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A review of the safety aspects of radio frequency ablation

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ABSTRACT

In light of recent reports showing high incidence of silent cerebral infarcts and organized atrial arrhythmias following radiofrequency (RF) atrial fibrillation (AF) ablation, a review of its safety aspects is timely. Serious complications do occur during supraventricular tachycardia (SVT) ablations and knowledge of their incidence is important when deciding whether to proceed with ablation. Evidence is emerging for the probable role of prophylactic ischemic scar ablation to prevent VT. This might increase the number of procedures performed. Here we look at the various complications of RF ablation and also the methods to minimize them. Electronic database was searched for relevant articles from 1990 to 2015. With better awareness and technological advancements in RF ablation the incidence of complications has improved considerably. In AF ablation it has decreased from 6% to less than 4% comprising of vascular complications, cardiac tamponade, stroke, phrenic nerve injury, pulmonary vein stenosis, atrio-esophageal fistula (AEF) and death. Safety of SVT ablation has also improved with less than 1% incidence of AV node injury in AVNRT ablation. In VT ablation the incidence of major complications was 5–11%, up to 3.4%, up to 1.8% and 4.1–8.8% in patients with structural heart disease, without structural heart disease, prophylactic ablations and epicardial ablations respectively. Vascular and pericardial complications dominated endocardial and epicardial VT ablations respectively. Up to 3% mortality and similar rates of tamponade were reported in endocardial VT ablation. Recent reports about the high incidence of asymptomatic cerebral embolism during AF ablation are concerning, warranting more research into its etiology and prevention.

1. Introduction

RF ablation has been part of clinical practice for more than two decades and has become an important treatment option for most clinically relevant cardiac arrhythmias. Achieving the optimal balance between efficacy and safety has proven to be challenging. Even though procedure-related acute complications are on the decline by virtue of better knowledge of arrhythmia physiology, experience of particular group with RF ablation and advancements in technology like mapping, cryoablation and newer ablation techniques such as magnetic navigation [1–3]. However the incidence of some chronic complications has risen, as procedures became more complex and time consuming.

Catheter ablation procedures are used to treat a diverse range of arrhythmias with vastly different natural histories and alternative treatment options. For the purposes of this review we will consider three broad types of procedures. Pulmonary vein isolation (PVI) for AF ablation for SVT and VT ablation.

Electronic database was searched for relevant articles from 1990 to 2015. Search terms namely radiofrequency ablation, safety, complications, AF, atrio ventricular reentry tachycardia (AVRT), atrio ventricular nodal reentry tachycardia (AVNRT), VT and atrial flutter (A Fl) were used separately and in combination. Out of 5390 articles obtained through this search, 315 journal articles pertaining to safety issues of RF ablation were carefully studied for the review. Prospective and retrospective designs, and review articles were included. Animal studies, in vitro studies, conference proceedings, case reports, comments, and surgical ablation articles were excluded.

2. Atrial fibrillation ablation

The technique of catheter ablation for atrial fibrillation has developed over a relatively short period of time. The incidence of major complications of AF ablation has decreased overtime. Studies from 1995 to 2010 show a reduction in serious complications from 6% to 3.7% of which vascular complications were the commonest [4,35].

2.1. Cerebrovascular accident

The reported incidence of clinical stroke in AF ablation is much less than 1% [5,6]. However, there is ample evidence to suggest that the subclinical cerebral embolism during left sided ablations especially pulmonary venous isolation (PVI) for AF is far more common. Asymptomatic

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cerebral lesion (ACL) was common ranging from 10 to 14% [5,7]. An even higher incidence of 41% was reported by the MACAP study when more sensitive 3 Tesla MRI imaging was performed [8].

Medi et al. found 13–20% prevalence of cognitive dysfunction at three months in AF patients treated with ablation compared to none in those managed medically [9]. The presence of spontaneous echo contrast and procedural duration before heparin administration were determinants of ACL [10]. Therapeutic periprocedural anticoagulation significantly reduced ACL [11].

The possible embolic sources are thrombus formation on the ablation electrode and sheath, debris from steam popping and charring, preexisting thrombus in the cardiac chamber, air embolus from within the sheath and fresh thrombus formed on damaged endothelial surface of endocardial lesions [5,12,13].

Factors which have been proven to increase embolic risk are increased catheter time in the left atrium (LA), chronicity of AF, activated clotting time (ACT) below 250 seconds, duration of individual ablations, larger LA size, non-irrigated ablation and the presence of spontaneous echo contrast [5,14]. Periprocedural cardioversion was associated with an increased incidence of embolic stroke in some studies, however this association was not consistent [15,5,7].

Various methods have been used to minimize this embolic complication, however none in isolation or in combination could completely eliminate the risk of cerebral embolization. Intracardiac thrombus causing embolism could be minimized by adequate periprocedural anticoagulation. Several studies have shown the ideal anticoagulation level to be 300–400 s of ACT [5,13]. Verma et al. successfully reduced silent embolism by submerged introduction of the catheter into its sheath to prevent air entry [13]. Using intracardiac echocardiography (ICE) Ren et al. demonstrated that thrombi mostly formed in the sheath or mapping catheter and could be managed by withdrawing the sheath and catheter from the LA [14]. Periprocedural continuation of Warfarin reduced the incidence of stroke significantly, without increasing major bleeding or tamponade in Kuwahara et al.'s study of 3280 AF ablation cases [16].

2.2. Esophageal tissue injury (ETI)

While esophageal injury appears to be common after AF ablation, the incidence of atrio-esophageal fistula (AEF), which is often fatal was rare at 0.05% [17]. The incidence of esophageal injury defined as erythema, hematoma or ulcer was 2.9%–47% [18–21]. Schmidt et al. reported the highest incidence of injury without fistula formation in 47% using the higher temperature, power and time limits of 50 °C, 50 W and 15 seconds of irrigated ablation [21]. The esophagus is often located less than 5 mm from the LA posterior wall and thermally mediated injury occurs due to direct heat transfer [97].

AEF typically occurs subacutely and up to 23 rd day post ablation has been reported [22]. Clinical features are caused by air embolism (stroke) and sepsis, which is associated with high mortality, greater than 80% [23]. The initial symptoms may be subtle and a high index of suspicion is required.

In one study, ETI was successfully averted by limiting esophageal endoluminal temperature rise to 41 °C [19], however this was not a consistent finding. Di Base et al. encountered 17% ETI even when ablation was discontinued at 39 °C of endoluminal temperature [24]. Endoluminal temperature underestimated esophageal tissue temperature by up to 20 °C and it peaked only 25 seconds after esophageal tissue temperature peak in a canine study [25]. Good et al. explained the discrepancy observed in endoluminal temperature by demonstrating more than 2 cm sideways movement of esophagus during conscious sedation, which could move the probe away from the ablation catheter [98].

Various factors such as the energy delivered to the LA posterior wall, LA dilatation, additional ablation lines, LA size, LA-esophageal distance, use of nasogastric tube in general anesthesia, low BMI and chronicity of AF had been identified as predictors of ETI complications [18,20,26]. Strategies used to prevent esophageal injury were reducing power to 25 W, reducing ablation duration to 30 seconds in the posterior wall and ICE guidance to restrict microbubble formation. Martinek et al. showed that esophageal visualization with barium contrast and limiting energy delivery to 15 W was effective in reducing ETI compared to limiting duration of ablation to 5 seconds without reducing power and without esophageal temperature monitoring [18]. None of these methods were successful in completely eliminating ETI [18,21].

2.3. Left atrial tachycardia

LA tachycardia especially atrial flutter which is usually incessant and poorly tolerated is a common complication of AF ablation [34]. The incidence could be as high as 29% [27,28]. It was more common in circumferential ablation compared to segmental isolation and also with additional ablation lines [29,30]. The common mechanism was macroreentry, which was attributed to non-transmural or non-durable lesions and non-contiguous ablation lines leading to reconnections across gaps [31]. The risk was lessened if bidirectional block was demonstrated after ablation. Half of atrial tachycardia cases persisted three months post-ablation warranting repeat ablation [32]. Cummings et al. demonstrated that the treatment need not be linear ablation and often disconnection of the electrically reconnected pulmonary vein was effective [33]. Mitral annular reentry was a common cause of atrial flutter after single ring or box isolation ablation for AF [34].

2.4. Pulmonary vein stenosis

Pulmonary vein stenosis (PVS) is defined as 50% or more narrowing of the venous lumen, and more than 70% stenosis is termed severe [23]. In 2002, Arentz et al. showed 28% incidence of PVS, which in later studies declined to 0.1–1.3% [22,35,36] and only 0.29% needed intervention [37]. This decreasing incidence was due to changing ablation site from pulmonary vein lumen to antrum, reducing power of ablation and adopting additional imaging modalities to better delineate the ostial anatomy [38,39]. Dong et al. showed that encircling individual veins carried more risk compared to encircling ipsilateral pairs [40].

Patients with exertional dyspnea, which is the commonest symptom usually have stenosis exceeding 70% in multiple veins [39]. CT scan is widely used to diagnose PVS. Holmes et al. identified a small lumen by pulmonary angiography in 50% of patients whom CT scan showed complete occlusion. This finding has treatment implications as total occlusion is not amenable to stenting [39]. MR imaging was also equally useful as CT scanning [23]. Functional assessment with V/Q scan helped in identifying asymptomatic patients with severe stenosis [38,39]. Progression of stenosis was variable. Saad et al. reported 8.8% progression mainly in first 3 months and regression in 10.4% [38].

Most clinicians perform stenting for residual stenosis after balloon angioplasty, whereas some prefer primary stenting [36,39]. Even though angioplasty and stenting reduced the incidence of restenosis in patients with symptomatic severe stenosis compared to balloon dilatation alone, the restenosis rates remained high at 30–50% [36,38,39]. Some clinicians prefer to intervene in severe stenosis irrespective of symptoms because progression to complete occlusion could be rapid which might preclude intervention [38,39].

2.5. Phrenic nerve injury

Phrenic nerve injury (PNI) has a prevalence of 0.1–0.5% after AF ablation [41]. Right PNI is often associated with ablation of the anteroinferior aspect of the right superior pulmonary vein (RSPV) or posteroseptal portion of superior venacava, owing to their close proximity to the nerve [42,48]. Although less common, left PNI was reported in AF ablation resulting from application of RF energy close to the proximal LA appendage roof [43].