REVIEW ARTICLE

Implantable Cardioverter-Defibrillators in Patients with ESRD: Complications, Management, and Literature Review

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Abstract: Background: Cardiovascular diseases are the leading cause of death among dialysis patients, accounting for about 40% of all their mortalities. Sudden cardiac death (SCD) is culpable for 37.5% of all deaths among patients with end-stage renal disease (ESRD). Implantable cardioverter-defibrillators (ICDs) should be considered in dialysis patients for the primary or secondary prevention of SCD. Recent studies on the implementation of ICD/cardiac resynchronization therapy do not exclude patients with ESRD; however, individualized decisions should be made in this group of patients. A thorough evaluation of the benefits of ICD implementation in patients with ESRD requires several large-scale mortality studies to compare and follow up patients with ESRD with and without ICDs. In the present study, we sought to determine and clarify the complications associated with ICD implementation and management thereof in patients suffering from ESRD.

Methods: To assess the complications allied to the implementation of ICDs and their management in patients with ESRD, we reviewed available related articles in the literature.

Results and Conclusions: ICD implementation in dialysis patients has several complications, which has limited its usage. Based on our literature review, the complications of ICD implementation can be categorized as follows: (1) Related to implantation procedures, hematoma, and pneumothorax; (2) Related to the device/lead such as lead fracture and lead dislodgment; (3) Infection; and (4) Central vein thrombosis. Hence, the management of the complications of ICDs in this specific group of patients is of vital importance.

Keywords: Cardioverter-defibrillators, patients, ESRD, complications, management, literature review.

1. INTRODUCTION

In this review article, we discuss the complications of ICD implementation in patients with ESRD (if indicated) and also the management of these complications according to previous experiences. We conducted an exhaustive literature review; we initially selected 200 articles with related topics from the year 1978 and eventually selected 100 of them for a thorough perusal. Finally, we drew upon 56 articles to write this review. The acceptable complication rates in the general population justify guideline-based ICD implementation; however, in some ESRD patients, the risks may somehow outweigh the benefits.

2. CHRONIC KIDNEY DISEASE AND SUDDEN CARDIAC DEATH

Cardiovascular diseases are the leading cause of death among dialysis patients in that, they account for about 40% of all mortalities in this patient population [1, 2], with ventricular arrhythmias and sudden cardiac death (SCD) being the most prevalent causes [2]. There is currently a paucity of precise analysis of SCD-related factors in individuals undergoing dialysis. What is clear, however, is that electrolyte imbalance plays an important role in the outcome of patients on hemodialysis [3].

3. MORTALITY BENEFIT OF IMPLANTABLE CAR-DIOVERTER-DEFIBRILLATORS IN END-STAGE RENAL DISEASE

Implantable cardioverter-defibrillators (ICDs) should be considered as an option for the primary or secondary prevention of SCD, wherever indicated, whether among patients on dialysis or among those with normal renal functions. The guidelines of the American College of Cardiology/American Heart Association and the European Society of Cardiology recommend that dialysis patients who have survived SCD be treated with conventional methods, including ICD implementation, for secondary prevention [4]. Nonetheless, what is still underutilized for the treatment of patients with end-stage renal disease (ESRD) is the ICD. A retrospective study
by Herzog et al. [5] on patients with ESRD showed that just 8% of the SCD survivors among their study population had undergone ICD implantation. In a large, contemporary, non-interventional study of community-based patients with heart failure and CKD, ICD placement was not significantly associated with improved survival but was associated with increased risk for subsequent hospitalization due to heart failure and all-cause hospitalization [6].

Large-scale prospective ICD cohorts/trials have excluded dialysis patients, and there is precious little information on the primary prevention of SCD in this group of patients.

Obviously, the survival benefit of ICDs is more considerable in non-dialysis patients than in dialysis patients [7]. Patients suffering from ESRD are admitted to hospitals for several other comorbidities and may die from other non-cardiovascular disorders. The majority of previous risk-benefit studies have focused on the indications and complications of ICD implementation in patients with chronic kidney disease (CKD) in comparison to those with normal kidney functions. A meticulous appraisal of the benefits of ICD implementation in patients with ESRD requires mortality studies seeking to compare ESRD patients with and without ICDs. Recent studies on the implementation of ICDs/cardiac resynchronization therapy have not excluded patients with ESRD; still, it is advisable that individualized decisions be made in this patient group [6-8]. In 2010, Hager et al. [9] showed better outcomes in their CKD patients treated with ICDs than in their CKD patients with conventional management. El Chami et al. in 2017 [10] showed ESRD patients are at significantly increased risk of mortality as compared with non-dialysis patients. While the majority of these patients survive more than one-year post-diagnosis, the three-year mortality is high (43%). Randomized studies addressing the benefits of ICDs in ESRD patients are needed to better define their value for primary prevention of SCD. Thus, the guideline-based usage of ICDs is recommended in patients suffering from CKD. The challenging issue here is the implementation of ICDs for primary or secondary prevention in stage 5 of kidney disease.

4. IMPLANTABLE CARDIOVERTER-DEFIBRILLATORS FOR PRIMARY PREVENTION

CKD is known to lessen the survival benefits of ICD implementation for primary prevention [11]. In a recent study in 2014, Pun et al. [12] performed a propensity-matched cohort study between ESRD patients with and without ICDs (for primary prevention) and reported no significant survival benefits for ICD usage in their study population.

The benefits of the primary prevention of SCD in ESRD patients may be attributed to age. Amin et al. [13] reported the survival benefits of ICD implantation in ESRD patients aged below 65 years. Hiremath et al. [14] in 2010 performed a small retrospective study, which compared ESRD patients with and without ICDs in terms of survival benefits. The authors focused on primary prevention indications and reported that ICD implementation was associated with a higher overall survival rate among their ESRD patients.

5. IMPLANTABLE CARDIOVERTER-DEFIBRILLATORS FOR SECONDARY PREVENTION

In 2005, Herzog et al. [5] conducted a retrospective cohort study on ESRD patients (460 with ICDs vs. 5582 without ICDs) based on Medicare Database and, in light of their results, supported the use of ICDs for secondary prevention after aborted SCD in dialysis patients. In a comparative study between ESRD patients with and without ICDs, Chen et al. [15] conducted a meta-analysis and showed increased overall survival benefits in their dialysis patients with ICDs. Another important issue is adequate medical treatment for heart failure with the use of such medications as beta-blockers, angiotensin-converting-enzyme inhibitors and angiotensin-receptor blockers in tandem with ICD implementation. Unfortunately, a factor liable to negatively affect survival among patients with ESRD is what is widely referred to as “therapeutic nihilism”: these patients are likely to receive inadequate guideline-directed medical therapy because of several associated comorbidities such as ischemic cardiac disease, diabetes mellitus, and chronic heart failure [11]. This confounds the survival benefits of ICD implementation in this group of patients. Indeed, the advantages or disadvantages of ICD implementation in CKD/ESRD patients may be correlated with several factors such as increased age, ICD type, diabetes mellitus, and concomitant guideline-directed medical treatment [16].

6. COMPLICATIONS OF IMPLANTABLE CARDIOVERTER-DEFIBRILLATORS IN PATIENTS WITH END-STAGE RENAL DISEASE AND REPORTED APPROPRIATE MANAGEMENT

In 2009, Aggarwal et al. [17] compared the short-term consequences of ICD implementation in ESRD patients between those on dialysis and their non-dialysis counterparts in the National Cardiovascular Data Registry (NCDR) and found a fivefold increase in in-hospital mortality as well as a 20% increase in complications in the former group. Charytan et al. [18] examined 9528 hemodialysis patients with ICDs between 1994 and 2006 for both primary and secondary prevention and revealed very high rates of bacteremia (52%), device infection (4.2%), and death (45%) per year.

6.1. Implantation Site Hematoma

This complication in patients with ESRD is probably related to inappropriate venous access, coagulopathy, or platelet dysfunction because of uremic state [19]. In a study, the rate of bleeding complications associated with ICD implantation in the ESRD patients was about 7.5% [20]. In 2001, Pavias et al. [21] described pocket hematoma as a common complication and suggested electro-cautery as a useful way to reduce pocket-related bleeding. Withholding or reversing antiplatelet and anticoagulation medications in patients with low risk for thromboembolic events and applying absorbable collagen hemostats, thrombin patches, gelatin foams, and pressure dressings to incision sites to throw hemostasis forward can greatly reduce the risk of hematoma formation [22].
Table 1. Brief review of recent studies on the complications and management of ICD implementation in patients with ESRD.

| Complication                  | Prevention/Management                                                                 | Author                          | Journal and Year of Publication                      |
|-------------------------------|---------------------------------------------------------------------------------------|---------------------------------|------------------------------------------------------|
| Lead dislodgment              | Pouch re-opening and lead reposition in early dislodgment                              | Arjit Dasgupta et al. [28]      | American Journal of Kidney Diseases (2007)           |
|                               | New lead implementation after lead extraction in late dislodgment                      |                                 |                                                      |
| Implantation site hematoma    | Withholding or reversing antiplatelet and anticoagulation medications in patients with low risk for thromboembolic events applying absorbable collagen hemostats, thrombin patches, gelatin foams, and pressure dressings to incision sites | Christine Tompkins et al. [20]  | Cardiovascular Electrophysiology (2011)              |
| Central vein stenosis         | Left subclavian or cephalic vein approach                                               | Theodore F. Saad et al. [29]    | Seminars in Dialysis (2012)                          |
|                               | Percutaneous balloon angioplasty                                                       |                                 |                                                      |
|                               | Removal of CIED leads with stent insertion                                              |                                 |                                                      |
|                               | Stenting the SVC over the CIED leads                                                  |                                 |                                                      |
| CIED infections               | Epicardial CIED leads re-establishment of the AV access and removal of the venous catheter. | Theodore F. Saad et al. [29]    | Seminars in Dialysis (2012)                          |
|                               | Wearable defibrillators                                                               |                                 |                                                      |
|                               | Avoiding the combination of long-term venous hemodialysis catheters and CIEDs         |                                 |                                                      |
| Central vein stenosis         | Epicardial CIED leads                                                                  | Arif Asif et al. [42]           | Seminars in Dialysis (2012)                          |
|                               | Use of subcutaneous ICDs if possible                                                   |                                 |                                                      |
| CIED infections               | Subcutaneous ICDs                                                                      | Arif Asif et al. [42]           | Seminars in Dialysis (2012)                          |
|                               | Epicardial CIED leads                                                                  |                                 |                                                      |
|                               | No entrapment of a lead by a bare-metal stent or stent graft                           |                                 |                                                      |
|                               | Percutaneous lead extraction                                                          |                                 |                                                      |
|                               | Peritoneal dialysis                                                                   |                                 |                                                      |
| CIED infections               | Complete lead displacement                                                             | Avirup Guha, et al. [40]        | Heart Rhythm (2015)                                  |
|                               | Medical therapy in bacteremia                                                          |                                 |                                                      |
| Central vein stenosis          | Subcutaneous ICDs                                                                      | Rajiv K. Dhamija et al. [47]    | American Journal of Kidney Diseases (2015)           |
|                               | PTA and stent placement                                                                |                                 |                                                      |

ESRD, End-stage Renal Disease; CIED, Cardiac implantable electronic device; ICD, Implantable cardioverter-defibrillator; PTA, Percutaneous transluminal angioplasty.

6.2. Pneumothorax

This is not a common complication and is related to operator experience and also the difficulty of the subclavian puncture [21]. The incidence rate is approximately between 0.4% and 1.3% [23, 24]. In a study, kidney dysfunction was not associated with a higher occurrence rate of pneumothorax in the patients suffering from ESRD [25].

6.3. Lead Fracture

It is not a very frequent complication in ESRD patients. In a case report published in 2010, Sony Jacob et al. [26] described an ESRD patient with episodes of syncope despite having an ICD and reported that lead fracture was responsible for this ominous event. Additionally, they suggested a novel method to extract the lead via the right femoral vein. This method, however, needs more evaluation.

6.4. Lead Dislodgement

It is a change not only in the tip position of the lead, which is evident in chest X-ray but also in electrical lead parameters. In a study by Eberhardt et al., [27] the lead dislodgement rate was approximately 2.0%. In another study conducted in 2007, Arjit Dasgupta et al. [28] compared 41 ESRD patients with ICDs with 123 non-dialysis patients with ICDs and reported that in 88% of the cases, the ICDs were placed on the contralateral side of the dialysis access. The authors also reported that 3 lead dislodgments happened in their ESRD patients, while no such event occurred in their control group. Management differs based on several factors. Generally, in early dislodgment, pocket re-opening and lead reposition are possible and in late displacements, lead extraction and lead implementation in the chamber in which displacement has occurred are advised [28].

6.5. Venous Hypertension

Patients with hemodialysis catheters who have ipsilateral ICD leads are significantly prone to venous hypertension due to a high rate of venous blood return [29]. The mean blood flow in major fistulae ranges from 780 to 1204 mL/min [30, 31]. Venous hypertension owing to arteriovenous hemodialysis access and ipsilateral ICD leads has been described in many case reports [32, 33], with the ligation of the arte-
riovenous access deemed an effective way to control venous hypertension [34]. Moreover, flow reduction can be utilized to control this complication [35].

6.6. Infection

Being on dialysis has been shown to be an independent predictor of ICD infection [20], which may be because of frequent bloodstream access for hemodialysis and also dialysis catheters [36]. ICD infection in ESRD patients increases in-hospital mortality and the longevity of the hospital stay [37]. The only intervention proven in randomized clinical trials to decrease infection is prophylactic intravenous antibiotics [38]. The use of chronic suppressive antibiotics has been previously suggested [20]; be that as it may, the efficacy of this method of treatment should be tested with large randomized trials. The majority of ICD infection cases require whole-system removal alongside intravenous antibiotics [39].

In a study, lead extraction within 2 months of diagnosed ICD infection was reported to be associated with improvement in survival in the ESRD patients [40]. It is also worthy of note that in patients suffering from ESRD, transvenous lead extraction in the presence of endocarditis is also associated with morbidity and mortality [41]. Hence, primarily all physicians should focus on preventive measures before the occurrence of complications.

Epicardial leads are not exposed to the bloodstream and can be good alternative management [33], and subcutaneous ICDs can reduce the risk of infection [42].

6.7. Central Vein Stenosis

ICD implementation ipsilateral to the dialysis catheter is associated with subclavian venous stenosis and thrombosis [43]. An injury to the vessel can lead to intimal hyperplasia and fibrosis [44]. These fibrous tissue bands may also contribute to the occlusive process. Unlike non-hemodialysis patients, ESRD patients are mostly symptomatic due to the high flow in the arteriovenous access [45]. The presence of hemodialysis can aggravate this stenosis. ESRD patients on hemodialysis whose arteriovenous fistulae in their upper extremity are ipsilateral to their ICD are at risk of symptoms related to venous stenosis such as edema of the face, neck, breast, shoulder, and arm [46].

Drew et al. [30] reported that central vein stenosis occurred in 21 of their 34 ESRD patients with cardiac rhythm devices. When central vein stenosis occurs, percutaneous balloon angioplasty and stent placement are the therapeutic options; still, the frequency of recurrence is noticeably high [47]. The expert consensus statements of the Heart Rhythm Society advise lead extraction before stent deployment [48]. Accordingly, in patients already on hemodialysis, contralateral lead placement is recommended. Using subcutaneous ICDs is an alternative with a view to preventing complications [47].

6.8. Peritoneal Dialysis

In a multicenter retrospective study in Italy, the incidence rate of SCD was not different between peritoneal dialysis and hemodialysis; however, the patients on hemodialysis had higher rates of comorbidities and mortality than those receiving peritoneal dialysis. Peritoneal dialysis is recommended in ESRD patients with no current AV access. In patients with venous catheters, wearable defibrillators and then peritoneal dialysis are recommended. If patients have transvenous ICDs and need an AV access, peripheral vein mapping is necessary to determine the risks and complications of another venous access [49].

7. ALTERNATIVE DEVICES

7.1. Wearable Defibrillators

Wearable ICDs have been shown to be effective for both secondary and primary preventions of SCD [50]. In a study, the event survival rate from these leads was 90 % in comparison with ICD therapy [51]. Wearable ICDs are indicated in cases in which the myocardial function may not permit the use of permanent devices such as uremia and uncontrolled volume overload [52]. Wearable ICDs are also indicated for use in previously infected devices in patients who are not paced dependent. Patients with ESRD are good candidates for wearable ICD therapy. The WED-HED trial, a multicenter cohort study, is an ongoing investigation to evaluate the impact of wearable ICD use on SCD in hemodialysis patients.

7.2. Subcutaneously Implantable Cardioverter-defibrillators

Subcutaneous ICDs do not transverse central veins and can minimize the risk of central vein stenosis and bacterial infections. In these devices, catheter and cardiac leads are placed in separate compartments instead of being placed in the bloodstream [18]. In a study on 79 patients with subcutaneous ICDs, the results showed that the subcutaneous ICDs did not increase the risk and complications in the dialysis and non-dialysis patients [53].

CONCLUSION

The total complication rate of ICDs has been reported to be significantly greater in patients with ESRD [15]. The rate of cardiovascular mortality remains high in these patients; nevertheless, more randomized clinical trials are required to further determine the risks and benefits [18]. Immune system dysfunction, uremic state, and coagulopathy are known to render patients with CKD/ESRD prone to greater device-related complications [54]. Decisions should be made on a case-by-case basis. The management of the complications of ICDs in this specific group of patients is vitally important. The 2 most common complications are ICD infection and central vein stenosis. In the case of infection, lead extraction should be considered. In addition, subcutaneous ICDs, wearable ICDs, and cardiac implantable electronic device lead greatly decrease the incidence of infection. For central vein stenosis, ICD lead removal and concomitant stent insertion, percutaneous balloon angioplasty, and subcutaneous ICD implementation are the recommended methods (Table 1).

The acceptable complication rates in the general population justify guideline-based ICD implementation; however,
in some ESRD patients, the risks may somehow outweigh the benefits.

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REFERENCES

[1] Levey AS, Coresh J, Balk E, et al. National Kidney Foundation practice guidelines for chronic kidney disease: Evaluation, classification, and stratification. Ann Intern Med 2003; 139(2): 137-47.

[2] Saravanan P, Davidson NC. Risk assessment for sudden cardiac death in dialysis patients. Circ Arrhythm Electrophysiol 2010; 3(5): 553-9.

[3] Genevosi S, Porcu L, Luise MC, et al. Sudden death in end stage renal disease: Comparing hemodialysis versus peritoneal dialysis. Blood Purif 2017; 44(1): 77-88.

[4] Al-Khatib SM, Yancy CW, Solomon SD, et al. 2016 AHA/ACC clinical performance and quality measures for prevention of sudden cardiac death. J Am Coll Cardiol 2016; 2016: 23062.

[5] Herzog CA, Li S, Weinhandl ED, Strief JW, Collins AJ, Gilbertson DT. Survival of dialysis patients after cardiac arrest and the impact of implantable cardioverter defibrillators. Kidney Int 2005; 68(2): 818-25.

[6] Bansal N, Szpiro A, Reynolds K, et al. Long-term outcomes associated with implantable cardioverter defibrillator in adults with chronic kidney disease. JAMA Intern Med 2018; 178(3): 390-8.

[7] Roberts PR, Green D. Republished article: Arrhythmias in chronic kidney disease. Postgrad Med J 2012; 88(1036): 97-104.

[8] Cledand JG, Mareev Y. CRT for heart failure and ESRD. J Am Coll Cardiol 2015; 66(23): 2630-2.

[9] Hager CS, Jain S, Blackwell J, Culp B, Song J, Chiles CD. Effect of renal function on survival after implantable cardioverter defibrillator placement. Am J Cardiol 2010; 106(9): 1297-300.

[10] El-Chami MF, Matar L, Smith P, et al. Long-term survival of implantable cardioverter defibrillator recipients with end-stage renal disease. J Arrhythm 2017; 33(5): 459-62.

[11] Cuculich PS, Sánchez J, Kerzner R, et al. Poor prognosis for patients with chronic kidney disease despite ICD therapy for the primary prevention of sudden death. Pacing Clinical Electrophysiol 2007; 30(2): 207-13.

[12] Pun PH, Hellkamp AS, Sanders GD, et al. Primary prevention implantable cardioverter defibrillators in end-stage kidney disease patients on dialysis: A matched cohort study. Nephrol Dial Transplant 2015; 30(5): 829-35.

[13] Amin MS, Fox AD, Kalahasty G, Shepard RK, Wood MA, Ellenbogen KA. Benefit of primary prevention implantable cardioverter-defibrillators in the setting of chronic kidney disease: A decision model analysis. J Cardiovasc Electrophysiol 2008; 19(12): 1275-80.

[14] Hiremath S, Punnam SR, Brar SS, et al. Implantable defibrillators improve survival in end-stage renal disease: Results from a multicenter registry. Am J Nephrol 2010; 32(4): 305-10.

[15] Chen TH, Wo HT, Chang PC, Wang CC, Wen MS, Chou CC. A meta-analysis of mortality in end-stage renal disease patients receiving implantable cardioverter defibrillators (ICDs). PLoS One 2014; 9(7): e99418.

[16] Cheema A, Singh T, Kanwar M, et al. Chronic kidney disease and mortality in implantable cardioverter-defibrillator recipients. Cardiol Res Pract 2010; 2010: pii: 989261.

[17] Aggarwal A, Wang Y, Rumsfeld JS, Curtis JP, Heidenreich PA, Registry NCD. Clinical characteristics and in-hospital outcome of patients with end-stage renal disease on dialysis referred for implantable cardioverter-defibrillator implantation. Heart Rhythm 2009; 6(11): 1565-71.

[18] Charytan DM, Patrick AR, Liu J, et al. Trends in the use and outcomes of implantable cardioverter-defibrillators in patients undergoing dialysis in the United States. Am J Kidney Dis 2011; 58(3): 409-17.

[19] Parkash K. Complications from implantable cardioverter defibrillator implantation: Do the risks outweigh the benefits?. Heart Rhythm 2009; 6(11): 1572-3.

[20] Tompkins C, Mclean R, Cheng A, et al. End-stage renal disease predicts complications in pacemaker and ICD implants. J Cardiovasc Electrophysiol 2011; 22(10): 1099-104.

[21] Pavia S, Wilkoff B. The management of surgical complications of pacemaker and implantable cardioverter-defibrillators. Curr Opin Cardiol 2001; 16(1): 66-71.

[22] Fluck R, Wilson J, Davies J, Blackbum R, O'Donoghue D, Tomson C. UK Renal Registry 11th Annual Report (December 2008): Chapter 12 Epidemiology of methicillin resistant Staphylococcus aureus bacteraemia amongst patients receiving renal replacement therapy in England in 2007. Nephron Clin Pract 2009; 111(Suppl. 1): c247-c56.

[23] AL-Khatib SM, Hellkamp AS, Lee KL, et al. Implantable cardioverter defibrillator therapy in patients with prior coronary revascularization in the Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT). J Cardiovasc Electrophysiol 2008; 19(10): 1059-65.

[24] Haines DE, Wang Y, Curtis J. Implantable cardioverter-defibrillator registry risk score models for acute procedural complications or death after implantable cardioverter-defibrillator implantation clinical perspective. Circulation 2011; 123(19): 2069-76.

[25] Buiten MS, De Bie MK, Van Der Heijden AC, et al. Chronic kidney disease and implantable cardioverter defibrillator related complications: 16 years of experience. J Cardiovasc Electrophysiol 2014; 25(9): 998-1004.

[26] Jacob S, Bhandare D, Mathew A, Jahania MS. A Novel approach to ICD lead revision in a patient with extensive vascular thrombosis. Indian Pacing Electrophysiol J 2010; 10(2): 108.

[27] Eberhardt F, Bode F, Bonnemeier H, et al. Long term complications in single and dual chamber pacing are influenced by surgical experience and patient morbidity. Heart 2005; 91(4): 500-6.

[28] Dasgupta A, Montalvo J, Medendorp S, et al. Increased complication rates of cardiac rhythm management devices in ESRD patients. Am J Kidney Dis 2007; 49(5): 656-63.

[29] Saad TF, Ahmed W, Davis K, Jurkovicz C. Cardiovascular implantable electronic devices in hemodialysis patients: Prevalence and implications for arteriovenous hemodialysis access interventions. Seminars in dialysis; 2015: Wiley Online Library; 2015. p. 94-100.

[30] Drew PA, Meyer KB, Weiner DE. Transvenous cardiac device wires and vascular access in hemodialysis patients. Am J Kidney Dis 2011; 58(3): 494-6.

[31] Moss AJ, Zareba W, Hall WI, et al. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. N Engl J Med 2002; 346(12): 877-83.

[32] Goudevenos JA, Reid PG, Adams PC, Holden MP, Williams DO. Epicardial cardiac rhythm Electrophysiol J 2010; 10(2): 108.

[33] Asif A, Carrillo R, Garisto JD, et al. Epicardial cardiac rhythm devices for dialysis patients: minimizing the risk of infection and preserving central veins. Seminars in dialysis; 2012: Wiley Online Library; 2012. p. 88-94.

[34] Bolad I, Karanam S, Mathew D, John R, Piemonte T, Martin D. Percutaneous treatment of superior vena cava obstruction following transvenous device implantation. Catheter Cardiovasc Interv 2005; 65(1): 54-9.

[35] Chamorro H, Rao G, Wholey MH. Superior vena cava syndrome: A complication of transvenous pacemaker implantation. J Radiol 1978; 126(2): 377-8.
[36] Tokars JI, Light P, Anderson J, et al. A prospective study of vascular access infections at seven outpatient hemodialysis centers. Am J Kidney Dis 2001; 37(6): 1232-40.

[37] Opelami O, Sahuja A, Liu X, Tang WW, Schold JD, Navaneethan SD. Outcomes of infected cardiovascular implantable devices in dialysis patients. Am J Nephrol 2014; 40(3): 280-7.

[38] de Oliveira JC, Martellini M, Nishioka SADO, et al. Efficacy of antibiotic prophylaxis before the implantation of pacemakers and cardioverter-defibrillators. Circ Arrhythm Electrophysiol 2009; 2(1): 29-34.

[39] Kennergren C. Management of cardiovascular implantable electronic devices infections in high-risk patients. Arrhythm Electrophysiol Rev 2015; 4(1): 53.

[40] Guha A, Maddox WR, Colombo R, et al. Cardiac implantable electronic device infection in patients with end-stage renal disease. Heart Rhythm 2015; 12(12): 2395-401.

[41] Bracke F. Complications and lead extraction in cardiac pacing and defibrillation. Netherlands Heart J 2008; 16(1): 27-30.

[42] Asif A, Salman L, Lopera G, Haqqie SS, Carrillo RG. Transvenous cardiac implantable electronic devices and hemodialysis catheters: Recommendations to curtail a potentially lethal combination. Seminars in dialysis; 2012: Wiley Online Library; 2012. p. 582-6.

[43] Teruya TH, Abou-Zamzam AM, Limm W, Wong L, Wong L. Symptomatic subclavian vein stenosis and occlusion in hemodialysis patients with transvenous pacemakers. Ann Vasc Surg 2003; 17(5): 526-9.

[44] Tan CS, Jie C, Joe J, et al. The impact of transvenous cardiac devices on vascular access patency in hemodialysis patients. Seminars in dialysis; 2013: Wiley Online Library; 2013. p. 728-32.

[45] Asif A, Salman LH, Lopera GG, Carrillo RG. The dilemma of transvenous cardiac rhythm devices in hemodialysis patients: time to consider the epicardial approach? Kidney Int 2011; 79(12): 1267-9.

[46] Asif A, Salman L, Carrillo RG, et al. ASDIN: Patency rates for angioplasty in the treatment of pacemaker-induced central venous stenosis in hemodialysis patients: Results of a multi-center study. Seminars in dialysis; 2009: Wiley Online Library; 2009. p. 671-6.

[47] Dhamija RK, Tan H, Philbin E, et al. Subcutaneous implantable cardioverter defibrillator for dialysis patients: A strategy to reduce central vein stenoses and infections. Am J Kidney Dis 2015; 66(1): 154-8.

[48] Wilkoff BL, Love CJ, Byrd CL, et al. Transvenous lead extraction: Heart Rhythm Society expert consensus on facilities, training, indications, and patient management: This document was endorsed by the American Heart Association (AHA). Heart Rhythm 2009; 6(7): 1085-104.

[49] Saad TF, Hentschel DM, Koplan B, et al. Cardiovascular implantable electronic device leads in CKD and ESRD patients: Review and recommendations for practice. Seminars in Dialysis; 2013: Wiley Online Library; 2013. p. 114-23.

[50] Feldman AM, Klein H, Tchou P, et al. Use of a wearable defibrillator in terminating tachyarrhythmias in patients at high risk for sudden death. Pacing Clin Electrophysiol 2004; 27(1): 4-9.

[51] Chung MK, Szymkiewicz SJ, Shao M, et al. Aggregate national experience with the wearable cardioverter-defibrillator: Event rates, compliance, and survival. J Am Coll Cardiol 2010; 56(3): 194-203.

[52] Adhyapak SM, Iyengar SS. Characteristics of a subset of patients with reversible systolic dysfunction in chronic kidney disease. Congest Heart Fail 2011; 17(3): 120-6.

[53] EL-Chami MF, Levy M, Kelli HM, et al. Outcome of subcutaneous implantable cardioverter defibrillator implantation in patients with end-stage renal disease on dialysis. J Cardiovasc Electrophysiol 2015; 26(8): 900-4.

[54] Coca SG, Krumholz HM, Garg AX, Parikh CR. Underrepresentation of renal disease in randomized controlled trials of cardiovascular disease. JAMA 2006; 296(11): 1377-84.