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].

Although up to 31% of patients with PNI can be asymptomatic after AF ablation, dyspnea is a cardinal symptom and is present in all symptomatic patients [43]. Other symptoms include cough and hiccough and the diagnosis is made by the demonstration of diaphragmatic elevation on chest radiograph [43]. In a study by Sacher et al., 66% of patients recovered completely at 36 ± 33 months after ablation, 17% partially recovered and 17% failed to recover [43]. Avoiding PNI may be possible by using high output "pace mapping" in high risk areas before ablation [43].

2.6. Perforation and tamponade

AF ablation carries more risk of perforation up to 2.4% compared to VT and SVT ablations [35,44,45], probably due to the longer catheter manipulation time, higher number of ablations and higher anticoagulation [46]. Using ICE for transeptal puncture and reducing the temperature limit of irrigated ablations to 42 °C had been recommended [6]. A 1.2% incidence of delayed tamponade was reported by Cappato et al. with an average presentation of 12 days post-ablation [47].

Majority of patients responded with pericardiocentesis and very few required surgical closures. Maximal power delivery in excess of 48 W was a significant risk factor for developing cardiac tamponade during atrial ablations and limiting power delivery to less than 42 W reduced the incidence of perforations [45]. The use of ICE in some studies facilitated early detection of effusion before overt hemodynamic instability [6,44].

2.7. Death

The leading causes of death of 0.15% in the world-wide survey were cardiac tamponade, stroke and atrio esophageal fistula. 22% of deaths occurred after a month, attributed to various causes namely, hematoma causing tracheal compression, intracranial bleeding and esophageal perforation from pre-procedural trans-esophageal echocardiogram use [23].

2.8. Radiation exposure

Catheter ablations for AF may require prolonged fluoroscopy times. Pre-procedural CT scanning for anatomical mapping may further increase the radiation burden. Prolonged radiation exposure during the procedure puts the patient and also the operator at risk of malignancy and genetic abnormalities. Fluoroscopy time for ablation of persistent AF was reported to be 80–100 min [49]. Sixty minutes of radiation exposure translates to 0.03% increased life time risk for fatal malignancies which was higher for obese patients [50]. Newer technologies for navigation such as magnetic navigation and 4D non-fluoroscopic ablation were shown to be effective in reducing fluoroscopy time [1,51].

2.9. Miscellaneous complications

Mitral valve injury during AF ablation by trapped circular catheter is a rare complication. Surgical extraction is often required to prevent injury to valve apparatus if gentle manipulation fails [23].

Perioesophageal vagal nerve injury usually presents with upper gastrointestinal symptoms following AF ablation and the incidence could be as high as 1%. Abnormal gastric motility and pyloric spasm is usually treated symptomatically however, severe cases need botulinum injection, surgery or gastric pacing. Prevention is similar to that for esophageal tissue injury [99].

Atrial size and contractility improved after most AF ablations suggesting a positive remodeling effect of the intervention. Loss of contractility was proportional to the amount of myocardium damaged as circumferential ablations resulted in more loss of atrial function compared to segmental ablation [32].

Vascular access complications have shown a favorable trend after the practice of ablation with uninterrupted warfarin had started, probably due to lesser use of bridging Enoxaparin. However, they are still the commonest [23] (Table 1).

2.10. Summary

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, PNI, PVS, AEF and death. ACL is a potentially significant issue with possible long-term consequences. Continuing warfarin and strict intra-procedural anticoagulation reduced its incidence. AEF is often a fatal complication, which could be prevented to an extent with esophageal temperature monitoring. Atrial tachycardia post-AF ablation, which is often very symptomatic, is a common complication and the incidence was reduced by demonstrating bidirectional block. Pulmonary vein stenosis is on the decline after circumferential PVI was adopted. Presenting symptom could be only dyspnea and high index of suspicion is required to diagnose. PNI could be prevented by high output pacing in high-risk areas before ablation. Reducing target temperature and also the delivered power reduced the incidence of pericardial tamponade. ICE guidance for transeptal puncture and pericardial monitoring also helped to reduce morbidity with this complication. Vascular access site complications were the commonest, which showed a favorable trend after performing procedure on warfarin.

3. Supraventricular tachycardia ablation

3.1. AV node injury

AV nodal (AVN) injury is predominantly a complication of AVNRT ablation. The incidence had been high initially at 5.6% in the MERF study when the fast pathway was targeted by virtue of its close proximity to the compact AV node [52]. With change in the ablation site to the slow pathway's posteroinferior location which is further away from the AV node, the incidence decreased to 0.07%–0.7% [53,54,55].

Ablations for aortic cusp SVT, accessory pathways and outflow tract VT were also associated with this complication [56]. In a 14 year study of 5330 consecutive SVT ablation cases of AVNRT, AVRT, A Fl and AT by O'Hara et al., permanent AVB was observed in 0.22% of AVNRT ablations and 0.17% of AVRT ablations [57]. French registry reported 0.1% and 1.5% incidence of AV nodal injury in AVRT and AVNRT ablations respectively [58].

3.2. Mortality

Calkins et al.'s prospective study of SVT ablations (1999) reported 0.1% mortality in AVRT ablations and none in AVNRT ablations [59]. Feldman et al. did not report any death in 1448 AVNRT ablations [53]. However, 0.04% mortality was reported in 1996 from the French registry of more than 5000 predominantly SVT cases [58].

3.3. Miscellaneous complications

Perforation occurred in 0.1–1.3% [60] (Table 2). Complications could occur during atrial flutter ablation as well which was shown by Brembilla-Perrot et al. where they have reported up to 1.6% chance of life threatening complications when an 8 mm tip catheter was used with setting of 70 W, 70 °C, for 60 seconds [61].

3.4. Summary

AV nodal injury is the most concerning complication of SVT ablation especially AVNRT and septal accessory pathways. Adoption of slow pathway ablation for AVNRT reduced the incidence to well below 1%.

Table 1
Complications of atrial fibrillation ablation.

Study	Type	Year	Procedure (n)	Major complications	Death	CVA	Tamponade	PVS	AEF	PNI	Vascular
Worldwide survey [35]	Multicenter survey	1995–2002	11,672	6	0.05	0.94	1.22	1.31 (chronic)	0.42	0.74	1
Updated world-wide survey [37]	Multicenter survey	2003–2006	20,825	4.5	0.15	0.94	1.31	0.29 (intervention)	0.04	0.17	1.5
Baman et al. [96]	Prospective	2007–2010	1295	3.5	0	0.5	1.2	–	0	0	1.9
Bertaglia et al. [95]	Retrospective	2011	2323	4	0	0.3	0.5	–	–	0.1	2.2
Stabile et al. [4]	Prospective	2011	2167	3.7	0	0.3	0.6	–	–	0.1	2.1

AEF—atrio-esophageal fistula.
CVA—cerebrovascular accident (including transient ischemic attack).
PNI—phrenic nerve injury (needing intervention).

4. Endocardial and epicardial ventricular tachycardia ablation

The incidence of major complications of VT ablation was reported to be 5–11%, up to 3.4% and up to 1.8% in patients with structural heart disease, without structural heart disease and prophylactic ablations respectively [2,46,62–65]. Prophylactic, scar VT ablations are those undertaken after the first arrhythmia as opposed to ablation after recurrent ventricular arrhythmias [63,64]. Up to 8.5% major complication rate was reported in epicardial ablations [66,67].

In Peichl et al.'s study of 722 patients, advanced age, LV dysfunction, renal failure and the proceduralist experience were identified as the predictors of complications [62]. Renal function was the only predictor of complications in VT ablation identified in Bohnen et al.'s study [46]. Neither advanced age nor LV dysfunction was a predictor of complications. Age more than 75 years was not a predictor in Inada et al.'s study either [68].

4.1. Death

The combined mortality in ischemic and non-ischemic VT ablations ranged from 0 to 3% [46,68–72], which was frequently due to fast VT leading to cardiogenic shock [68,71,73]. Incomplete procedural success was a predictor of in-hospital mortality [72].

4.2. Perforation and tamponade

The incidence of cardiac perforation ranged from 1 to 2.7% [74,75]. Tokuda et al. reported 1% incidence of cardiac perforation during VT ablation in the largest single center study [74]. More than half of these patients with cardiac perforations required surgical repair if preceded by steam pop and most perforations occurred during thin-walled RV ablation, in particular the outflow tract.

During epicardial ablation, tamponade was the commonest major complication [67,76], constituting 5.1% out of 7% major complications

in a study [67]. Inadvertent RV puncture occurred in 20% of cases during epicardial access without any adverse consequence.

4.3. Coronary artery injury

Coronary artery injury is an uncommon complication of RFA with reported incidence of 0.09% of all ablations [77], and 1.5% of epicardial ablations [67]. Safe distance of ablation from a coronary artery had been suggested from 2 mm to 12 mm by different authors [78,79,80]. The manifestations of coronary injury could be acute, delayed or chronic [67,77,81]. Acute effects included vasospasm, intimal damage and thrombus formation [78,82]. Chronic effects were fibrosis and thickening of all three layers of the artery [81]. The artery damage was inversely proportional to vessel size [83].

This complication could occur during both endocardial and epicardial ablations performed in close proximity to the coronary arteries. High-risk areas are the posteroseptal region, sub-eustachian isthmus and coronary sinus and its branches. Injury had also been reported following ablations for typical atrial flutter, AVNRT, AVRT and coronary sinus ablations [84].

Acute coronary occlusion warrants angioplasty and stenting [77]. Coronary angiography before energy delivery in the epicardium could help in preventing coronary injury [67].

4.4. Miscellaneous complications

Vascular complications were the commonest in VT ablation, which was reported up to 4.7%. The incidence of CVA ranged from 0% to 1.4% [68–71], while high grade AV block occurred in up to 1.8% [72,68,70].

The use of ICE was found to be useful in early detection of complications and visualization of great arteries and coronaries in outflow tract ablations [3] High output pacing before ablation near the lateral wall of LV should be considered to avoid phrenic nerve injury in epicardial ablations [76]. A dedicated VT ablation multidisciplinary intensive care team, complete with support staff as shown by Della Bella et al. has

Table 2
Complications of supra ventricular tachycardia ablation.

Study	Type	Year	Procedure (n)	SVT type (%)	AV block[a] (%)	CVA[b] (%)	Tamponade (%)	Death (%)
MERFS [52]	Prospective	1987–1992	880	AVNRT	5.6	–	–	–
Feldman et al. [53]	Retrospective	1999–2009	1419	AVNRT	0.07	–	–	–
O'Hara et al. [57]	Prospective	1993–2006	5330	AVNRT	0.22	0	0	0
				AVRT	0.17	0	0.09	0
				AT	0	0	0	0
				A Fl	0	0	0	0

AP—accessory pathway, AVNRT—AV nodal reentrant tachycardia.
A Fl—atrial flutter.
[a] High grade requiring pacemaker implantation.
[b] Stroke and TIA.

Table 3
Complications of ventricular tachycardia ablation.

Study	Type	Year	Proc (n)	VT type	Major complications	Death	CVA	Tamponade	Other
Structural heart disease									
Sauer et al. [69]	Prospective	1999–2005	327	ICM, NICM	2.1%	Nil	0.9%	1.2	–
Euro VT [94]	Prospective	1999–2003	63	ICM	1.5%	0	0	0	
Bohnen et al. [46]	Prospective	2009–2011	250	SHD	6%	0.4%	0.8%	1.4%	
Mallidi et al. [70]	Meta-analysis	1965–2010	457	SHD	6.3%	1%	1%	–	AV block[a] 1.6% Perforation 1%
Tokuda et al. [74]	Prospective	1999–2010	226	NICM	5%	0	0	0	Perforation 1.8%
Dinov et al. help-VT study [65]	Prospective	2008–2011	227	ICM, DCM	11%	0.4%	–	0.8%	AV block 0.8% Shock 2.2%
Peichl et al. [62]	Prospective	2006–2012	473		8%	0	0.8%	0.6%	AV block 1.3% Vascular 4.7%
Della Bella et al. [2]	Prospective	2007–2012	634	SHD	7%	0.1%	0	2%	Vascular 4%
Idiopathic									
Inada et al. [68]	Prospective	1999–2008	285	IVT	7%	3.8%	0.7%	0.7%	AV block 1%
Bohnen et al. [46]	Prospective	2009–2011	119	IVT	3.4%	0	0.8%	0.8%	
Peichl et al. [62]	Prospective	2006–2012	249	IVT	2.8%	0	0.4%	0	AV block 0.4% Vascular 1.6%
Prophylactic									
SMASH VT [64]	RCT	2004–2006	64	ICM	0	0	0	0	1 DVT, 1 CCF
VTACH [63]	RCT	2002–2006	54	ICM	1.8%	0	1.8%	–	1 ST elevation
Epicardial									
Della Bella et al. [76]	Multicenter Survey	2001–2009	218	SHD, NSHD	4.1%	0	0	3.7%	1 abdominal hemorrhage
Sacher et al. [67]	Multicenter Survey	2001–2007	136	SHD	7%	0	0	5.1%	CA stenosis 0.6%
Tung et al. [66]	Single center Survey	2004–2011	109	SHD, NSHD	8.8%	0	0	0	6.7% epicardial bleeding

RCT — randomized controlled trial.
CVA—cerebrovascular accident (including transient ischemic attack).
IVT- Idiopathic Ventricular Tachycardia
SHD- Structural Heart Disease
NSHD- No Structural Heart Disease
ICM- Ischemic Cardiomyopathy
NICM- Non Ischemic Cardiomyopathy
  [a] High grade requiring pacemaker implantation.

improved safety of VT ablation with approximately 3% non-vascular major complications. (4% vascular complications) [2] (Table 3).

4.5. Summary

VT ablation suffered the highest incidence of complication among RF ablations. 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. Coronary artery injury was more common in epicardial ablation. Up to 3% mortality and similar rates of tamponade were reported in endocardial VT ablation. Dedicated VT multidisciplinary team and ICE guidance during procedure helped to reduce morbidity.

The extremes of age need special mention. In pediatric SVT ablations, Lee et al. reported that the incidence of complications was similar to that in adults [85]. The risk of AVN injury was at maximum with anterior and mid-septal pathways [86]. Death occurred in 0.14% ablations as reported by Vitello et al. in their study of 5000 procedures [87]. Schaffer et al. observed that it was related to the lower body weight, presence of structural heart disease and left sided procedures [88]. Special care needs to be taken to reduce radiation in pediatric population for obvious reasons [89]. Tomaske et al. did not report any complications in 97 pediatric SVT ablations [90].

The impact of advanced age on safety of RF ablations is less clear. Earlier report by Chen et al. in 1996 in 3966 RF ablation procedures, showed that elderly patients were at a higher risk for complications [91]. Piechl et al. also recently reported that the complications in VT ablation were associated with advanced age [62]. However, both Santangeli et al. in AF ablation and Inada et al. in VT ablation did not report increased complication in elderly [68,92].

5. Newer technology

Magnetic Navigation System (MNS) is a new technological advancement in radiofrequency ablation [93], in which two powerful magnets are used to navigate the magnetic irrigated catheter precisely to the destination. In one study MNS ablations suffered only 0.34% major complications when compared to 3.2% with conventional ablation in 610 consecutive patients with various arrhythmias [1].

Non-fluoroscopic 4D ablation technology, popularly known as MediGuide, uses pre acquired X-ray images to superimpose catheter position. This considerably reduces radiation exposure. Real time tracking of catheter accounting for respiratory and cardiac movements is another advantage [51].

Conflict of interest

No conflict of interest.

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