide [633], or vernakalant [634] can improve the efficacy of electrical cardioversion, and similar effects are likely for flecainide [584] and propafenone [635]. Beta-blockers [636], verapamil, diltiazem [637–639], and digoxin [640, 641] do not reliably terminate AF or facilitate electrical cardioversion. When antiarrhythmic drug therapy is planned to maintain sinus rhythm after cardioversion, it seems prudent to start therapy 1–3 days before cardioversion (amiodarone: a few weeks) to promote pharmacological conversion and to achieve effective drug levels [584, 601].

11.1.4 Anticoagulation in patients undergoing cardioversion. Cardioversion carries an inherent risk of stroke in non-anticoagulated patients [642], which is reduced substantially by the administration of anticoagulation [643]. Immediate initiation of anticoagulation is important in all patients scheduled for cardioversion [644–646]. Patients who have been in AF for longer than 48 h should start OAC at least 3 weeks before cardioversion and continue it for 4 weeks afterwards (in patients without a need for long-term anticoagulation). OAC should be continued indefinitely in patients at risk of stroke. This practice has never been evaluated in controlled trials, but seemed safe in a large observational data set from Finland [647]. When early cardioversion is desired, TOE can exclude the majority of left atrial thrombi, allowing immediate cardioversion [648, 649]. Ongoing studies will inform about the safety and efficacy of newly initiated anticoagulation using NOACs in patients scheduled for cardioversion.

11.2 Long-term antiarrhythmic drug therapy

The aim of antiarrhythmic drug therapy is improvement in AF-related symptoms [41, 580]. Hence, the decision to initiate long-term antiarrhythmic drug therapy needs to balance symptom burden, possible adverse drug reactions, and patient preferences. The principles of antiarrhythmic drug therapy outlined in the 2010 ESC AF guidelines [369] are still relevant and should be observed:

1. Treatment is aimed at reducing AF-related symptoms;
2. Efficacy of antiarrhythmic drugs to maintain sinus rhythm is modest;
3. Clinically successful antiarrhythmic drug therapy may reduce rather than eliminate the recurrence of AF;
4. If one antiarrhythmic drug 'fails', a clinically acceptable response may be achieved with another agent;

Table 16: Antiarrhythmic drugs for pharmacological cardioversion

Drug	Route	1st dose	Follow-up dose	Risks	References
Flecainide	Oral IV	200–300 mg 1.5–2 mg/kg over 10 min	N/A	Hypotension, atrial flutter with 1:1 conduction, QT prolongation. Avoid in patients with IHD and/or significant structural heart disease.	595, 598
Amiodarone	IV[a]	5–7 mg/kg over 1–2 hours	50 mg/hour to a maximum of 1.0 g over 24 hours	Phlebitis, hypotension, bradycardia/AV block. Will slow ventricular rate. Delayed conversion to sinus rhythm (8–12 hours).	596–601
Propafenone	IV Oral	1.5–2 mg/kg over 10 min 450–600 mg		Hypotension, atrial flutter with 1:1 conduction, QRS prolongation (mild). Avoid in patients with IHD and/or significant structural heart disease.	622, 625
Ibutilide[b]	IV	1 mg over 10 min	1 mg over 10 min after waiting for 10 min	QT prolongation, polymorphic ventricular tachycardia/torsades de pointes (3–4% of patients). Will slow ventricular rate. Avoid in patients with QT prolongation, hypokalemia, severe LVH or low ejection fraction.	614, 615
Vernakalant	IV	3 mg/kg over 10 min	2 mg/kg over 10 min after waiting for 15 min	Hypotension, non-sustained ventricular arrhythmias, QT and QRS prolongation. Avoid in patients with SBP <100 mmHg, recent (<30 days) ACS, NYHA Class III and IV heart failure, QT interval prolongation (uncorrected QT >440 ms) and severe aortic stenosis.	602–605, 618

ACS = acute coronary syndromes; AV = atrioventricular; IHD = ischaemic heart disease; i.v. = intravenous; LVH = left ventricular hypertrophy; NYHA = New York Heart Association; SBP = systolic blood pressure.
[a]Use a large peripheral vessel and change to oral amiodarone within 24 h of i.v. (central line) administration.
[b]Ibutilide is only available in selected European countries.

5. Drug-induced pro-arrhythmia or extracardiac side-effects are frequent;
6. Safety rather than efficacy considerations should primarily guide the choice of antiarrhythmic drug.

Antiarrhythmic drug therapy approximately doubles sinus rhythm maintenance compared with no therapy [580]. There is no appreciable effect on mortality or cardiovascular complications, but rhythm control therapy can slightly increase the risk of hospitalizations (often for AF) [41, 578, 579, 582, 589–593]. To reduce the risk of side-effects [201, 580], a shorter duration of antiarrhythmic drug therapy seems desirable. As an example, short-term treatment (4 weeks) with flecainide for 4 weeks after cardioversion of AF was well-tolerated and prevented most (80%) AF recurrences when compared with long-term treatment [584]. Short-term antiarrhythmic drug therapy is also used to avoid early AF recurrences after catheter ablation [650], and may be reasonable in patients deemed at increased risk of antiarrhythmic drug side-effects or in those with a low perceived risk of recurrent AF.

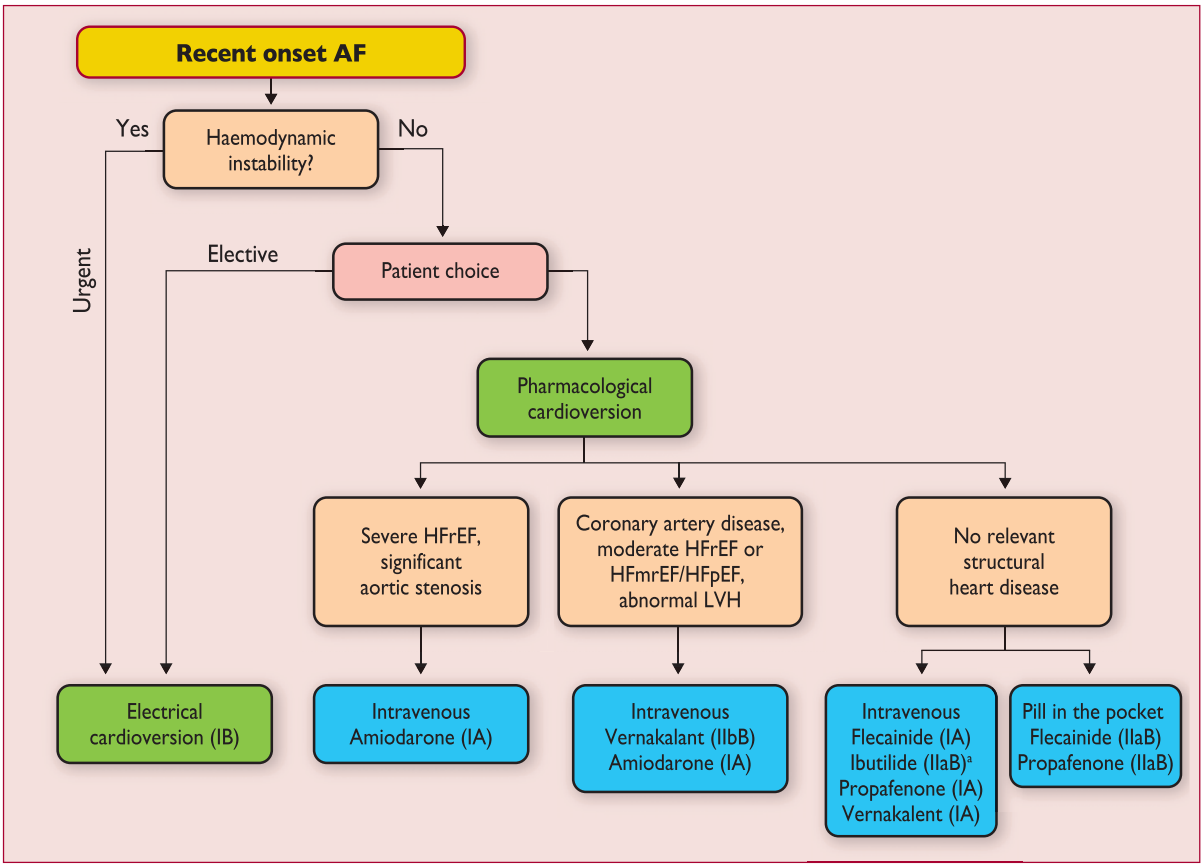
In addition to antiarrhythmic drug therapy and catheter ablation (see section 11.3), management of concomitant cardiovascular conditions can reduce symptom burden in AF and facilitate the maintenance of sinus rhythm [203, 204, 296, 312]. This includes weight reduction, blood pressure control, heart failure treatment, increasing cardiorespiratory fitness, and other measures (see Chapter 7).

11.2.1 Selection of antiarrhythmic drugs for long-term therapy: safety first! Usually, the safety of antiarrhythmic drug therapy determines the initial choice of antiarrhythmic drugs (Figure 17). The following major antiarrhythmic drugs are available to prevent AF:

11.2.1.1 *Amiodarone*. Amiodarone is an effective multichannel blocker, reduces ventricular rate, and is safe in patients with heart failure [582, 651]. Torsades de pointes pro-arrhythmia can occur, and QT interval and TU waves should be monitored on therapy (see Table 17) [652]. Amiodarone often causes extracardiac side-effects, especially on long-term therapy [653, 654], rendering it a second-line treatment in patients who are suitable for other antiarrhythmic drugs. Amiodarone appears less suitable to episodic short-term therapy (unless after catheter ablation) [655], probably because of its long biological half-life.

11.2.1.2 *Dronedarone*. Dronedarone maintains sinus rhythm, reduces ventricular rate, and prevents cardiovascular hospitalizations (mostly due to AF) and cardiovascular death in patients with paroxysmal or persistent AF or flutter who had at least one relevant cardiovascular comorbidity [583, 588, 656]. Dronedarone increases mortality in patients with recently decompensated heart failure (with or without AF) [657], and in patients with permanent AF in whom sinus rhythm is not restored [658]. Dronedarone moderately increases serum creatinine, reflecting a reduction in creatinine excretion rather than a decline in kidney function [659].

11.2.1.3 *Flecainide and propafenone*. Flecainide and propafenone are effective in preventing recurrent AF [581, 584, 620]. They should only be used in patients without significant ischaemic heart disease or heart failure to avoid the risk of life-threatening ventricular arrhythmias [660]. High ventricular rates resulting from the conversion of AF into atrial flutter with 1:1 conduction by flecainide or propafenone can be prevented by pre-administering a beta-blocker, verapamil, or diltiazem.



AF = atrial fibrillation; HFmrEF = heart failure with mid-range ejection fraction; HFpEF = heart failure with preserved ejection fraction; HFrEF = heart failure with reduced ejection fraction; LVH = left ventricular hypertrophy.
[a]Ibutilide should not be used in patients with long QT interval.

Figure 16: Rhythm control management of recent onset atrial fibrillation.

11.2.1.4 *Quinidine and disopyramide*. Quinidine and disopyramide have been associated with an increase in all-cause mortality (OR 2.39; 95% CI 1.03–5.59; number needed to harm 109; 95% CI 34–4985) at 1-year follow-up [580, 661], likely due to ventricular arrhythmias (torsades de pointes) [580, 661]. Although this pro-arrhythmic effect is more common at higher doses, they are less commonly used for rhythm control in AF. Disopyramide may be useful in 'vagally mediated' AF (e.g. AF occurring in athletes and/or during sleep [76]), and has been shown to reduce LV outflow gradient and improve symptoms in patients with hypertrophic cardiomyopathy [662–664].

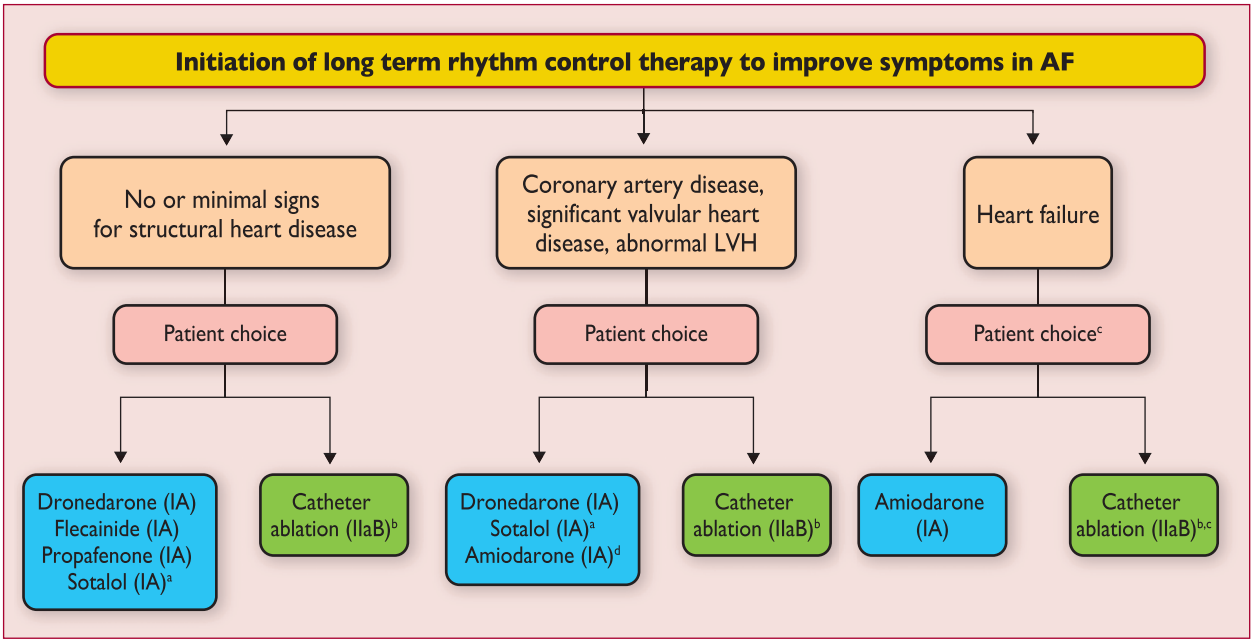
11.2.1.5 *Sotalol*. Sotalol has a relevant risk of torsades de pointes [1% in the Prevention of Atrial Fibrillation After Cardioversion (PAFAC) trial [118]]. Its d-enantiomer is associated with increased mortality compared to placebo in patients with LV dysfunction after a myocardial infarction [665], probably due to ventricular arrhythmias (OR 2.47; 95% CI 1.2–5.05; number needed to harm 166; 95% CI 61–1159) [580, 665]. On the other hand, d,l-sotalol has been used in AF patients without safety signals in two controlled trials [581, 601].

11.2.1.6 *Dofetilide*. Dofetilide is another potassium channel blocker that is mainly available outside of Europe. Dofetilide restores and maintains sinus rhythm in heart failure patients [666], and occasionally in patients refractory to other antiarrhythmic drugs [667].

Overall, it seems prudent to limit the use of quinidine, disopyramide, dofetilide, and sotalol to specific situations. Furthermore, combinations of QT-prolonging antiarrhythmic drugs should generally be avoided for rhythm control in AF (Table 17).

11.2.2 The twelve-lead electrocardiogram as a tool to identify patients at risk of pro-arrhythmia. Identifying patients at risk of pro-arrhythmia can help to mitigate the pro-arrhythmic risk of antiarrhythmic drugs [668]. In addition to the clinical characteristics mentioned above, monitoring PR, QT, and QRS durations during initiation of antiarrhythmic drug therapy can identify patients at higher risk of drug-induced pro-arrhythmia on longer-term treatment [669–671]. In addition, the presence of 'abnormal TU waves' is a sign of imminent torsades de pointes [652]. Periodic ECG analysis for pro-arrhythmia signs has been used successfully in recent antiarrhythmic drug trials [118, 584, 672]. Specifically, ECG monitoring was used systematically on days 1–3 in patients receiving flecainide, propafenone, or sotalol to identify those at risk of pro-arrhythmia [118, 584, 601]. Based on this evaluated practice, we suggest to record an ECG in all patients before initiation of antiarrhythmic drugs. Scheduled ECGs during the initiation period seem reasonable (Table 17).

11.2.3 New antiarrhythmic drugs. Several compounds that inhibit the ultrarapid potassium current (I_{Kur}) and other inhibitors of atypical ion channels are in clinical development [673–675]. They are not available for clinical use at present. The antianginal



AF = atrial fibrillation; HF = heart failure; LVH = left ventricular hypertrophy;
[a]Sotalol requires careful evaluation of proarrhythmic risk.
[b]Catheter ablation should isolate pulmonary veins and can be performed using radiofrequency or cryoballoon catheters.
[c]Catheter ablation as a first-line therapy is usually reserved for heart failure patients with tachycardiomyopathy.
[d]Amiodarone is a second-choice therapy in many patients because of its extracardiac side-effects.

Figure 17: Initiation of long-term rhythm control therapy in symptomatic patients with atrial fibrillation.

compound ranolazine inhibits potassium and sodium currents and increases glucose metabolism at the expense of free fatty acid metabolism, thereby enhancing the efficient use of oxygen [676, 677]. Ranolazine was safe in patients with non–ST-segment elevation myocardial infarction and unstable angina evaluated in the MERLIN (Metabolic Efficiency With Ranolazine for Less Ischemia in Non ST-Elevation Acute Coronary Syndrome) trial [678]. In a *post hoc* analysis of continuous ECG recordings obtained during the first 7 days after randomization, patients assigned to ranolazine had a trend towards fewer episodes of AF than those on placebo [75 (2.4%) vs. 55 (1.7%) patients; $P = 0.08$] [679]. In the HARMONY (A Study to Evaluate the Effect of Ranolazine and Dronedarone When Given Alone and in Combination in Patients With Paroxysmal Atrial Fibrillation) trial, the highest tested dose of a combination of ranolazine (750 mg twice daily) and dronedarone (225 mg twice daily) slightly reduced AF burden in 134 subjects with paroxysmal AF and dual-chamber pacemakers [680]. Small, open-label studies suggest that ranolazine might enhance the antiarrhythmic effect of amiodarone for cardioversion [681–683], whereas the results from a controlled trial of ranolazine and the ranolazine–dronedarone combination to prevent AHRE in pacemaker patients were ambiguous [684]. At present, there is insufficient evidence to recommend ranolazine as an antiarrhythmic drug, alone or in combination with other antiarrhythmic drugs. Of note, the 'funny channel blocker' ivabradine, which is used for angina and heart failure, increases the risk of AF [685].

11.2.4 Antiarrhythmic effects of non-antiarrhythmic drugs. ACE inhibitors or ARBs appear to prevent new-onset AF in patients with LV dysfunction and in hypertensive patients with LV hypertrophy [219, 236, 237, 239, 246, 250, 686]. Neprilysin inhibition needs to be studied further, but does not seem to enhance this effect [224]. A Danish cohort study also suggested that initial treatment of uncomplicated hypertension with ACE inhibitors or ARBs reduces incident AF compared with other hypertensive agents [245]. ARB therapy did not reduce the AF burden in patients with AF without structural heart disease [241]. Thus, ACE inhibitors or ARBs are unlikely to have a relevant direct antiarrhythmic effect. However, it might be justified to consider adding ACE inhibitors or ARB therapy to antiarrhythmic drugs to reduce AF recurrences after cardioversion [248, 249, 687].

Compared with placebo, beta-blockers are associated with a reduced risk of new-onset AF in patients with HFrEF and sinus rhythm [23]. Beta-blockers have also been reported to reduce symptomatic AF recurrences [580, 636, 688], but this finding may be driven by the beneficial effect of rate control, which will render AF more often asymptomatic.

Peri-operative statin therapy appeared to reduce the risk of post-operative AF in a number of small RCTs; [689, 690] however, an adequately powered placebo-controlled trial has shown no effect of peri-operative rosuvastatin therapy on post-operative AF [691]. Statin treatment does not prevent AF in other settings [692, 693]. Similarly, polyunsaturated fatty acids failed to show convincing benefit [241, 694–698]. The role of aldosterone antagonists in the management of AF has not been extensively investigated in humans. Although preliminary evidence from trials of eplerenone is encouraging for primary prevention [243], at present there is no robust evidence to make any recommendation for the use of aldosterone antagonists for secondary prevention of AF [699–701].

11.3 Catheter ablation

Since the initial description of triggers in the pulmonary veins that initiate paroxysmal AF [108], catheter ablation of AF has

Table 17: Oral antiarrhythmic drugs used for maintaining sinus rhythm after cardioversion

Drug	Dose	Main contra-indications and precautions	Warning signs warranting discontinuation	AV nodal slowing	Suggested ECG monitoring during initiation
Amiodarone	600 mg in divided doses for 4 weeks, 400 mg for 4 weeks, then 200 mg once daily	Caution when using concomitant therapy with QT-prolonging drugs and in patients with SAN or AV node and conduction disease. The dose of VKAs and of digitalis should be reduced. Increased risk of myopathy with statins. Caution in patients with pre-existing liver disease.	QT prolongation >500 ms	10–12 bpm in AF	Baseline, 1 week, 4 weeks
Dronedarone	400 mg twice daily	Contra-indicated in NYHA Class III or IV or unstable heart failure, during concomitant therapy with QT-prolonging drugs, or powerful CYP3A4 inhibitors (e.g. verapamil, diltiazem, azole antifungal agents), and when CrCl <30 ml/min. The dose of digitalis, beta-blockers, and of some statins should be reduced. Elevations in serum creatinine of 0.1–0.2 mg/dL are common and do not reflect a decline in renal function. Caution in patients with pre-existing liver disease.	QT prolongation >500 ms	10–12 bpm in AF	Baseline, 1 week, 4 weeks
Flecainide Flecainide slow release	100–150 mg twice daily 200 mg once daily	Contra-indicated if CrCl <50 mg/mL, liver disease, IHD or reduced LV ejection fraction. Caution in the presence of SAN or AV node or conduction disease. CYP2D6 inhibitors (e.g. fluoxetine or tricyclic antidepressants) increase plasma concentration.	QRS duration increases >25% above baseline	None	Baseline, day 1, day 2–3
Propafenone Propafenone SR	150–300 mg three times daily 225–425 mg twice daily	Contra-indicated in IHD or reduced LV ejection fraction. Caution in the presence of SAN or AV node and conduction disease, renal or liver impairment, and asthma. Increases concentration of digitalis and warfarin.	QRS duration increase >25% above baseline	Slight	Baseline, day 1, day 2–3
d,l sotalol	80–160 mg twice daily	Contra-indicated in the presence of significant LV hypertrophy, systolic heart failure, asthma, pre-existing QT prolongation, hypokalaemia, CrCl<50 mg/mL. Moderate renal dysfunction requires careful adaptation of dose.	QT interval >500 ms, QT prolongation by >60 ms upon therapy initiation	Similar to high dose blockers	Baseline, day 1, day 2–3

AF = atrial fibrillation; AV = atrioventricular; b.p.m. = beats per minute; CrCl = creatinine clearance; CYP2D6 = cytochrome P450 2D6; CYP3A4 = cytochrome P450 3A4; ECG = electrocardiogram; IHD = ischaemic heart disease; LV = left ventricular; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; SAN = sino-atrial node; VKA = vitamin K antagonist.

developed from a specialized, experimental procedure into a common treatment to prevent recurrent AF [587, 715]. This is primarily achieved through isolation of the pulmonary veins, probably requiring complete isolation for full effectiveness [716], and additional ablation in the posterior left atrial wall. AF ablation, when performed in experienced centres by adequately trained teams, is more effective than antiarrhythmic drug therapy in maintaining sinus rhythm, and the complication rate, though not negligible, is similar to the complication rate for antiarrhythmic drugs [585, 717].

11.3.1 Indications. Catheter ablation of AF is effective in restoring and maintaining sinus rhythm in patients with symptomatic paroxysmal, persistent, and probably long-standing persistent AF, in general as second-line treatment after failure of or intolerance to antiarrhythmic drug therapy. In such patients, catheter ablation is more effective than antiarrhythmic drug therapy [185, 586, 713, 717–720]. As first-line treatment for paroxysmal AF, randomized trials showed only modestly improved rhythm outcome with catheter ablation compared to antiarrhythmic drug therapy [585, 721–723]. Complication rates were similar, when ablation was performed in expert centres, justifying catheter ablation as first-line therapy in selected patients with paroxysmal AF who ask for interventional therapy. Fewer data are available reporting the effectiveness and safety of catheter ablation in patients with persistent or long-standing persistent AF, but all point to lower recurrence rates after catheter ablation compared to antiarrhythmic drug therapy with or without cardioversion (Web Figure 2) [185, 717, 723–726, 1039]. In patients who experience symptomatic recurrences of AF despite antiarrhythmic drug therapy, all RCTs showed better sinus rhythm maintenance with catheter ablation than on antiarrhythmic drugs [586, 713, 727, 728]. There is no current indication for catheter ablation to prevent cardiovascular outcomes (or desired withdrawal of anticoagulation), or to reduce hospitalization [40, 594].

11.3.2 Techniques and technologies. Complete pulmonary vein isolation (PVI) on an atrial level is the best documented target for catheter ablation [716, 729–731], achievable by point-by-point radiofrequency ablation, linear lesions encircling the

Recommendations for rhythm control therapy

Recommendations	Class[a]	Level[b]	Ref[c]
General recommendations			
Rhythm control therapy is indicated for symptom improvement in patients with AF.	I	B	120, 586, 601
Management of cardiovascular risk factors and avoidance of AF triggers should be pursued in patients on rhythm control therapy to facilitate maintenance of sinus rhythm.	IIa	B	203, 204, 296, 312
With the exception of AF associated with haemodynamic instability, the choice between electrical and pharmacological cardioversion should be guided by patient and physician preferences.	IIa	C	
Cardioversion of AF			
Electrical cardioversion of AF is recommended in patients with acute haemodynamic instability to restore cardiac output.	I	B	612, 702-704
Cardioversion of AF (either electrical or pharmacological) is recommended in symptomatic patients with persistent or long-standing persistent AF as part of rhythm control therapy.	I	B	584, 601, 627, 628, 648, 705
Pre-treatment with amiodarone, flecainide, ibutilide, or propafenone should be considered to enhance success of electrical cardioversion and prevent recurrent AF.	IIa	B	248, 584, 633
In patients with no history of ischaemic or structural heart disease, flecainide, propafenone or vernakalant are recommended for pharmacological cardioversion of new-onset AF.	I	A	602–605, 614, 618, 622, 706, 707
In patients with no history of ischaemic or structural heart disease, ibutilide should be considered for pharmacological conversion of AF.	IIa	B	
In selected patients with recent-onset AF and no significant structural or ischaemic heart disease, a single oral dose of flecainide or propafenone (the 'pill in the pocket' approach) should be considered for patient-led cardioversion, following safety assessment.	IIa	B	620, 621
In patients with ischaemic and/or structural heart disease, amiodarone is recommended for cardioversion of AF.	I	A	597–601
Vernakalant may be considered as an alternative to amiodarone for pharmacological conversion of AF in patients without hypotension, severe heart failure or severe structural heart disease (especially aortic stenosis).	IIb	B	602–605, 616, 618
Stroke prevention in patients designated for cardioversion of AF			
Anticoagulation with heparin or a NOAC should be initiated as soon as possible before every cardioversion of AF or atrial flutter.	IIa	B	708, 709
For cardioversion of AF/atrial flutter, effective anticoagulation is recommended for a minimum of 3 weeks before cardioversion.	I	B	648, 708
Transoesophageal echocardiography (TOE) is recommended to exclude cardiac thrombus as an alternative to preprocedural anticoagulation when early cardioversion is planned.	I	B	648, 708
Early cardioversion can be performed without TOE in patients with a definite duration of AF <48 hours.	IIa	B	648
In patients at risk for stroke, anticoagulant therapy should be continued long-term after cardioversion according to the long-term anticoagulation recommendations, irrespective of the method of cardioversion or the apparent maintenance of sinus rhythm. In patients without stroke risk factors, anticoagulation is recommended for 4 weeks after cardioversion.	I	B	353, 710
In patients where thrombus is identified on TOE, effective anticoagulation is recommended for at least 3 weeks.	I	C	
A repeat TOE to ensure thrombus resolution should be considered before cardioversion.	IIa	C	
Anti-arrhythmic drugs for the long-term maintenance of sinus rhythm/prevention of recurrent AF			
The choice of AAD needs to be carefully evaluated, taking into account the presence of comorbidities, cardiovascular risk and potential for serious proarrhythmia, extracardiac toxic effects, patient preferences, and symptom burden.	I	A	41, 580
Dronedarone, flecainide, propafenone, or sotalol are recommended for prevention of recurrent symptomatic AF in patients with normal left ventricular function and without pathological left ventricular hypertrophy.	I	A	581, 583, 584, 588, 601
Dronedarone is recommended for prevention of recurrent symptomatic AF in patients with stable coronary artery disease, and without heart failure.	I	A	583, 588
Amiodarone is recommended for prevention of recurrent symptomatic AF in patients with heart failure.	I	B	596–598
Amiodarone is more effective in preventing AF recurrences than other AAD, but extracardiac toxic effects are common and increase with time. For this reason, other AAD should be considered first.	IIa	C	596–598
Patients on AAD therapy should be periodically evaluated to confirm their eligibility for treatment.	IIa	C	583, 588, 657, 658, 660

Recommendations for rhythm control therapy (continued)

Recommendations	Class[a]	Level[b]	Ref[c]
AAD for the long-term maintenance of sinus rhythm/prevention of recurrent AF (continued)			
ECG recording during the initiation of AAD therapy should be considered to monitor heart rate, detect QRS and QT interval prolongation, and the occurrence of AV block.	IIa	B	582–584, 588,601
AAD therapy is not recommended in patients with prolonged QT interval (>0.5 s) or those with significant sinoatrial node disease or AV node dysfunction who do not have a functioning permanent pacemaker.	III (harm)	C	
Adding atrial-based bradycardia pacing to drug treatment that induces or exacerbates sinus node dysfunction should be considered to allow continuation of AAD therapy in patients in whom AF ablation is declined or not indicated.	IIa	B	711, 712
Continuation of AAD therapy beyond the blanking period after AF ablation should be considered to maintain sinus rhythm when recurrences seem likely.	IIa	B	713
Antiarrhythmic effects of non-antiarrhythmic drugs			
ACE-Is, ARBs and beta-blockers should be considered for prevention of new-onset AF in patients with heart failure and reduced ejection fraction.	IIa	A	23,219, 236,237, 239,250, 714
ACE-Is and ARBs should be considered for prevention of new-onset AF in patients with hypertension, particularly with LV hypertrophy.	IIa	B	238,246, 686,714
Pre-treatment with ACE-Is or ARBs may be considered in patients with recurrent AF undergoing electrical cardioversion and receiving antiarrhythmic drug therapy.	IIb	B	236,237, 248,249
ACE-Is or ARBs are not recommended for the secondary prevention of paroxysmal AF in patients with little or no underlying heart disease.	III (no benefit)	B	241,697

ACE = angiotensin-converting enzyme; AF = atrial fibrillation; ARB = angiotensin receptor blocker; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female); ECG = electrocardiogram; LV = left ventricular; LVH = left ventricular hypertrophy; NOAC = non-vitamin K antagonist oral anticoagulant; TOE = transoesophageal echocardiography.

[a]Class of recommendation.

[b]Level of evidence.

[c]Reference(s) supporting recommendations.

pulmonary veins, or cryoballoon ablation, with similar outcomes [732–734]. Complete isolation of the pulmonary veins has better rhythm outcomes than incomplete isolation [716]. PVI was initially tested in patients with paroxysmal AF, but appears to be non-inferior to more extensive ablation in persistent AF as well [729, 735]. More extensive ablations have been used in patients with persistent AF, but there are insufficient data to guide the use of these at present [117, 718, 719, 735–737]. Extended ablation procedures (beyond PVI) consistently require longer procedures and more ionizing radiation, potentially creating risk for patients. Left atrial macro re-entrant tachycardia is relatively uncommon after PVI (≈5%). It also seems rare after cryoballoon ablation [734], but may occur in up to 25% of patients after left atrial substrate modification ablation, often due to incomplete ablation lines. Thus, for patients with persistent AF, ablation of complex fractionated electrograms, ablation of rotors, or routine deployment of linear lesions or other additional ablations does not seem justified in the first procedure [735, 738, 739]. However, additional ablation on top of complete PVI [716] may be considered in patients with recurrent AF after the initial ablation procedure [719, 740, 741]. In patients with documented right atrial isthmus-dependent flutter undergoing AF ablation, right atrial isthmus ablation is recommended. Adenosine testing to identify patients in need of additional ablation remains controversial after evaluation in several reports [739, 742–744]. Ablation of so-called 'rotors', guided by body surface mapping or endocardial mapping, is under evaluation and cannot be recommended for routine clinical use at present.

11.3.3 Outcome and complications. 11.3.3.1 *Outcome of catheter ablation for atrial fibrillation*. The rhythm outcome after catheter ablation of AF is difficult to predict in individual patients [173, 227, 713, 728]. Most patients require more than one procedure to achieve symptom control [713, 726, 728]. In general, better rhythm outcome and lower procedure-related complications can be expected in younger patients with a short history of AF and frequent, short AF episodes in the absence of significant structural heart disease [745]. Catheter ablation is more effective than antiarrhythmic drug therapy in maintaining sinus rhythm (Web Figure 2) [746, 1039]. Sinus rhythm without severely symptomatic recurrences of AF is found in up to 70% of patients with paroxysmal AF, and around 50% in persistent AF [713, 728, 735]. Very late recurrence of AF after years of sinus rhythm is not uncommon and may reflect disease progression, with important implications for continuation of AF therapies [728]. Multiple variables have been identified as risk factors for recurrence after catheter ablation of AF, but their predictive power is weak. The

Table 18: Complications related to catheter ablation of atrial fibrillation

Complication severity	Complication type	Rate [727,748, 750,754-759]
Life-threatening complications	Periprocedural death	<0.2%
	Oesophageal injury (perforation/fistula)[a]	<0.5%
	Periprocedural stroke (including TIA/air embolism)	<1%
	Cardiac tamponade	1–2%
Severe complications	Pulmonary vein stenosis	<1%
	Persistent phrenic nerve palsy	1–2%
	Vascular complications	2–4%
	Other severe complications	≈1%
Other moderate or minor complications		1–2%
Unknown significance	Asymptomatic cerebral embolism (silent stroke)[b]	5–20%
	Radiation exposure	

TIA = transient ischaemic attack.
[a]Oesophageal fistula should be suspected in patients presenting with the triad of unspecific signs of infection, chest pain, and stroke or TIA in the first weeks after an ablation procedure. It requires immediate therapy.
[b]<10% for cryoablation or radiofrequency ablation, >20% for phased radiofrequency ablation.

decision for catheter ablation, thus, should be based on a shared decision-making process [747] (see Chapter 8), following thorough explanation of the potential benefits and risks, and of the alternatives such as antiarrhythmic drugs or acceptance of the current symptoms without rhythm control therapy [175].

11.3.3.2 *Complications of catheter ablation for atrial fibrillation.* There is a clear need to systematically capture complications in clinical practice to improve the quality of AF ablation procedures [175]. The median length of hospital stay in AF patients undergoing their first ablation as part of the EURObservational Research Programme (EORP) was 3 days (interquartile range 2–4 days), based on data from 1391 patients from hospitals performing at least 50 ablations per year. Five to seven per cent of patients will suffer severe complications after catheter ablation of AF, and 2–3% will experience life-threatening but usually manageable complications [727, 748–750]. Intraprocedural death has been reported, but is rare (<0.2%) [751]. The most important severe complications are stroke/TIA (<1%), cardiac tamponade (1–2%), pulmonary vein stenosis, and severe oesophageal injury leading to atrio-oesophageal fistula weeks after ablation (Table 18). 'Silent strokes' (i.e. white matter lesions detectable by brain MRI) have been observed in around 10% of patients treated with radiofrequency and cryoballoon ablation [752]. The clinical relevance of this observation is unclear [749]. Post-procedural complications include stroke, with the highest risk within the first week [753], late pericardial tamponade several days after catheter ablation [751], and oesophageal fistulas, which usually become apparent 7–30 days after ablation. Timely detection of atrio-oesophageal fistulas can be life-saving and should be based on the typical triad of infection without a clear focus, retrosternal pain, and stroke or TIA [748].

11.3.4 Anticoagulation: before, during, and after ablation. Patients anticoagulated with VKAs should continue therapy during ablation (with an INR of 2–3) [760]. Anticoagulation with NOACs is an alternative to warfarin [478, 761–765]. There is no safety signal from observational cohorts treated with uninterrupted NOAC therapy undergoing catheter ablation in experienced centres [761, 763, 766, 767]. The first controlled trial comparing continuous NOAC and VKA therapy in AF ablation patients, enrolling around 200 patients, has recently been published [768], as well as several observational data sets [761, 769, 770]. Ongoing studies compare uninterrupted VKA with NOAC therapy in AF patients undergoing ablation [e.g. AXAFA – AFNET 5 (Anticoagulation using the direct factor Xa inhibitor apixaban during Atrial Fibrillation catheter Ablation: Comparison to vitamin K antagonist therapy; NCT02227550) and RE-CIRCUIT (Randomized Evaluation of dabigatran etexilate Compared to warfarin in pulmonaRy vein ablation: assessment of different periproCedUral anticoagulation sTrategies; NCT02348723)]. During ablation, heparin should be given to maintain an activated clotting time >300 s. Anticoagulation should be maintained for at least 8 weeks after ablation for all patients. The true incidence of thrombo-embolic events after catheter ablation has never been systematically studied and the expected stroke risk has been adopted from non-ablation AF cohorts. Although observational studies suggest a relatively low stroke rate in the first few years after catheter ablation of AF [737, 771–776], the long-term risk of recurrent AF and the safety profile of anticoagulation in ablated patients need to be considered. In the absence of controlled trial data, OAC after catheter ablation should follow general anticoagulation recommendations, regardless of the presumed rhythm outcome.

11.3.5 Ablation of atrial fibrillation in heart failure patients. Catheter ablation, compared with amiodarone therapy, significantly reduces recurrent AF in AF patients with HFrEF [777]. Selected patients with HFrEF and AF can achieve recovery of LV systolic function after catheter ablation (probably reflecting tachycardiomyopathy). Several smaller trials suggest improved LV function after catheter ablation in HFrEF patients [185, 226–228, 778, 779] and reduced hospitalizations [720, 777], especially in patients without a previous myocardial infarction [780]. Larger trials are warranted to confirm these findings. Catheter ablation can be demanding in these patients. Thus, indications for catheter ablation in HFrEF patients should be carefully balanced, and the procedures performed in experienced centres.

11.3.6 Follow-up after catheter ablation. Patients and physicians involved in the follow-up after catheter ablation should know the signs and symptoms of late complications to allow swift referral for treatment (Table 18). Patients should also be aware that symptomatic and asymptomatic AF recurrences are frequent after catheter ablation [119, 781, 782]. In line with the primary goal of rhythm control therapy, asymptomatic episodes should generally not trigger further rhythm control therapy in routine care. Patients should be seen at least once by a rhythm

specialist in the first 12 months after ablation. Further rhythm control options should be considered in patients with symptomatic recurrences, including discussion in a Heart Team (Figure 17, Figure 19).

11.4 Atrial fibrillation surgery

11.4.1 Concomitant atrial fibrillation surgery. The Cox maze procedure was first performed 30 years ago as a 'cut-and-sew' technique, including isolation of the posterior left atrium, a connection to the posterior mitral annulus, a cavotricuspid connection, a cavocaval connection, and exclusion of the LAA (Figure 18) [783]. Thereby, the Cox maze procedure creates an electrical labyrinth (maze) of passages through which the sinoatrial node impulse finds a route to the atrioventricular node while preventing fibrillatory conduction. The Cox maze procedure and other, often simpler, forms of AF surgery have mainly been used in patients undergoing other open heart surgical procedures [461, 466, 784–798]. In a systematic review commissioned for these guidelines, performing concomitant AF surgery resulted in increased freedom from AF, atrial flutter, and atrial tachycardia compared to no concomitant AF surgery (RR 1.94; 95% CI 1.51–2.49; *n* = 554 from seven RCTs) (Web Figure 3) [1040]. Patients undergoing the Cox maze procedure required pacemaker implantation more often (RR 1.69; 95% CI 1.12–2.54; *n* = 1631 from 17 RCTs), without a detectable difference in other outcomes or complications. These findings are underpinned by an analysis of the Society of Thoracic Surgeons database comprising 67 389 patients in AF undergoing open heart surgery: mortality or major morbidity was not affected by concomitant AF surgery (adjusted OR 1.00; 95% CI 0.83–1.20), but pacemaker implantation was more frequent (adjusted OR 1.26; 95% CI 1.07–1.49) [799]. Predictors of AF recurrence after surgery include left atrial dilatation, older age, >10-year history of AF, and non-paroxysmal AF [800–804]. Regarding AF type, surgical PVI seems effective in paroxysmal AF [805]. Biatrial lesion patterns may be more effective in persistent and long-standing persistent AF [797, 803, 806]. The suggested management of patients with AF-related symptoms undergoing cardiac surgery is displayed in Figure 19, with an important contribution of the AF Heart Team to advise and inform patient choice.

11.4.2 Stand-alone rhythm control surgery. Current technology (e.g. bipolar radiofrequency or cryothermy) renders the Cox maze procedure easier, and more reproducible and feasible, via a mini-thoracotomy [786, 807, 808]. Thoracoscopic PVI with bipolar radiofrequency prevents recurrence of paroxysmal AF (69–91% freedom from arrhythmias at 1 year, see Figure 18B for lesion set) [468, 809, 810], and seems effective in patients refractory to catheter ablation [811]. The average length of hospital stay for thoracoscopic ablation varies from 3.6 to 6.0 days [468, 812, 813]. The FAST (Atrial Fibrillation Catheter Ablation vs. Surgical Ablation Treatment) trial [468], and another smaller trial [814], suggested that thoracoscopic AF surgery could be more

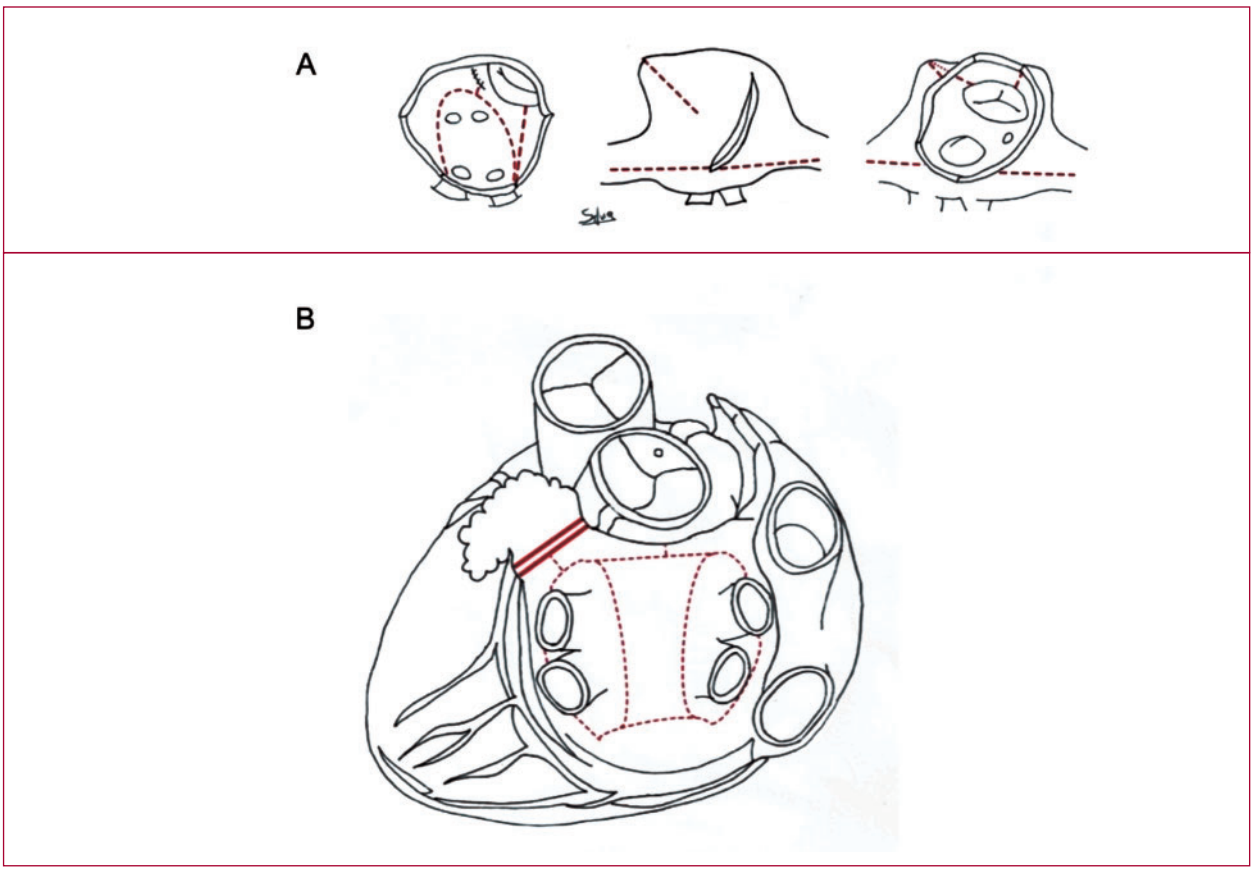
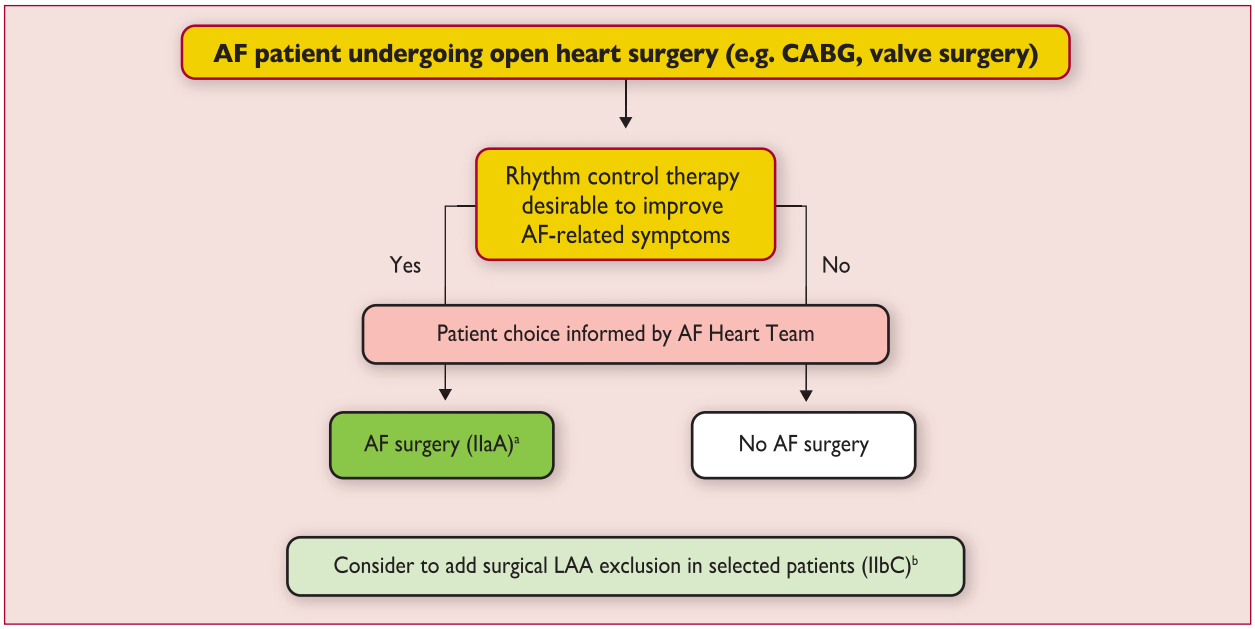


Figure 18: A: Surgical lesion sets for the biatrial Cox maze procedure. Surgeon's view showing left atrial lesions (left panel) and right atrial lesions (middle and right panel). B: Left atrial lesions in a thoracoscopic minimally invasive surgical procedure (dashed lines), including left atrial appendage exclusion (double line).



AF = atrial fibrillation; CABG = coronary artery bypass graft; LAA = left atrial appendage; PVI = pulmonary vein isolation.
[a]AF surgery may be PVI in paroxysmal AF and biatrial maze in persistent or long-standing persistent AF.
[b]Oral anticoagulation should be continued in patients at risk of stroke irrespective of AF surgery or LAA exclusion.

Figure 19: Surgical rhythm control in patients with atrial fibrillation undergoing cardiac surgery.

Table 19: Complications of thoracoscopic atrial fibrillation surgery

Complication	Rate [468,815,822,826]
Conversion to sternotomy	0–1.6%
Pacemaker implantation	0–3.3%
Drainage for pneumothorax	0–3.3%
Pericardial tamponade	0–6.0%
Transient ischaemic attack[a]	0–3.0%

[a]The rate of asymptomatic cerebral embolism is unknown.

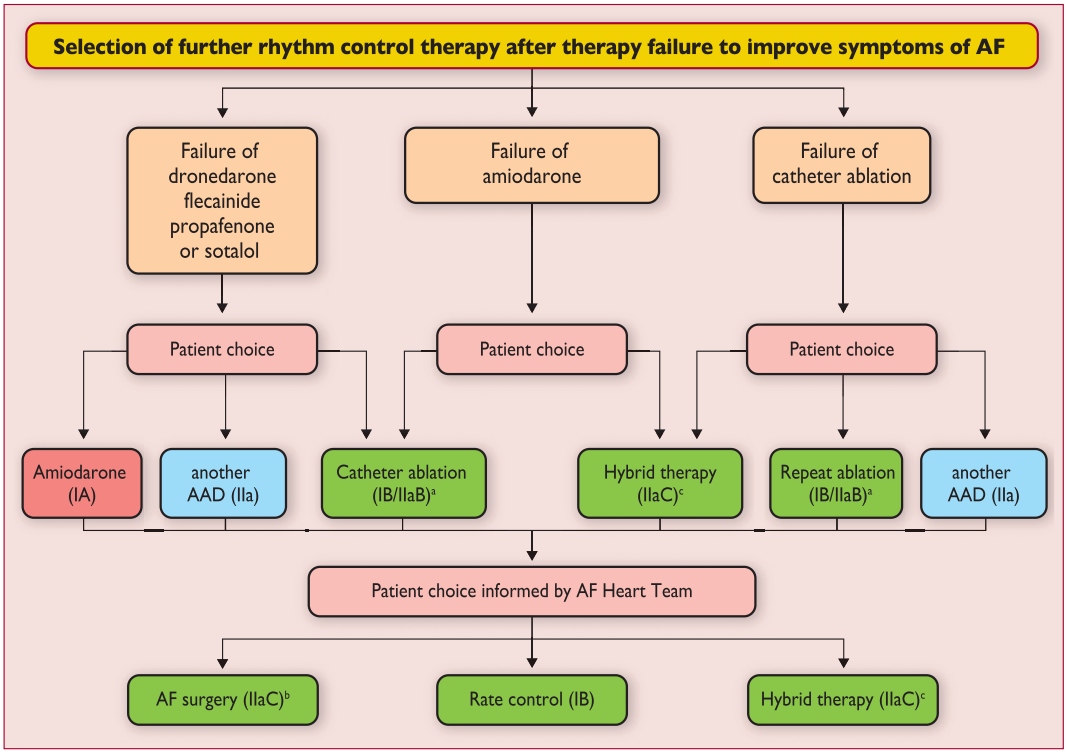
effective than catheter ablation for the maintenance of sinus rhythm [468, 814], while also causing more complications (Table 19) [815]. To improve results [468, 816–818], more extensive lesion sets have been performed, including connecting lines between the PVI ("box lesion") and lines towards the mitral annulus [812, 819–822]. To improve the generation of transmural lesions [716], endo-epicardial ablation strategies have recently been proposed [812, 823–825]. Although preliminary experience with hybrid simultaneous ablation shows promise, procedural time and rates of bleeding complications are higher [812, 823].

11.5 Choice of rhythm control following treatment failure

There is insufficient evidence to underpin clear recommendations on how to treat patients with recurrent AF after catheter ablation. Early recurrences of AF or atrial tachycardias after ablation (occurring within 8 weeks) may be treated with cardioversion. Many of the published series of patients undergoing AF ablation included those who failed antiarrhythmic drug therapy. Thus, considering ablation therapy in patients who have symptomatic recurrences on antiarrhythmic drug therapy is often reasonable. Alternatively, trialling another antiarrhythmic drug can be considered. Combining an antiarrhythmic drug with ablation ('hybrid therapy', see Chapter 12) should be considered based on the different and possibly synergistic effects of these drugs with AF ablation, possibly benefitting patients in whom either treatment alone was previously ineffective. Rate control without rhythm control, surgical ablation, or repeat catheter ablation should be considered as well (Figure 20). Patient preferences and local access to therapy are important considerations to inform the therapy choice in patients who are in need of further rhythm control therapy after an initial therapy failure.

11.6 The Atrial Fibrillation Heart Team

In view of the complexity of the different treatment options in patients with failed rhythm control therapy who still require or demand further rhythm control therapy, this Task Force proposes that decisions involving AF surgery or extensive AF ablation should be based on advice from an AF Heart Team. This will also apply to reversal to a rate control strategy in patients with severe (EHRA III or IV) AF symptoms. An AF Heart Team should consist of a cardiologist with expertise in antiarrhythmic drug therapy, an interventional electrophysiologist, and a cardiac surgeon with expertise in appropriate patient selection, techniques, and technologies for interventional or surgical AF ablation (Figure 20). Such AF Heart Teams—and a collaborative infrastructure supporting a continued interaction between physicians delivering continued care, AF cardiologists, interventional electrophysiologists, and AF surgeons—should be established to provide optimal



AAD = antiarrhythmic drug; AF = atrial fibrillation; PVI = pulmonary vein isolation.
[a]Catheter ablation should target PVI. IB for paroxysmal AF, IIaB for persistent and long-standing persistent AF.
[b]AF surgery may be PVI (e.g. in paroxysmal AF) or maze surgery (e.g. in therapy-refractory or persistent and long-standing persistent AF).
[c]Hybrid therapy involves combination of antiarrhythmic drugs, catheter ablation, and/or AF surgery.

Figure 20: Choice of rhythm control therapy following treatment failure.

advice, and ultimately to improve rhythm outcomes for patients in need of advanced and complex rhythm control interventions.

12. HYBRID RHYTHM CONTROL THERAPY

AF has many different drivers, which are only partially targeted by antiarrhythmic drugs or catheter ablation [96]. Hence, combination or 'hybrid' rhythm control therapy seems reasonable, although there is little evidence from controlled trials supporting its use.

12.1 Combining antiarrhythmic drugs and catheter ablation

Antiarrhythmic drug therapy is commonly given for 8–12 weeks after ablation to reduce early recurrences of AF after catheter ablation, supported by a recent controlled trial where amiodarone halved early AF recurrences compared with placebo [650]. Prospective studies have not been done, but a meta-analysis of the available (weak) evidence suggests slightly better prevention of recurrent AF in patients treated with antiarrhythmic drugs after catheter ablation [713]. Many patients are treated with antiarrhythmic drug therapy after catheter ablation (most often amiodarone or flecainide) [587], and this seems a reasonable option in patients with recurrent AF after ablation. It seems common sense to consider antiarrhythmic drug therapy in patients who are in need of further rhythm control therapy after catheter ablation, but controlled trials to confirm this are desirable.

Combining cavotricuspid isthmus ablation and antiarrhythmic drugs may lead to improved rhythm control without the need for left atrial ablation in patients who develop 'drug-induced atrial flutter' on therapy with flecainide, propafenone, or amiodarone [834–836], although recurrent AF is a concern in the long-term [837, 838].

12.2 Combining antiarrhythmic drugs and pacemakers

In selected patients with sick sinus syndrome and fast ventricular response during AF paroxysms requiring rate control therapy, the addition of a pacemaker not only optimizes rate control but may also help to control rhythm [711, 712]. Moreover, when antiarrhythmic drug treatment leads to sinus node dysfunction and bradycardia, pacing may permit uptitration of the antiarrhythmic drug dose. Such strategies have never been prospectively investigated and the existing populations studied are highly selected [839, 840]. Some patients with AF-induced bradycardia may benefit from catheter ablation of AF, obviating the need for antiarrhythmic drugs and pacemaker implantation [829, 830].

13. SPECIFIC SITUATIONS

13.1 Frail and 'elderly' patients

Many AF patients present at older age (e.g. >75 or >80 years). There are no studies suggesting that cardiovascular risk reduction is less effective in these 'elderly' AF patients than in younger patients. Rather, age is one of the strongest predictors/risk factors for ischaemic stroke in AF [382]. Good data are available to support the use of anticoagulants in older patients from BAFTA (Birmingham Atrial Fibrillation Treatment of the Aged Study)

Recommendations for catheter ablation of atrial fibrillation and atrial fibrillation surgery

Recommendations	Class[a]	Level[b]	Ref[c]
Catheter ablation of symptomatic paroxysmal AF is recommended to improve AF symptoms in patients who have symptomatic recurrences of AF on antiarrhythmic drug therapy (amiodarone, dronedarone, flecainide, propafenone, sotalol) and who prefer further rhythm control therapy, when performed by an electrophysiologist who has received appropriate training and is performing the procedure in an experienced centre.	I	A	585–587, 713,727
Ablation of common atrial flutter should be considered to prevent recurrent flutter as part of an AF ablation procedure if documented or occurring during the AF ablation.	IIa	B	827
Catheter ablation of AF should be considered as first-line therapy to prevent recurrent AF and to improve symptoms in selected patients with symptomatic paroxysmal AF as an alternative to antiarrhythmic drug therapy, considering patient choice, benefit, and risk.	IIa	B	585
All patients should receive oral anticoagulation for at least 8 weeks after catheter (IIaB) or surgical (IIaC) ablation.	IIa	B C	727
Anticoagulation for stroke prevention should be continued indefinitely after apparently successful catheter or surgical ablation of AF in patients at high-risk of stroke.	IIa	C	
When catheter ablation of AF is planned, continuation of oral anticoagulation with a VKA (IIaB) or NOAC (IIaC) should be considered during the procedure, maintaining effective anticoagulation.	IIb	B C	760,768
Catheter ablation should target isolation of the pulmonary veins using radiofrequency ablation or cryothermy balloon catheters.	IIa	B	585,715, 716,734, 735
AF ablation should be considered in symptomatic patients with AF and heart failure with reduced ejection fraction to improve symptoms and cardiac function when tachycardiomyopathy is suspected.	IIa	C	185, 226–228, 720, 777–779, 828
AF ablation should be considered as a strategy to avoid pacemaker implantation in patients with AF-related bradycardia.	IIa	C	829,830
Catheter or surgical ablation should be considered in patients with symptomatic persistent or long-standing persistent AF refractory to AAD therapy to improve symptoms, considering patient choice, benefit and risk, supported by an AF Heart Team.	IIa	C	468,735, 777,831, 832,1040
Minimally invasive surgery with epicardial pulmonary vein isolation should be considered in patients with symptomatic AF when catheter ablation has failed. Decisions on such patients should be supported by an AF Heart Team.	IIa	B	468,812, 819,823
Maze surgery, possibly via a minimally invasive approach, performed by an adequately trained operator in an experienced centre, should be considered by an AF Heart Team as a treatment option for patients with symptomatic refractory persistent AF or post-ablation AF to improve symptoms.	IIa	C	808,832
Maze surgery, preferably biatrial, should be considered in patients undergoing cardiac surgery to improve symptoms attributable to AF, balancing the added risk of the procedure and the benefit of rhythm control therapy.	IIa	A	461,466, 790,791, 796,797
Concomitant biatrial maze or pulmonary vein isolation may be considered in asymptomatic AF patients undergoing cardiac surgery.	IIb	C	796,797, 833

AF = atrial fibrillation; NOAC = non-vitamin K antagonist oral anticoagulant; VKA = vitamin K antagonist.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

[362], the NOAC trials [39], and from analyses in elderly Americans (Medicare) [396]. Elderly AF patients are at higher risk of stroke and, thus, are more likely to benefit from OAC than younger patients [841], and yet OAC is still underutilized in the elderly [220, 842]. Although the evidence base is smaller for other treatment options in AF, the available data support the use of available rate and rhythm control interventions, including pacemakers and catheter ablation, without justification to discriminate by age group. Individual patients at older age may present with multiple comorbidities including dementia, a tendency to falls, CKD, anaemia, hypertension, diabetes, and cognitive dysfunction. Such conditions may limit quality of life more than AF-related symptoms. Impairment of renal and hepatic function and multiple simultaneous medications make drug interactions and adverse drug reactions more likely. Integrated AF management and careful adaptation of drug dosing seem reasonable to reduce the complications of AF therapy in such patients [843].

13.2 Inherited cardiomyopathies, channelopathies, and accessory pathways

Several inherited cardiac conditions are associated with early-onset AF (Table 20). Treatment of the underlying cardiac condition is an important contribution to AF management in these young patients (see also ESC guidelines on sudden cardiac death [844] and hypertrophic cardiomyopathy [845]).

13.2.1 Wolff–Parkinson–White syndrome. Patients with pre-excitation and AF are at risk of rapid conduction across the accessory pathway, resulting in a fast ventricular rate, possible ventricular fibrillation, and sudden death. In AF patients with evidence of an antegrade accessory pathway, catheter ablation of the pathway is recommended [869, 870]. This procedure is safe and effective and may be considered as a prophylactic treatment

Table 20: Inherited cardiomyopathies, channelopathies, and pathways associated with atrial fibrillation

Syndrome	Gene	Functional alteration	AF prevalence	References
Long QT syndrome	KCNQ1 KCNH2 SCN5A ANK2 Others	I_{Ks} ↓ I_{Kr} ↓ I_{Na} ↑ $I_{Na,K}$ ↓ Various effects	5–10%	846–850
Brugada syndrome	SCN5A GPDIL SCN1B CACNA1C CACNB2b Others	I_{Na} ↓ I_{Na} ↓ I_{Na} ↓ I_{Ca} ↓ I_{Ca} ↓ Others	10–20%	851–855
Short QT syndrome	KCNQ1 KCNH2 KCNJ2 CACNA1C CACNB2b	I_{Ks} ↑ I_{Kr} ↑ I_{K1} ↑ I_{Ca} ↓ I_{Ca} ↓	Up to 70%	853, 856–858
Catecholaminergic VT	RYR2 CASQ2	Abnormal Ca^{2+} release from sarcoplasmic reticulum	Variable but common	859–861
Hypertrophic cardiomyopathy	Sarcomeric genes		5–15%	862–864
Wolff-Parkinson-White syndrome	PRKAG		Variable	865
Holt-Oram syndrome	TBX5		Variable	866
Arrhythmogenic right ventricular cardiomyopathy	Several desmosomal genes, unknown gene loci	Reduced mechanical cell-cell contacts	>40% in patients with VTs	867, 868

AF = atrial fibrillation; VT = ventricular tachycardia.

strategy [871, 872]. In AF patients surviving a sudden death event with evidence of an accessory pathway, urgent catheter ablation of the pathway is recommended [869]. A documented short pre-excited RR interval (<250 ms) during spontaneous or induced AF is one of the risk markers for sudden death in Wolff–Parkinson–White syndrome (WPW) syndrome, in addition to a history of symptomatic tachycardia, the presence of multiple accessory pathways, and Ebstein's anomaly. Intravenous procainamide, propafenone, or ajmaline can be used to acutely slow ventricular rate [873, 874], whereas digoxin, verapamil, and diltiazem are contraindicated [875]. Intravenous amiodarone should be used with caution, as there are case reports of accelerated ventricular rhythms and ventricular fibrillation in patients with pre-excited AF receiving intravenous amiodarone infusion [876].

13.2.2 Hypertrophic cardiomyopathy. AF is the most common arrhythmia in patients with hypertrophic cardiomyopathy, affecting approximately one-quarter of this population [877]. Observational data highlight a high stroke risk in hypertrophic cardiomyopathy patients with AF, confirming the need for OAC [878]. While there is more experience with VKAs, there are no data to suggest that NOACs cannot be used in these patients [845]. Studies of rate or rhythm control medications in patients with hypertrophic cardiomyopathy are relatively scarce. Beta-blockers and diltiazem or verapamil seem reasonable treatment options for rate control in these patients. In the absence of significant LV outflow tract obstruction, digoxin can be used alone or in combination with beta-blockers [845]. Amiodarone seems a safe antiarrhythmic drug in AF patients with hypertrophic cardiomyopathy [879], and expert opinion suggests that disopyramide may be beneficial in those with outflow tract obstruction. AF ablation is effective to suppress symptomatic AF recurrences [880–884]. Surgical treatment of AF may be appropriate in patients with hypertrophic cardiomyopathy undergoing surgery (e.g. for LV outflow tract obstruction or mitral valve surgery), but experience is limited.

13.2.3 Channelopathies and arrhythmogenic right ventricular cardiomyopathy. Many channelopathies and inherited cardiomyopathies are associated with AF. AF prevalence ranges from 5–20% in patients with long QT syndrome or Brugada syndrome, and is up to 70% in short QT syndrome (Table 20) [853, 856–858]. Penetrance of disease phenotype including AF is variable [61, 852, 885, 886]. Both shortening as well as prolongation of the atrial action potential have been demonstrated as likely mechanisms underlying AF in these diseases. It seems reasonable to consider antiarrhythmic drugs that reverse the suspected channel defect in AF patients with inherited cardiomyopathies (e.g. a sodium channel blocker in LQT3 [852], or quinidine in Brugada syndrome [887]). More importantly, new-onset AF in young, otherwise healthy individuals should trigger a careful search for such inherited conditions, including clinical history, family history, ECG phenotype, and echocardiography and/or other cardiac imaging.

Monogenic defects only account for 3–5% of all patients with AF, even in younger populations [846, 848, 888–890]. Furthermore, there is no clear link between detected mutations and specific outcomes or therapeutic needs. For these reasons, genetic testing is not recommended in the general AF population [77]. Other guidelines have described the indications for genetic testing in patients with inherited arrhythmogenic diseases [844, 891].

Recommendations for inherited cardiomyopathies

Recommendations	Class[a]	Level[b]	Ref[c]
WPW syndrome			
Catheter ablation of the accessory pathway in WPW patients with AF and rapid conduction over the accessory pathway is recommended to prevent sudden cardiac death.	I	B	892–894
Catheter ablation of the accessory pathway is recommended without delay in WPW patients who survive sudden cardiac death.	I	C	869
Asymptomatic patients with overt pre-excitation and AF should be considered for accessory pathway ablation after careful counselling.	IIa	B	872,892
Hypertrophic cardiomyopathy			
Lifelong oral anticoagulation to prevent stroke is recommended in HCM patients who develop AF.	I	B	878
Restoration of sinus rhythm by electrical or pharmacological cardioversion to improve symptoms is recommended in HCM patients with symptomatic new-onset AF.	I	B	845
In haemodynamically stable HCM patients with AF, ventricular rate control using beta-blockers and diltiazem/verapamil is recommended.	I	C	845
Treatment of LV outflow tract obstruction should be considered in AF patients with HCM to improve symptoms.	IIa	B	896
Amiodarone should be considered to achieve rhythm control and maintain sinus rhythm in HCM patients with recurrent symptomatic AF.	IIa	C	845,897
Inherited cardiomyopathies and channelopathies			
Targeted genetic testing should be considered in patients with AF and a suspicion of inherited cardiomyopathies or channelopathies based on clinical history, family history or electrocardiographic phenotype.	IIa	A	852

AF = atrial fibrillation; HCM = hypertrophic cardiomyopathy; LV = left ventricular; WPW = Wolff–Parkinson–White syndrome.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

13.3 Sports and atrial fibrillation

Physical activity improves cardiovascular health, which translates into a lower risk of AF [898]. Therefore, physical activity is a cornerstone of preventing AF. Intensive sports practice, especially endurance sports (>1500 h of endurance sports practice) [899], increases the risk of AF later in life [900–902], probably mediated by altered autonomic tone, volume load during exercise, atrial hypertrophy, and dilatation [903, 904]. This results in a U-shaped relationship of physical activity and incident AF [214, 898, 902, 905, 906]. Detraining can reduce AF in models [904] and reduces ventricular arrhythmias in athletes [907], but the role of detraining for AF in human athletes is unknown. The management of athletes with AF is similar to general AF management, but requires a few special considerations. Clinical risk factors will determine the need for anticoagulation. Sports with direct bodily contact or prone to trauma should be avoided in patients on OAC. Beta-blockers are not well tolerated and at times prohibited, and digoxin, verapamil, and diltiazem are often not potent enough to slow heart rate during exertional AF. Catheter ablation for AF probably has similar outcomes in athletes as in non-athletes [908, 909], but further data are needed. Pill-in-the-pocket therapy has been used as well [620]. After ingestion of flecainide or propafenone as pill-in-the-pocket, patients should refrain from sports as long as AF persists and until two half-lives of the antiarrhythmic drug have elapsed. Prophylactic ablation of the flutter circuit may be considered in athletes treated with sodium channel blockers [910].

Recommendations for physical activity in patients with atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
Moderate regular physical activity is recommended to prevent AF, while athletes should be counselled that long-lasting intense sports participation can promote AF.	I	A	214,898, 900–902, 905,906
AF ablation should be considered to prevent recurrent AF in athletes.	IIa	B	908,909
The ventricular rate while exercising with AF should be evaluated in every athlete (by symptoms and/or by monitoring), and titrated rate control should be instituted.	IIa	C	
After ingestion of pill-in-the-pocket flecainide or propafenone, patients should refrain from sports as long as AF persists and until two half-lives of the antiarrhythmic drug have elapsed.	IIa	C	620

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

13.4 Pregnancy

AF in pregnant women is rare and is usually associated with pre-existing heart disease. AF is associated with increased complications for the mother and foetus [911, 912]. Better treatment of congenital heart diseases will probably increase the incidence of AF during pregnancy in the future [913]. Pregnant women with AF should be managed as high-risk pregnancies in close collaboration with cardiologists, obstetricians, and neonatologists.

13.4.1 Rate control. Owing to a lack of specific data, beta-blockers, verapamil, diltiazem, and digoxin all carry a US Food and Drug Administration pregnancy safety category of C (benefits may outweigh risk), except for atenolol (category D: positive evidence of risk). Their use should be at the lowest dose and for the shortest time required. None of the agents are teratogenic, but they readily cross the placenta [914]. Beta-blockers are commonly used in pregnant women with cardiovascular conditions (e.g. for management of gestational hypertension and pre-eclampsia), but may be associated with intrauterine growth retardation [915], and hence growth scans after 20 weeks' gestation are recommended. Digoxin is considered safe for maternal and foetal arrhythmias [916]. There are insufficient data to comment on verapamil or diltiazem, hence rate control using beta-blockers and/or digoxin is recommended [917]. With regards to breastfeeding, all rate control agents are present in breast milk, although levels of beta-blockers, digoxin, and verapamil are too low to be considered harmful. Diltiazem will be present at high levels and should be considered second-line treatment [918].

13.4.2 Rhythm control. Rhythm control therapy in pregnant patients with AF has only been reported in case studies. Amiodarone is associated with severe adverse foetal side-effects and should only be considered for emergency situations [919]. Flecainide and sotalol can both be used for conversion of foetal arrhythmias without major adverse effects [920], and thus are likely to be safe to treat maternal symptomatic AF. Electrical cardioversion can be effective for restoration of sinus rhythm when tachyarrhythmia is causing haemodynamic instability, with low rates of adverse outcomes for both mother and foetus [921]. However, in view of the risk of foetal distress, electrical cardioversion should only be carried out where facilities are available for foetal monitoring and emergency caesarean section. As with other emergencies during pregnancy, patients should receive 100% oxygen, intravenous access should be established early, and the mother should be positioned in the left lateral position to improve venous return [922].

13.4.3 Anticoagulation. VKAs should be avoided in the first trimester because of teratogenic effects, and in the 2–4 weeks preceding delivery to avoid foetal bleeding. Low-molecular-weight heparins are a safe substitute, as they do not cross the placenta [923]. In the third trimester, frequent laboratory checks for adequate anticoagulation (e.g. every 10–14 days) and corresponding dose adjustments are advised, given that in some women high doses of both VKA and heparin may be needed to maintain adequate anticoagulation. Pregnant patients with AF and mechanical prosthetic valves who elect to stop VKA treatment in consultation with their specialist team between 6–12 weeks of gestation, should receive continuous, dose-adjusted unfractionated heparin or dose-adjusted subcutaneous low-molecular-weight heparin. As only limited data are available about teratogenesis for NOACs, these drugs should be avoided during pregnancy.

Recommendations during pregnancy

Recommendations	Class[a]	Level[b]	Ref[c]
Electrical cardioversion can be performed safely at all stages of pregnancy, and is recommended in patients who are haemodynamically unstable due to AF, and whenever the risk of ongoing AF is considered high for the mother or the foetus.	I	C	
Anticoagulation is recommended in pregnant patients with AF at risk of stroke. To minimize teratogenic risk and intrauterine bleeding, dose-adjusted heparin is recommended during the first trimester of pregnancy and in the 2–4 weeks before delivery. Vitamin K antagonists or heparin can be used in the remaining parts of the pregnancy.	I	B	923
NOACs should be avoided in pregnancy and in women planning a pregnancy.	III (harm)	C	

AF = atrial fibrillation; NOAC = non-vitamin K antagonist oral anticoagulants.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

13.5 Post-operative atrial fibrillation

AF is common after cardiac surgery (occurring in 15–45% of patients) [924–926], and is associated with increased length of hospital stay and higher rates of complications and mortality [927]. Post-operative AF is also not uncommon after other major surgery, especially in elderly patients. The treatment of post-operative AF is mainly based on studies of patients undergoing cardiac surgery, with much less evidence in the non-cardiac surgery setting.

13.5.1 Prevention of post-operative atrial fibrillation. Beta-blockers reduce post-operative AF and supraventricular tachycardias, albeit with high heterogeneity and moderate risk of bias in a systematic review of published studies. The most commonly studied drug was propranolol, with AF in 16.3% of the treatment group vs. 31.7% in the control group [925]. In the majority of these studies, beta-blockers were administered post-operatively, a regimen supported in a recent meta-analysis [928]. Amiodarone reduced the incidence of post-operative AF

compared to beta-blocker therapy in several meta-analyses, also reducing hospital stay [925, 929–931].

Despite initial reports from meta-analyses [689, 932, 933], pre-operative treatment with statins did not prevent post-operative AF in a prospective controlled trial [934]. Other therapies have also been studied in small, hypothesis-generating trials, but have not demonstrated clear beneficial effects. These include magnesium [925, 935, 936], n-3 polyunsaturated fatty acids [937–945], colchicine [946], corticosteroids [947, 948], and posterior pericardectomy [949]. Post-operative overdrive biatrial pacing has not gained widespread use despite some suggestion of prophylactic effects [925, 950].

13.5.2 Anticoagulation. Post-operative AF is associated with an increased early stroke risk, increased morbidity, and 30-day mortality [927, 951, 952]. In the long-term, patients with an episode of post-operative AF have a two-fold increase in cardiovascular mortality, and a substantially increased risk of future AF and ischaemic stroke, compared with patients that remain in sinus rhythm after surgery [952–958]. OAC at discharge has been associated with a reduced long-term mortality in patients with post,-operative AF [959], without evidence from controlled trials. Good quality data are needed to determine whether long-term anticoagulation can prevent strokes in patients with post-operative AF at high stroke risk [368, 386], and to assess whether short episodes of post-operative AF (e.g. <48 h) carry a similar risk as longer episodes [960]. The indication and timing of OAC in post-operative AF patients should take into consideration the risk of post-operative bleeding.

Recommendations for preventing post-operative atrial fibrillation

Recommendations	Class[a]	Level[b]	Ref[c]
Peri-operative oral beta-blocker therapy is recommended for the prevention of post-operative AF after cardiac surgery.	I	B	925,928
Restoration of sinus rhythm by electrical cardioversion or antiarrhythmic drugs is recommended in post-operative AF with haemodynamic instability.	I	C	
Long-term anticoagulation should be considered in patients with AF after cardiac surgery at risk for stroke, considering individual stroke and bleeding risk.	IIa	B	368,386
Antiarrhythmic drugs should be considered for symptomatic post-operative AF after cardiac surgery in an attempt to restore sinus rhythm.	IIa	C	
Peri-operative amiodarone should be considered as prophylactic therapy to prevent AF after cardiac surgery.	IIa	A	905
Asymptomatic post-operative AF should initially be managed with rate control and anticoagulation.	IIa	B	962
Intravenous vernakalant may be considered for cardioversion of post-operative AF in patients without severe heart failure, hypotension, or severe structural heart disease (especially aortic stenosis).	IIb	B	603

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

13.5.3 Rhythm control therapy in post-operative atrial fibrillation. In haemodynamically unstable patients, cardioversion and consideration of antiarrhythmic drugs is recommended. Amiodarone or vernakalant have been efficient in converting post-operative AF to sinus rhythm [603, 950, 961]. A recent medium-sized trial randomizing patients with post-operative AF to either rhythm control therapy with amiodarone or to rate control did not find a difference in hospital admissions during a 60-day follow-up [962], underpinning that the aim of rhythm control therapy should be to improve AF-related symptoms in post-operative AF. In asymptomatic patients and in those with acceptable symptoms, rate control or deferred cardioversion preceded by anticoagulation is a reasonable approach.

13.6 Atrial arrhythmias in grown-up patients with congenital heart disease

Atrial arrhythmias (AF, atrial flutter, atrial tachycardias) often occur late after surgical repair of congenital heart defects, occurring in 15–40% of grown-up patients with congenital heart disease (GUCH). They are associated with heart failure, syncope, thromboembolic events, and sudden death [963–967]. The pathophysiological substrate is complex, associated with hypertrophy, fibrosis, hypoxaemia, chronic haemodynamic overload, and surgical scars and patches. Additionally, related primary anomalies in the conduction pathways can lead to re-entrant atrial and ventricular tachycardia, heart block, and sinus node dysfunction [963]. Macro re-entrant atrial tachycardia or atypical atrial flutter may be seen after nearly any surgical procedure involving atriotomy or atrial patches.

13.6.1 General management of atrial arrhythmias in grown-up patients with congenital heart disease. The conventional stroke risk factors should be used to inform decisions on long-term anticoagulation in GUCH patients with AF. In addition, anticoagulation should be considered in GUCH patients with atrial arrhythmias when they present with intracardiac repair, cyanosis, Fontan palliation, or systemic right ventricle [968]. Beta-blockers, verapamil, diltiazem, and digitalis can be used. Care should be taken to avoid bradycardia and hypotension.

Sodium channel blockers suppress approximately half of atrial arrhythmias in Fontan patients [969]. Amiodarone is more effective, but long-term treatment with an antiarrhythmic drug carries a high risk of extracardiac side-effects in this relatively young population. Intracardiac thrombi are common in GUCH patients undergoing cardioversion for AF, but also in patients with atrial tachycardias or atrial flutter [970]. Therefore, both a TOE and anticoagulation for a few weeks before the planned cardioversion should be considered [964]. Radiofrequency ablation may be a

good option for symptomatic GUCH patients with atrial arrhythmias, especially in those with atrial flutter and other macro re-entrant tachycardias. Interventions should be performed in adequately qualified centres by specialized teams.

13.6.2 Atrial tachyarrhythmias and atrial septal defects. Atrial flutter and fibrillation occur in 14–22% of adults with unoperated atrial septal defects, especially in older patients [971], and can lead to heart failure [972]. Early repair can reduce but not eliminate the risk of AF [973]. Biatrial volume overload [974], pulmonary hypertension [975], and possibly the arrhythmogenic effect of atrial patches can contribute to these arrhythmias [976]. Anticoagulation should be decided upon based on stroke risk factors. In patients with a history of paroxysmal or persistent AF, AF surgery could be considered at the time of surgical closure, or catheter ablation at the time of interventional atrial septal defect closure. Catheter ablation of late atrial arrhythmias has been shown to be effective in small cohorts of patients after surgical atrial septal defect [977].

13.6.3 Atrial tachyarrhythmias after Fontan operation. Atrial arrhythmias occur in up to 40% of patients with a Fontan circulation, and can manifest as atrial flutter, primary atrial tachycardia, AF, and accelerated junctional rhythm or junctional tachycardia [978] with or without sinoatrial node dysfunction [979]. Patients with atriopulmonary anastomoses (possibly due to higher atrial volume and pressure load) and those with early postoperative atrial arrhythmias are more likely to develop long-term atrial arrhythmias [980]. Atrial arrhythmias can also be the first manifestation of obstruction of the atriopulmonary anastomosis, a complication that must be identified. Right atrial thrombus formation is common in Fontan patients with atrial arrhythmias and requires oral anticoagulation [981]. Operative conversion to total cavopulmonary artery connection with concomitant arrhythmia surgery can, in some patients, improve heart failure symptoms and reduce recurrent arrhythmias [969, 982], with low recurrence rates of clinically apparent atrial arrhythmias in the first few years after repeat surgery [983–985]. Catheter ablation of atrial arrhythmia in Fontan patients has been successful in selected patients [986].

13.6.4 Atrial tachyarrhythmias after tetralogy of Fallot correction. After repair of tetralogy of Fallot, approximately one-third of patients develop atrial arrhythmias, including intra-atrial re-entrant tachycardia, focal atrial tachycardia, and AF [987]. Circuits involving the cavotricuspid isthmus and areas of presumed surgical right atrial scarring have been described as responsible for atrial arrhythmias.

13.7 Management of atrial flutter

The goals for the management of atrial flutter are similar to those for AF [992]. Based on the available evidence, the stroke risk in patients with atrial flutter is not much different from that in AF [827]. Furthermore, many patients diagnosed with atrial flutter develop AF [993–995]. Thus, anticoagulation should be used in patients with atrial flutter similar to that in patients with AF. Rate control in atrial flutter is achieved with the same medications as in AF, but is often more difficult to achieve. Flecainide, propafenone, dofetilide, and intravenous ibutilide are useful for cardioversion of atrial flutter. They should be combined with a rate-controlling agent to avoid 1:1 conduction of slowing flutter waves to the ventricles. Ibutilide is more effective for conversion of atrial flutter than AF, whereas vernakalant is less effective in converting typical atrial flutter [996, 997]. Electrical cardioversion of atrial flutter can be performed using lower energies (50–100 J) than for AF [998, 999]. Atrial overdrive pacing through pacemaker leads or endocardial or transoesophageal catheters can convert atrial flutter to sinus rhythm [1000, 1001]. Anticoagulation and TOE around cardioversion or overdrive pacing should be used similar to that in AF.

Recommendations in patients with grown-up congenital heart disease

Recommendations	Class[a]	Level[b]	Ref[c]
Atrial septal defect closure should be considered before the fourth decade of life to diminish the chance of atrial flutter and fibrillation.	IIa	C	971,972, 974
In patients who need surgical closure of an atrial septal defect and who have a history of symptomatic atrial arrhythmia, AF ablation should be considered at the time of surgical closure.	IIa	C	204,988, 989
Cox maze surgery should be considered in patients with symptomatic AF and an indication for corrective repair of congenital heart defects. All such surgery should be done in experienced centres.	IIa	C	988,990
Oral anticoagulation should be considered in all adult patients with intracardiac repair, cyanosis, Fontan palliation or systemic right ventricle and a history of AF, atrial flutter or intra- atrial reentrant tachycardia. In all other congenital heart disease patients with AF, anticoagulation should be considered if CHA_2DS_2–VASC score is ≥1.	IIa	C	968
Catheter ablation of atrial arrhythmias associated with congenital heart defects may be considered when performed in experienced centres.	IIb	C	991
In patients with congenital heart disease, transoesophageal echocardiography may be considered together with 3-week anticoagulation therapy before cardioversion.	IIb	C	964,970, 988,990

AF = atrial fibrillation; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female); GUCH = grown-up patients with congenital heart disease; OAC = oral anticoagulation; TOE = transoesophageal echocardiography.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

Ablation of the cavotricuspid isthmus for isthmus-dependent right atrial flutter (either the common counter-clockwise atrial flutter or the less-common clockwise atrial flutter) restores and maintains sinus rhythm with a success rate of 90–95% [1002]. It may also reduce AF recurrences in selected patients [1003, 1004], and help to prevent hospitalizations [1004, 1005]. Isthmus ablation is comparably safe and more effective than antiarrhythmic drug therapy, and is recommended for recurrent atrial flutter [585–587, 713]. Catheter ablation of left atrial macro re-entrant tachycardia is more complex, with lower success rates and higher recurrence rates [1006, 1007].

Recommendations for management of atrial flutter

Recommendations	Class[a]	Level[b]	Ref[c]
For patients with atrial flutter, antithrombotic therapy is recommended according to the same risk profile used for AF.	I	B	827
Overdrive atrial pacing of atrial flutter should be considered as an alternative to electrical cardioversion, depending on local availability and experience.	IIa	B	1000, 1001
Management of typical atrial flutter with ablation of the cavotricuspid isthmus is recommended for patients failing antiarrhythmic drug therapy or as first-line treatment considering patient preference.	I	B	158
If atrial flutter has been documented before AF ablation, ablation of the cavotricuspid isthmus should be considered as part of the AF ablation procedure.	IIa	C	

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

14. PATIENT INVOLVEMENT, EDUCATION, AND SELF-MANAGEMENT

14.1 Patient-centred care

Autonomous, informed patients are better placed to adhere to long-term therapy, and it is very likely that long-term management of chronic conditions such as AF will benefit from informed patients who are aware of their own responsibilities in the disease management process [328]. Shared decision-making [747] and patient-centred organization of care can help to ensure adherence to management and empower patients, and respect individual patient preferences, needs, and values (see section 8.2) [326, 1008, 1009]. Patients in an active role tend to have better health outcomes and care experiences, and engagement itself can be considered as an intermediate outcome [1010].

14.2 Integrated patient education

Education is a prerequisite for informed, involved patients and patient-centred care. However, lack of AF-related knowledge in patients is common, even in those who have received verbal and written information [32, 1011, 1012], indicating the need to further develop structured patient education. Several patient information tools have been developed, largely focusing on oral anticoagulation [1013–1016]. This task force has developed a dedicated app for AF patients to support patient information and education. Understanding patients' perceptions and attitudes towards AF and its management can improve AF management and related outcomes [1017]. This includes tailored patient education focusing on the disease, symptom recognition, therapy, modifiable risk factors for AF, and self-management activities [1018, 1019].

14.3 Self-management and shared decision-making

Self-management is primarily focused on tasks to manage the condition, such as adhering to a therapeutic regimen or modifying behaviour (e.g. resulting in smoking cessation or weight loss) [1020]. It requires understanding of the treatment modalities and goals [350]. Within a multidisciplinary team, allied health professionals can guide this interactive process in which communication, trust, and reciprocal respect foster patient engagement [1021]. Shared decision-making should be considered as a routine part of the decision-making process [747], supported by decision aids where applicable [1022]. Models of care that integrate education, engagement, and shared decision making are now available [1023], and may be of particular value in the management of AF.

Recommendations for patient involvement, education, and self-management

Recommendations	Class[a]	Level[b]	Ref[c]
Tailored patient education is recommended in all phases of AF management to support patients' perception of AF and to improve management.	I	C	1014, 1017
Patient involvement in the care process should be considered to encourage self-management and responsibility for lifestyle changes.	IIa	C	328, 1010
Shared decision making should be considered to ensure that care is based on the best available evidence and fits the needs, values and preferences of the patient.	IIa	C	747

AF = atrial fibrillation.
[a]Class of recommendation.
[b]Level of evidence.
[c]Reference(s) supporting recommendations.

15. GAPS IN EVIDENCE

There are some areas of AF management that are supported by excellent evidence from multiple, adequately powered randomized trials (e.g. oral anticoagulation). Other areas, such as rhythm control therapy, integrated AF management, and lifestyle modifications are

clearly developing the required evidence, while areas such as rate control are in dire need of better studies to underpin future guidelines. Here, we identify areas in need of further research.

15.1 Major health modifiers causing atrial fibrillation

Atrial fibrillation has different causes in different patients. More research is needed into the major causes (and electrophysiological mechanisms) of AF in different patient groups [176, 1024]. Such research should consider the major comorbidities associated with AF, and characterize the response to AF therapy in patients with different, pathophysiologically distinct types of AF.

15.2 How much atrial fibrillation constitutes a mandate for therapy?

Technological advances allow screening for an irregular pulse using patient-operated ECG devices, smartphones, and a variety of other technologies. These may be very useful to detect silent, undiagnosed AF [157]. Adequately powered studies evaluating the diagnostic accuracy of such technologies, the diagnostic yield in different populations, the shortest duration and pattern of atrial arrhythmias conveying a stroke risk, and the effect of ECG screening on outcomes are needed.

15.3 Atrial high-rate episodes (AHRE) and need for anticoagulation

All of the information on the benefit of OAC has been generated in patients with AF diagnosed by ECG. Technological advances allow ready detection of AHRE in patients with implanted devices and an atrial lead. Such patients are at increased stroke risk, but it is unclear whether they benefit from OAC. Controlled trials evaluating OAC in AHRE patients are ongoing and will provide evidence on the best antithrombotic therapy in these patients.

15.4 Stroke risk in specific populations

Several specific AF groups should be studied to better characterize their risk for AF, stroke, and other AF-related complications (e.g. patients with one stroke risk factor, and non-Caucasian patients). Confounding factors (e.g. different therapy of concomitant cardiovascular diseases) may help to explain the variability in the reported rates of incident AF, prevalent AF, and AF complications. This also applies to the effect of gender in AF patients [47].

15.5 Anticoagulation in patients with severe chronic kidney disease

The use of NOACs has not been tested in patients with creatinine clearance <30 mL/min, and there is very little evidence on the effects of OAC in patients on haemodialysis or on other forms of renal replacement therapy. Studies evaluating OAC in patients with severe CKD are needed to inform the best management in this patient group at high risk for stroke and bleeding.

15.6 Left atrial appendage occlusion for stroke prevention

The most common justification for LAA occlusion devices in clinical practice is a perceived high bleeding risk and, less often, contraindications for OAC [459]. Unfortunately, LAA occluders have not been tested in such populations. Furthermore, LAA occluders have not been compared with NOAC therapy in patients at risk for bleeding, or with thoracoscopic LAA clipping. There is a clear need to conduct adequately designed and powered trials to define the clinical role of LAA occluders compared with NOAC therapy in patients with relative or absolute contraindications for anticoagulation, and/or in those suffering from an ischaemic stroke on anticoagulant therapy.

15.7 Anticoagulation in atrial fibrillation patients after a bleeding or stroke event

At least 2% of anticoagulated patients with AF will experience a serious bleeding event per year. Observational data suggest that OAC can be reinitiated even after an intracerebral bleeding event [460, 484]. Controlled studies evaluating different anticoagulation and stroke prevention interventions are urgently needed to provide evidence on the best management of patients who have suffered a bleeding event that would usually lead to withholding OAC. Some studies (e.g. APACHE-AF [Apixaban versus Antiplatelet drugs or no antithrombotic drugs after anticoagulation-associated intraCerebral HaEmorrhage in patients with Atrial Fibrillation] [1025]) are ongoing, but adequately powered trials are needed. Similarly, prospectively collected data are needed on the stroke prevention and bleeding risk following (re-)initiation of OAC after stroke or intracranial bleeding.

15.8 Anticoagulation and optimal timing of non-acute cardioversion

Based on retrospective data, previous recommendations on the safe time-window in which a cardioversion can be performed in new-onset AF used ≤48 h as the 'gold standard' for non-protected cardioversion. However, new evidence has emerged that initiating pre-cardioversion anticoagulation in patients with AF episodes of <24 h or even <12 h would provide even better safety [642, 647, 1026–1028]. Further research is needed to establish a clear safety margin in this clinical situation.

15.9 Competing causes of stroke or transient ischaemic attack in atrial fibrillation patients

Prospective RCTs have demonstrated the superiority of carotid endarterectomy compared to stenting in patients with symptomatic high-degree stenosis of the internal carotid artery [1029]. As endartectomy minimizes the need for combination therapy with OAC and antiplatelets [1030], this approach has appeal in patients with AF to reduce bleeding risk. However, few of these studies included patients with AF. In a large observational study, the composite of in-hospital mortality, post-procedural stroke, and cardiac complications was higher in AF patients undergoing carotid stenting (457/7668; 6.0%) compared with endarterectomy (4438/51 320; 8.6%; $P < 0.0001$) [1031]. Despite adjustment for baseline risk, this may just reflect the type of patients referred for each procedure, and further randomized studies are needed to confirm the optimal treatment strategy in AF patients with carotid disease.

15.10 Anticoagulation in patients with biological heart valves (including transcatheter aortic valve implantation) and specific forms of valvular heart disease

The optimal antithrombotic therapy in the first months after biological valve replacement (including after catheter-based valve replacement) is not known. VKAs remain the mainstay during the initial post-operative period; NOACs probably deliver the same protection. In patients without AF, many centres use platelet inhibitors only. NOACs appear to be equally effective as VKAs in patients with moderate aortic stenosis, based on a subanalysis from the ROCKET-AF trial [1032], as well as the Loire Valley AF project [1033]. Further data would be helpful to confirm these observations [1034]. The safety and efficacy of NOACs in patients with rheumatic mitral valve disease has not been evaluated and should be studied.

15.11 Anticoagulation after 'successful' catheter ablation

In view of the long-term recurrence rates of AF, this Task Force recommends that OAC is continued in AF patients after 'successful' catheter ablation. Nonetheless, observational data suggest that the stroke risk may be lower after catheter ablation of AF compared with other AF patients. The ongoing EAST – AFNET 4 trial will inform, in a more general way, whether rhythm control therapy can reduce stroke rates in anticoagulated AF patients. In addition, there seems to be a place for a controlled trial evaluating the termination of OAC therapy at an interval after 'successful' catheter ablation.

15.12 Comparison of rate control agents

Although the use of rate control therapy is very common in AF patients, robust data comparing rate control therapies are scant, with the majority of studies being small uncontrolled trials over short periods of follow-up. Some studies are ongoing [e.g. RATE-AF (Rate Control Therapy Evaluation in Permanent Atrial Fibrillation) [559]] and will investigate the potential benefits of different rate-controlling agents, characteristics, or biomarkers that can help to personalize the use of rate control, and the adverse event profile of specific drugs in defined groups of patients.

15.13 Catheter ablation in persistent and long-standing persistent atrial fibrillation

While a few recent randomized studies support the use of catheter or surgical ablation in patients with persistent AF and long-standing persistent AF [1042], there is a clear need for more data evaluating this intervention in adequately powered randomized trials.

15.14 Optimal technique for repeat catheter ablation

PVI emerges as the most important target for catheter ablation of AF. Although a plethora of different additional ablation techniques have been published, their added value is questionable in patients undergoing a first catheter ablation, including those with persistent AF [735, 1042]. Many patients are in need of multiple catheter ablation procedures, and such interventions often follow local or operator-specific protocols without clear evidence to support the choice of ablation target or intervention. There is a clear clinical need to define the best approach in patients who are in need of a second ablation procedure.

15.15 Combination therapy for maintenance of sinus rhythm

In the follow-up after initially successful catheter ablation, even when done in experienced centres, many patients will experience symptomatic recurrences of AF. These patients are often managed with antiarrhythmic drugs. There is a surprising paucity of data evaluating different rhythm control interventions in patients with recurrent AF after catheter ablation. Such studies seem reasonable and feasible.

15.16 Can rhythm control therapy convey a prognostic benefit in atrial fibrillation patients?

The progress in rhythm control therapy (catheter ablation, new antiarrhythmic drugs) and observational long-term analyses suggest that rhythm control therapy may have a prognostic benefit in anticoagulated AF patients. Ongoing trials such as CABANA and EAST – AFNET 4 will provide initial answers to this important question, but more data are needed, including trials of surgical ablation techniques.

15.17 Thoracoscopic 'stand-alone' atrial fibrillation surgery

Minimally invasive epicardial ablation surgery for the treatment of stand-alone AF was reported a decade ago [1035]. The procedure has since evolved towards a totally thoracoscopic procedure [1036], and lesion sets were extended to a complete left atrial maze [822]. Randomized trials using a standardized procedure are urgently needed to clearly define the benefits and risks of thoracoscopic AF ablation, and to further support decisions of the AF Heart Team.

15.18 Surgical exclusion of the left atrial appendage

Exclusion of the LAA has been performed by cardiothoracic surgeons for decades, but prospective randomized studies comparing the rate of ischaemic stroke with or without left appendage exclusion are presently lacking. The LAAOS (Left Atrial Appendage Occlusion Study) III is currently randomizing cardiac surgery patients with AF to undergo concomitant occlusion or no occlusion of the appendage [467]. More data are also needed to confirm the safety and efficacy of thoracoscopic exclusion, following early positive observational data [1037].

15.19 Concomitant atrial fibrillation surgery

Adequately powered randomized trials are needed, employing systematic follow-up with uniform lesion sets and energy sources, to evaluate the benefits and risks of concomitant AF surgery in symptomatic AF patients. An RCT on non-uniform lesion sets with long-term follow-up is due to publish shortly [1038]. Such trials will assist the AF Heart Team to decide on optimal therapy for individual patients, including the full repertoire of medical and surgical options for the treatment of AF.

16. TO DO AND NOT TO DO MESSAGES FROM THE GUIDELINES

Recommendations	Class[a]	Level[b]
Recommendations for diagnosis and screening of AF		
ECG documentation is required to establish the diagnosis of AF.	I	B
Opportunistic screening for AF is recommended by pulse taking or ECG rhythm strip in patients >65 years of age.	I	B
In patients with TIA or ischaemic stroke, screening for AF is recommended by short-term ECG recording followed by continuous ECG monitoring for at least 72 hours.	I	B
It is recommended to interrogate pacemakers and ICDs on a regular basis for atrial high rate episodes (AHRE). Patients with AHRE should undergo further ECG monitoring to document AF before initiating AF therapy.	I	B
Recommendations for general management of AF		
Tailored patient education is recommended in all phases of AF management to support patients' perception of AF and to improve management.	I	C
A full cardiovascular evaluation, including an accurate history, careful clinical examination, and assessment of concomitant conditions, is recommended in all AF patients.	I	C
Use of the modified EHRA symptom scale is recommended in clinical practice and research studies to quantify AF-related symptoms.	I	C
Transthoracic echocardiography is recommended in all AF patients to guide management.	I	C
The assessment of kidney function by serum creatinine or creatinine clearance is recommended for all AF patients to detect kidney disease and to support correct dosing of AF therapy.	I	A
Recommendations for stroke prevention in AF		
The CHA_2DS_2-VASc score is recommended for stroke risk prediction in patients with AF.	I	A
Oral anticoagulation therapy to prevent thromboembolism is recommended for all male AF patients with a CHA_2DS_2-VASc score of 2 or more.	I	A
Oral anticoagulation therapy to prevent thromboembolism is recommended for all female AF patients with a CHA_2DS_2-VASc score of 3 or more.	I	A
When oral anticoagulation is initiated in a patient with AF who is eligible for a non vitamin-K-antagonist oral anticoagulant (apixaban, dabigatran, edoxaban, or rivaroxaban), a NOAC is recommended in preference to a vitamin K antagonist.	I	A
Vitamin K antagonist therapy (INR 2.0–3.0 or higher) is recommended for stroke prevention in AF patients with moderate-to-severe mitral stenosis or mechanical heart valves.	I	B
NOACs (apixaban, dabigatran, edoxaban, and rivaroxaban) are not recommended in patients with mechanical heart valves (Level of evidence B) or moderate-to-severe mitral stenosis (Level of evidence C).	III (harm)	B C
When patients are treated with a vitamin K antagonist, time in therapeutic range (TTR) should be kept as high as possible and closely monitored.	I	A
Combinations of oral anticoagulants and platelet inhibitors increase bleeding risk and should be avoided in AF patients without another indication for platelet inhibition.	III (harm)	B
In male or female AF patients without additional stroke risk factors, anticoagulant or antiplatelet therapy is not recommended for stroke prevention.	III (harm)	B
Antiplatelet monotherapy is not recommended for stroke prevention in AF patients, regardless of stroke risk.	III (harm)	A
After surgical occlusion or exclusion of the left atrial appendage, it is recommended to continue anticoagulation in at-risk patients with AF for stroke prevention.	I	B
Genetic testing before the initiation of vitamin K antagonist therapy is not recommended.	III (no benefit)	B
In AF patients with severe active bleeding events, it is recommended to interrupt oral anticoagulation therapy until the underlying cause is resolved.	I	C
NOACs should be avoided in pregnancy and in women planning a pregnancy.	III (harm)	C
For patients with atrial flutter, antithrombotic therapy is recommended according to the same risk profile used for AF.	I	B
Management of typical atrial flutter with ablation of the cavotricuspid isthmus is recommended for patients failing antiarrhythmic drug therapy or as first-line treatment considering patient preference.	I	B
Lifelong oral anticoagulation to prevent stroke is recommended in hypertrophic cardiomyopathy patients who develop AF.	I	B
Anticoagulation with heparin or low-molecular-weight heparin immediately after ischaemic stroke is not recommended in AF patients.	III (harm)	A
Systemic thrombolysis with a recombinant tissue plasminogen activator is not recommended if the INR is above 1.7 (or, for patients on dabigatran, if activated partial thromboplastin time is outside the normal range).	III (harm)	C
After TIA or stroke, combination therapy of OAC and an antiplatelet is not recommended.	III (harm)	B

Recommendations	Class[a]	Level[b]
Recommendations for rate control of AF		
Beta-blockers, digoxin, diltiazem, or verapamil are recommended to control heart rate in AF patients with LVEF ≥40%.	I	B
Beta-blockers and/or digoxin are recommended to control heart rate in AF patients with LVEF <40%.	I	B
In patients with permanent AF (i.e. where no attempt to restore sinus rhythm is planned), antiarrhythmic drugs should not routinely be used for rate control.	III (harm)	A
Recommendations for rhythm control of AF		
Rhythm control therapy is indicated for symptom improvement in patients with AF.	I	B
Cardioversion of AF (either electrical or pharmacological) is recommended in symptomatic patients with persistent or long-standing persistent AF as part of rhythm control therapy.	I	B
In patients with no history of ischaemic or structural heart disease, flecainide, propafenone, or vernakalant are recommended for pharmacological cardioversion of new-onset AF.	I	A
In patients with ischaemic and/or structural heart disease, amiodarone is recommended for cardioversion of AF.	I	A
For cardioversion of AF/atrial flutter, effective anticoagulation is recommended for a minimum of 3 weeks before cardioversion.	I	B
Transoesophageal echocardiography (TOE) is recommended to exclude cardiac thrombus as an alternative to preprocedural anticoagulation when early cardioversion is planned.	I	B
The choice of antiarrhythmic drug needs to be carefully evaluated, taking into account the presence of comorbidities, cardiovascular risk and potential for serious proarrhythmia, extracardiac toxic effects, patient preferences, and symptom burden.	I	A
Dronedarone, flecainide, propafenone, or sotalol are recommended for prevention of recurrent symptomatic AF in patients with normal left ventricular function and without pathological left ventricular hypertrophy.	I	A
Dronedarone is recommended for prevention of recurrent symptomatic AF in patients with stable coronary artery disease, and without heart failure.	I	A
Amiodarone is recommended for prevention of recurrent symptomatic AF in patients with heart failure.	I	B
Antiarrhythmic drug therapy is not recommended in patients with prolonged QT interval (>0.5 s) or with significant sinoatrial node disease or atrioventricular node dysfunction who do not have a functioning permanent pacemaker.	III (harm)	C
Catheter ablation of symptomatic paroxysmal AF is recommended to improve AF symptoms in patients who have symptomatic recurrences of AF on antiarrhythmic drug therapy (amiodarone, dronedarone, flecainide, propafenone, sotalol) and who prefer further rhythm control therapy, when performed by an electrophysiologist who has received appropriate training and is performing the procedure in an experienced centre.	I	A
ACE-Is or ARBs are not recommended for the secondary prevention of paroxysmal AF in patients with little or no underlying heart disease.	III (no benefit)	B
Moderate regular physical activity is recommended to prevent AF, while athletes should be counselled that long-lasting, more intense sports participation can promote AF.	I	A

ACE = angiotensin-converting enzyme; AF = atrial fibrillation; AHRE = atrial high rate episodes; ARB = angiotensin receptor blocker; CHA_2DS_2-VASc = Congestive Heart failure, hypertension, Age ≥75 (doubled), Diabetes, Stroke (doubled), Vascular disease, Age 65–74, and Sex (female); ECG = electrocardiogram; EHRA = European Heart Rhythm Association; ICD = implantable cardioverter defibrillator; INR = international normalized ratio; LV = left ventricular; LVEF = left ventricular ejection fraction; LVH = left ventricular hypertrophy; NOAC = non-vitamin K antagonist oral anticoagulant; OAC = oral anticoagulation; TIA = transient ischaemic attack; TOE = transoesophageal echocardiography; TTR = time in therapeutic range; VKA = vitamin K antagonist.

17. A SHORT SUMMARY OF THE MANAGEMENT OF ATRIAL FIBRILLATION PATIENTS

Here, we provide 17 simple rules to guide the diagnosis and management of AF patients according to the 2016 ESC Guidelines for the management of atrial fibrillation developed in cooperation with EACTS.

1. Use ECG screening in at-risk populations for AF, especially stroke survivors and the elderly.
2. Document AF by ECG before starting treatment.
3. Evaluate all AF patients by clinical evaluation, ECG, and echocardiogram for underlying cardiovascular conditions such as hypertension, heart failure, valvular heart disease, and others.
4. Provide tailored information and education to AF patients to empower them to support AF management.
5. Propose lifestyle changes to all suitable AF patients to make their management more effective.
6. Treat underlying cardiovascular conditions adequately, e.g. valve repair or replacement in AF patients with significant valvular heart disease, treatment of heart failure, or management of hypertension, among others.
7. Use oral anticoagulation in all AF patients unless they are at low risk for stroke based on the CHA_2DS_2VASc score or have true contraindications for anticoagulant therapy.
8. Anticoagulate patients with atrial flutter similar to AF. Offer isthmus ablation to symptomatic flutter patients.
9. Reduce all modifiable bleeding risk factors in all AF patients on oral anticoagulation, e.g. by treating hypertension, minimizing the duration and intensity of concomitant antiplatelet and non-steroidal anti-inflammatory drug therapy, treating anaemia and eliminating causes for blood loss, maintaining stable INR values in patients on VKAs, and moderating alcohol intake.
10. Check ventricular rate in all AF patients and use rate control medications to achieve lenient rate control.
11. Evaluate AF-related symptoms in all AF patients using the modified EHRA symptoms scale. Whenever patients have AF-related symptoms, aim to improve symptoms by adjustment of rate control therapy and by offering antiarrhythmic drugs, cardioversion, or catheter or surgical ablation.
12. Select antiarrhythmic drugs based on their safety profile and consider catheter or surgical ablation when antiarrhythmic drugs fail.
13. Do not offer routine genetic testing in AF patients unless there is suspicion of an inherited cardiac condition.
14. Do not use antiplatelet therapy for stroke prevention in AF.
15. Do not permanently discontinue oral anticoagulation in AF patients at increased risk of stroke unless such a decision is taken by a multidisciplinary team.
16. Do not use rhythm control therapy in asymptomatic AF patients, nor in patients with permanent AF.
17. Do not perform cardioversion or catheter ablation without anticoagulation, unless an atrial thrombus has been ruled out transoesophageal echocardiogram.

18. WEB ADDENDA

Three additional Web figures and two additional Web tables can be accessed in the Web addenda to the 2016 ESC AF Guidelines, available at European Heart Journal online and also via the ESC Website (www.escardio.org/guidelines).

19. APPENDIX

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ESC National Cardiac Societies actively involved in the review process of the 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS:

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