Chapter

# Practical Approach to Chest Pain Related to Cardiac Implantable Electronic Device Implantation

*Umashankar Lakshmanadoss, Imran Sulemankhil and Karnika Senthilkumar*

## Abstract

In this review article, we described the common causes and approach for chest pain that happens after cardiac device implantation surgeries. We also describe the clinical features and appropriate treatment for them.

**Keywords:** CIED implant, chest pain, pericardial effusion, pneumothorax, erosion of device

## 1. Introduction

Cardiac implantable electronic devices (CIED) are being implanted for more than 600,000 patients on a yearly basis [1]. These CIEDs include pacemakers, implantable cardioverter defibrillators, and cardiac resynchronization therapy devices [2]. These implantation surgeries are not without risk, as there are many potential complications that can occur either immediately or in a delayed setting [3–6]. Many of the complications could have a common presentation of chest pain, and depending on the etiology, morbidity, and mortality can vary widely [7]. The surgical process itself during the cardiac implantation device surgery can result in chest pain [8]. However, it is paramount to differentiate chest pain due to acute coronary syndrome (ACS) from non-ischemic causes. In the setting of a ventricular paced rhythm or left bundle branch block, this can be difficult with electrocardiography as the ST segments or T waves may hide or mimic ACS [9]. In this situation, the modified Sgarbossa criteria can be implemented to improve the diagnostic accuracy of electrocardiography in this patient population [10–12]. Hence, it is very important to identify the causes of chest pain after any cardiac implantation device surgery. In this chapter, we will discuss a practical approach to chest pain after cardiac implantation device surgery.

## 2. Chest pain after CIED implantation

For practical purposes, the etiology of chest pain after device implantation surgery could be divided based on the time of occurrence. We classified it into the following three categories:

1. Immediate chest pain (during the procedure)

2. Post procedural chest pain (in the immediate postoperative period, within 1–2 days)

3. Delayed chest pain

Just like any other surgical process, placing the leads and the devices resulted in various forms of trauma and by itself can produce chest pain. These adverse effects can occur during the procedure, in the immediate postoperative period, and well after the implant procedure.

## 2.1 Immediate chest pain during the procedure

### *2.1.1 Musculoskeletal*

Most of these CIED surgeries are performed with moderate sedation [13]. Patients who undergo CIED surgeries are commonly elderly and have multiple co-morbid conditions [14]. This clearly limits the options for adequate analgesia and sedation due to concerns for adverse effects of sedatives and analgesics. Hence, adequate local anesthesia plays a major role in terms of pain control. If the patients are not adequately anesthetized with local anesthesia, they may experience sharp pain during various parts of device implantation. Even if they are adequately anesthetized with local anesthesia, this will be effective predominantly within the subcutaneous tissue [15]. Furthermore, patients may feel sharp pain when the muscle tissue is being manipulated, especially if they have to have a suture or cauterization of the muscles secondary to inadvertent bleeding. Safe vascular access is very important to minimize the complications of CIED surgery. Hence, most of the operating physicians try to use the junction between the clavicle and first rib as a landmark to minimize the risk of pneumothorax. Typically, the axillary vein can be accessed just at the level of the first rib [16]. If the needle passes the veins "through and through" and hits the periosteum of the first rib, patients may feel this discomfort. After venous access, when the sheath is being advanced into the venous system, it could stretch the periosteum of the costoclavicular ligament which in turn can be uncomfortable for the patient. Hence, during this part of the procedure, it is very important to provide appropriate analgesia for the patient.

### *2.1.2 Pneumothorax*

Pneumothorax, hemothorax, and hydropneumothorax are some of the dangerous complications after CIED implantation [17]. Implanting-physicians always strive to minimize these complications as they increase the morbidity and mortality. These complications are reduced by using micropuncture access needles, using contrast venography to identify the veins, and using ultrasound to identify the veins [18–20]. In addition to this, some physicians also use a bolus of intravenous fluid to engorge veins. Similarly, Trendelenburg positioning or elevating the patient's legs with a wedge under the leg (without tilting the operating table) could be useful [21]. Some physicians also inject contrast when they are gaining access because the contrast tends to engorge the veins. In spite of these careful and meticulous approaches, sometimes pneumothorax is inevitable. Even though, the vein is accessed via the extrathoracic veins, it is possible that the patients may have a small bleb secondary to COPD, which through inadvertent entry may produce a pneumothorax [22]. Pneumothorax could be suspected at the earliest, when there is

aspiration of air with the introducer needle, before entering into the venous system. It is also imperative to note that the needle should be attached to the syringe air tight. Otherwise, it could give a false opinion of aspiration of air into the syringe. During access, after entering into the vein, if the patient has obstructive sleep apnea, they could create huge negative intrathoracic pressure during deep inspiration which in turn can suck in air (**Figure 1**).

Causes of pneumothorax:

1. Advancing the needle deep into the lung parenchyma, beyond the first rib
2. Accidental puncture of superficial blebs
3. Medial puncture (intrathoracic part of the subclavian vein)

If the operating physician noted any signs of aspiration of air into the syringe, then the patient should be carefully monitored for possible pneumothorax. In addition to this, patients may also develop sudden onset of chest pain, cough, hypoxia or tachycardia. During this situation, fluoroscopy can be implemented immediately to evaluate for any pneumothorax; keeping in mind that supine positioning is not the ideal method of assessing for pneumothorax.

### *2.1.3 Mediastinal bleed*

Any mediastinal bleed during CIED implantation could produce acute chest pain. This pain is typically very diffuse and radiates toward the posterior aspect of the chest secondary to mediastinal reflection [23, 24]. Patients may manifest tachycardia secondary to sympathetic stimulation and hypotension, depending upon the extent of the blood loss. This is one of the dangerous conditions, which needs to be identified and addressed as soon as possible. Inadvertent access of the subclavian artery could produce mediastinal bleed. Hence, accessing the axillary vein at the

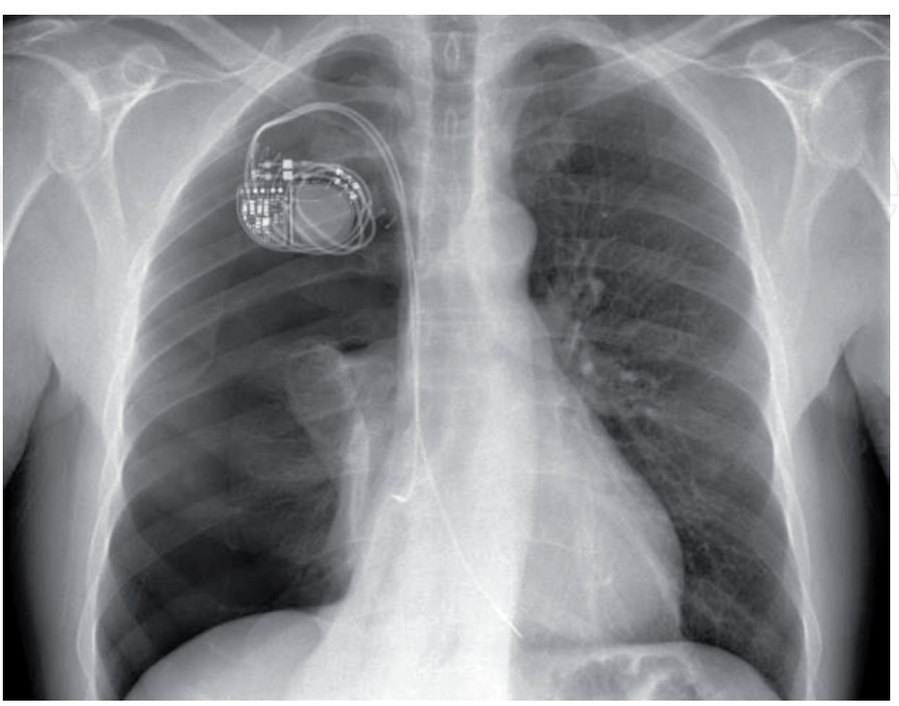

**Figure 1.**
*Chest X-ray showing right sided pneumothorax.*

level of the first rib is a preferred approach as it allows for manual compression in this situation [25, 26]. After getting access into the central system, it is very important to advance the guide wire below the diaphragm to confirm placement within the inferior vena cava and not in the arterial side prior to introduction of the sheath. This way, even if there is any inadvertent arterial access, the chances of mediastinal bleeding will be minimized. In the elderly patients, the venous system could be very tortuous especially at the level of the brachiocephalic system [27–29]. Hence, the wire and the sheath have to be advanced very carefully. If there is any resistance noted during advancement of the sheath, further advancement has to be done under fluoroscopic guidance.

#### *2.1.4 Pericardial effusion/tamponade*

During device implantation, it is possible that patients may have an acute pericardial bleed leading to either pericardial effusion or pericardial tamponade [17]. Typically, patients have chest pain, tachycardia, and clinical features consistent with cardiogenic shock [30]. Pericardial chest pain typically radiates toward the shoulder blades and also toward the trapezius muscle, at the nape of the neck, due to the pericardial reflection. Further, it may be pleuritic in nature due to rubbing of the pericardium with the pleura [31]. When there is a clinical suspicion for pericardial effusion or pericardial tamponade, immediate imaging is required without any delay; this needs to be addressed immediately, as appropriate treatment is lifesaving. Perforation at the level of the intra-pericardial superior vena cava, right atrium, right atrial appendage, coronary sinus, or right ventricle are all possible and can lead to pericardial effusion [32, 33]. If there is any suspicion of pericardial effusion, immediate fluoroscopic evaluation looking for the lateral movement of the pericardium is useful. Imaging with transthoracic echocardiogram or intracardiac echocardiogram is also of great benefit. Immediate pericardiocentesis will be lifesaving [34]. It is also possible that there may be a slow and progressively worsening pleural effusion, which may not produce any clinical symptoms immediately and patients may present with late pericardial effusion. Minimal or small pericardial effusion could be managed conservatively by following the patient very closely. High dose aspirin, colchicine, and oral corticosteroids can be used to minimize the inflammatory response [31]. However, if there is any hemodynamic compromise, pericardiocentesis is then indicated. Depending on the clinical situation, lead revision may also be indicated (**Figure 2**).

### 2.2 Intermediate chest pain, during the recovery and within 1–2 days

#### *2.2.1 Surgical site pain*

As in any surgical procedure, the most common reason for the pain is usually due to postoperative swelling and will typically respond to simple analgesics and cold compression. In addition to this, it could be due to mechanical reasons including superficial placement of the device within the subcutaneous tissue leading to too much pressure on the skin, lateral device placement in the infraclavicular region leading to mechanical irritation of the axillary nerve, nerve entrapment, etc. [35–37]. Very rarely, patients can also develop allergic reactions to the components of the CIED including titanium, cadmium, chromium, and nickel [38–40]. As these patients are typically advised to use an arm sling, their arm movements can be completely restricted which in turn could lead to shoulder pain [41, 42]; this is similar to early phase of adhesive capsulitis.

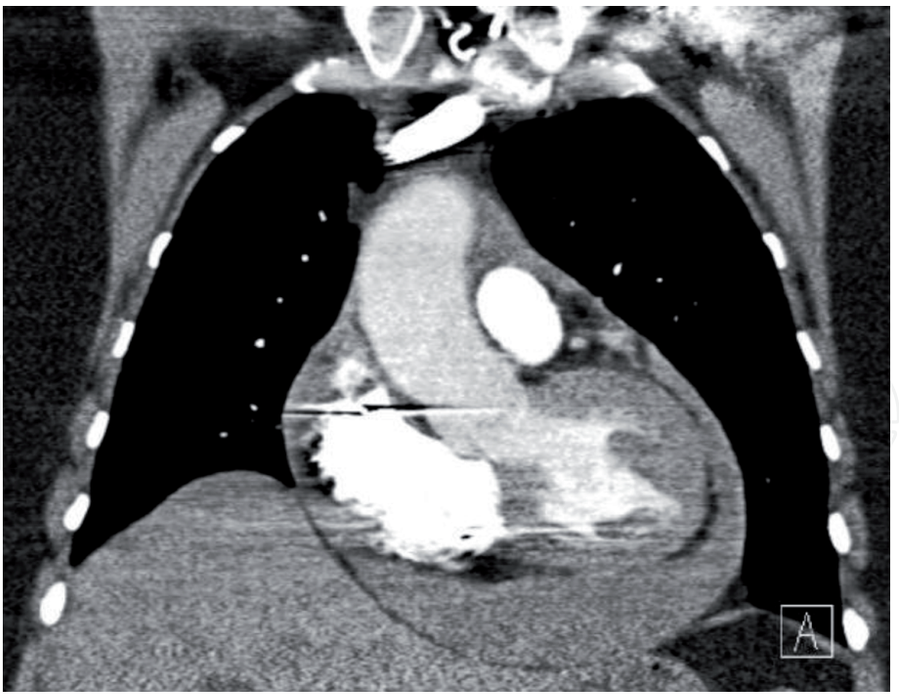


**Figure 2.**
*CT chest showing pericardial effusion.*

### *2.2.2 Pleuritic/pericardial involvement*

As discussed above, pneumothorax, pneumopericardium, hydropneumothorax, and pericardial effusion can produce delayed symptoms of pleural or pericardial pain leading to chest pain. This is typically due to a break in the continuity of the pleural or pericardial membrane secondary to lead perforation. It could be secondary to micro or macro perforations [43–45]. Nevertheless, patient symptoms of chest pain have to be evaluated very carefully and investigated accordingly. Simple chest X-ray and transthoracic echocardiogram would be sufficient in most cases [46]. Use of a CT chest could result in overreading lead perforation due to the presence of artifacts [47]. If there is any clinical suspicion for lead dislodgment, in most cases, lead revision would take care of the chest pain immediately.

### *2.2.3 Stress cardiomyopathy*

Patients may develop stress cardiomyopathy/Takotsubo cardiomyopathy, in the postoperative period. Clinically, they may present with chest pain, shortness of breath, new onset arrhythmias, and positive troponins. Transthoracic echocardiogram will show apical ballooning and basal septal sparing [48]. Cardiac catheterization can confirm the absence of any major obstructive coronary artery disease. Even though the pathophysiology of the stress cardiomyopathy is evident, etiology of stress cardiomyopathy in the setting of pacemaker implantation is not very clear. This could be secondary to the stress events which led to the device implantation, medications used for sedation, pacing induced dyssynchrony, and/or due to the stress of the surgical procedure itself [49–51].

### *2.2.4 Diaphragmatic pacing*

In a small percent of the population, it is possible that patients may have diaphragmatic pacing due to direct capture of the phrenic nerve [52]. This can be

interpreted as chest discomfort/hiccups, manifesting predominantly in certain position [53]. For a CRT device, the coronary sinus lead would be placed into the posterolateral or lateral branches which would abut the lateral wall of the left ventricle [54, 55]. The left phrenic nerve runs very close toward the lateral border of the left ventricle. Hence, this lead could be pacing the phrenic nerve and producing diaphragmatic contractions. Usually, during lead placement, high output pacing will be performed from the coronary sinus lead to rule out any phrenic nerve capture. However, secondary to displacement of the leads, it is possible that the leads can move and capture the phrenic nerve leading on to diaphragmatic contractions [56]. The right ventricular lead typically does not produce diaphragmatic pacing except in the following situations: (1) perforation of the right ventricle and migration of the lead inferiorly to produce direct capture of the diaphragm; (2) extreme RV dilation to the extent that the lateral border of the cardiac silhouette is situated near the right ventricular apex [57]. These situations require lead revision. On the other hand, the right-sided phrenic nerve travels along the lateral border of the right atrium, distant from the right atrial appendage, and can lead to diaphragmatic pacing if the right atrial lead becomes dislodged and captures the right phrenic nerve [58, 59].

## 2.3 Delayed onset chest pain

### *2.3.1 Surgical site pain*

In most patients, surgical site chest pain would resolve within a week or so. However, some patients may have prolonged, local chest discomfort secondary to increased sensitivity. Other conditions including superficial device placement leading on to pressure on the skin (usually at the margin of the device), nerve entrapment, hematoma, allergic reactions, erosion, infection, etc., have to be ruled out [35–40]. Depending upon the etiology, we may have to open the pocket again and address the primary reason for the chest pain (**Figure 3**).

### *2.3.2 Delayed cardiac perforation*

Delayed cardiac perforation secondary to CIED leads is uncommon when compared to acute perforation [60–62]. Patients will typically have symptoms of chest pain and the clinical presentation may not be as dramatic as an acute perforation. Hence a high degree of clinical suspicion needs to be maintained and early imaging including X-ray, echocardiogram, and, if needed, CT scan could be beneficial in these patients [62]. Further, device interrogation may show loss of capture, even at high output. Often these patients may need a multi-disciplinary approach including electrophysiologists and cardiothoracic surgeons [63].

### *2.3.3 Pacemaker-mediated angina*

In patients who have underlying coronary artery disease, angina can be precipitated secondary to rapid pacing [64]. Usually, pacemakers are programmed to minimize right ventricular pacing. However, dual-chamber pacemakers tract the atrial electrical activity and the ventricular pacing follows. Hence, in patients with a high sinus rate or atrial tachycardia, the right ventricle could be paced at a higher rate, thereby resulting in demand ischemia [65, 66]. In the setting of underlying clinical or subclinical coronary artery disease, this in turn can lead to angina. This presents as a classical anginal form of chest pain. This can be identified by altering the pacemaker rate. Treatment typically involves reprogramming the device

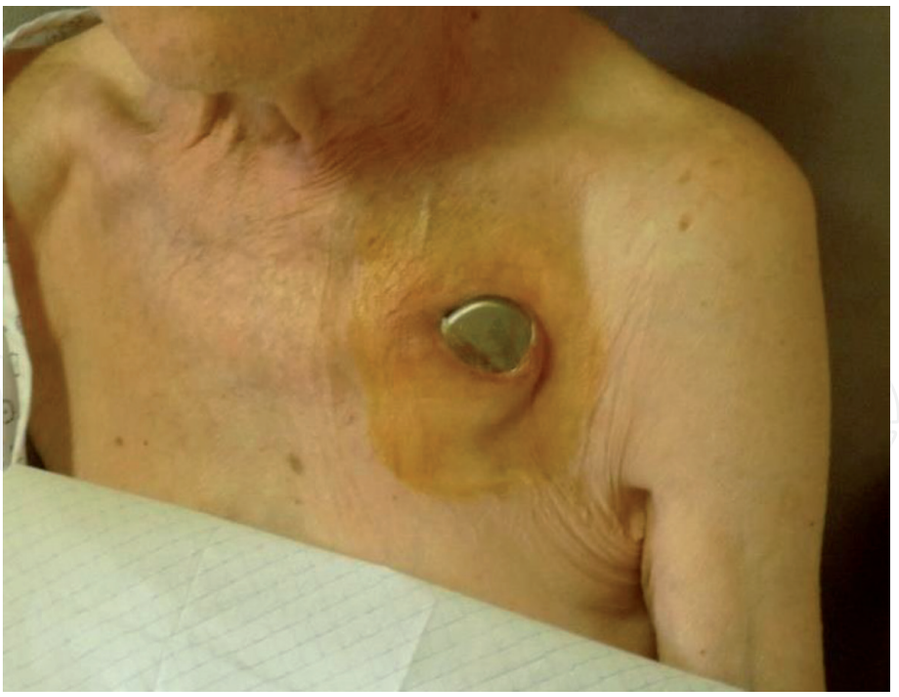

**Figure 3.**
*Cardiac implantable electronic device erosion.*

to minimize right ventricular pacing and eventually taking care of the underlying coronary artery disease [67].

*2.3.4 Post cardiac injury syndrome*

Patients who underwent CRT-D implantation may have a 3–6 week delayed onset of chest pain; this is more pericardial in nature and similar to Dressler syndrome. The main differentiating factor from delayed pericardial effusion/pericardial tamponade is that there is no pericardial fluid in this situation [68]. The pathogenesis of post cardiac injury syndrome is immune mediated. Imazio et al. proposed diagnostic criteria for post cardiac injury syndrome with at least two out of five being required [69].

1. Unexplained fever

2. Pleuritic or pericardial chest pain

3. Pericardial rub on auscultation

4. New or worsening pericardial/pleural effusion on imaging

5. Elevated inflammatory markers including CRP

These patients respond very well to high-dose of aspirin, colchicine, or oral corticosteroids.

*2.3.5 Painful left bundle branch block syndrome*

Painful left bundle branch block (LBBB) syndrome is one of the uncommon delayed conditions seen with CIED placement [70]. Patients who have right ventricular pacemaker will have left bundle branch block morphology when pacing the

right ventricle. On electrocardiography, this can be differentiated from an acute LBBB using the six criteria outlined by Shvilkin et al. [70]: abrupt onset of chest pain coinciding with the development of LBBB; simultaneous resolution of symptoms with resolution of LBBB; normal 12-lead ECGs before and after LBBB; absence of myocardial ischemia during functional stress testing; normal left ventricular function and the absence of other abnormalities to explain symptoms; and low precordial S/T wave ratio consistent with new-onset LBBB (<1.8 in this series) and inferior QRS axis.

Most of the patients tolerate right ventricular pacing without any significant clinical features. However, a small population of patients may develop significant chest pain, independent of coronary artery disease [71, 72]. Although the underlying mechanism is unclear, several mechanisms have been postulated: (1) dyssynchronous ventricular contraction occur due to paradoxical septal movement during ventricular pacing, (2) there is abnormal activation of the neurons responsible for interception ventricular pacing, and (3) there is microvascular ischemia during ventricular pacing as noted by elevated concentration of lactic acid in the coronary sinus [73–75]. A careful history and observation of chest pain only during right ventricular pacing is the clue to the correct diagnosis. Treatment of these patients is very challenging but patients may respond very well to either CRT therapy or His bundle pacing [74, 76–78].

## 3. Conclusion

Almost all the patients that undergo CIED implantation will have some sort of chest pain dependent on the time of occurrence (**Table 1**). Most of the time this is secondary to surgical site pain. However, this could also be secondary to multiple reasons including life-threatening complications. Hence, early diagnosis and prompt treatment is warranted to minimize morbidity and mortality.

| **Delayed chest pain** | **Post procedural chest pain (postoperative period, 1–2 days)** | **Immediate chest pain (perioperative period)** |
|---|---|---|
| Surgical site pain | Surgical site pain | Musculoskeletal |
| Delayed cardiac perforation | Pleuritic/pericardial involvement | Pneumothorax |
| Pacemaker-mediated angina | Stress cardiomyopathy | Mediastinal bleed |
| Post cardiac injury syndrome | Diaphragmatic pacing | Pericardial effusion/tamponade |
| Painful left bundle branch block syndrome | | |

**Table 1.**
*Chest pain occurrence after cardiac implantable electronic device.*

## Conflict of interest

The authors declare no conflict of interest.

## Author details

Umashankar Lakshmanadoss[1*], Imran Sulemankhil[2] and Karnika Senthilkumar[3]

1 Mercy Heart Institute, Cincinnati, OH, USA

2 Department of Medicine, Jewish Hospital of Cincinnati, Cincinnati, OH, USA

3 Cambridge International School, Dubai, UAE

*Address all correspondence to: drlumashankar@gmail.com

## References

[1] Wood MA, Ellenbogen KA. Cardiology patient pages. Cardiac pacemakers from the patient's perspective. Circulation. 2002;**105**(18):2136-2138

[2] Steffen MM, Osborn JS, Cutler MJ. Cardiac implantable electronic device therapy: Permanent pacemakers, implantable cardioverter defibrillators, and cardiac resynchronization devices. The Medical Clinics of North America. 2019;**103**(5):931-943

[3] Chauhan A, Grace AA, Newell SA, Stone DL, Shapiro LM, Schofield PM, et al. Early complications after dual chamber versus single chamber pacemaker implantation. Pacing and Clinical Electrophysiology. 1994;**17** (11 Pt 2):2012-2015

[4] Silva KR, Albertini CM, Crevelari ES, Carvalho EI, Fiorelli AI, Martinelli MF, et al. Complications after surgical procedures in patients with cardiac implantable electronic devices: Results of a prospective registry. Arquivos Brasileiros de Cardiologia. 2016;**107**(3):245-256

[5] Blomstrom-Lundqvist C, Traykov V, Erba PA, Burri H, Nielsen JC, Bongiorni MG, et al. European heart rhythm association (EHRA) international consensus document on how to prevent, diagnose, and treat cardiac implantable electronic device infections-endorsed by the heart rhythm society (HRS), the Asia pacific heart rhythm society (APHRS), the Latin American heart rhythm society (LAHRS), international society for cardiovascular infectious diseases (ISCVID) and the European society of clinical microbiology and infectious diseases (ESCMID) in collaboration with the European association for cardio-thoracic surgery (EACTS). Europace. 2020;**22**(4):515-549

[6] Nichols CI, Vose JG. Incidence of bleeding-related complications during primary implantation and replacement of cardiac implantable electronic devices. Journal of the American Heart Association. 2017;**6**(1):e004263. DOI: 10.1161/JAHA.116.004263

[7] Ruigomez A, Rodriguez LA, Wallander MA, Johansson S, Jones R. Chest pain in general practice: Incidence, comorbidity and mortality. Family Practice. 2006;**23**(2):167-174

[8] Biocic M, Vidosevic D, Boric M, Boric T, Giunio L, Fabijanic D, et al. Anesthesia and perioperative pain management during cardiac electronic device implantation. Journal of Pain Research. 2017;**10**:927-932

[9] Sgarbossa EB, Pinski SL, Barbagelata A, Underwood DA, Gates KB, Topol EJ, et al. Electrocardiographic diagnosis of evolving acute myocardial infarction in the presence of left bundle-branch block. GUSTO-1 (global utilization of streptokinase and tissue plasminogen activator for occluded coronary arteries) investigators. The New England Journal of Medicine. 1996;**334**(8):481-487

[10] Smith SW, Dodd KW, Henry TD, Dvorak DM, Pearce LA. Diagnosis of ST-elevation myocardial infarction in the presence of left bundle branch block with the ST-elevation to S-wave ratio in a modified sgarbossa rule. Annals of Emergency Medicine. 2012;**60**(6):766-776

[11] Abraham AS, Vinson DR, Levis JT. ECG diagnosis: Acute myocardial infarction in a ventricular-paced rhythm. The Permanente Journal. 2019;**23**: 19-001. DOI: 10.7812/TPP/19-001

[12] Maloy KR, Bhat R, Davis J, Reed K, Morrissey R. Sgarbossa criteria are

highly specific for acute myocardial infarction with pacemakers. The Western Journal of Emergency Medicine. 2010;**11**(4):354-357

[13] Furniss SS, Sneyd JR. Safe sedation in modern cardiological practice. Heart. 2015;**101**(19):1526-1530

[14] Lim WY, Prabhu S, Schilling RJ. Implantable cardiac electronic devices in the elderly population. Arrhythmia & Electrophysiology Review. 2019;**8**(2):143-146

[15] Becker DE, Reed KL. Essentials of local anesthetic pharmacology. Anesthesia Progress. 2006;**53**(3):98-108

[16] Poole JE, Larson W. Surgical Implantation of Cardiac Rhythm Devices. United States: Elsevier Health Sciences; 2017. pp. 20-25

[17] Aktaa S, Fatania K, Gains C, White H. Chest pain following permanent pacemaker insertion... a case of pneumopericardium due to atrial lead perforation. BML Case Reports. 2018:**2018**. DOI: 10.1136/bcr,2018-226318

[18] Gunda S, Reddy M, Pillarisetti J, Atoui M, Badhwar N, Swarup V, et al. Differences in complication rates between large bore needle and a long micropuncture needle during epicardial access: Time to change clinical practice? Circulation. Arrhythmia and Electrophysiology. 2015;**8**(4):890-895

[19] Seto AH, Abu-Fadel MS, Sparling JM, Zacharias SJ, Daly TS, Harrison AT, et al. Real-time ultrasound guidance facilitates femoral arterial access and reduces vascular complications: FAUST (femoral arterial access with ultrasound trial). JACC. Cardiovascular Interventions. 2010;**3**(7):751-758

[20] Albertini CMM, Silva KRD, Leal Filho JMDM, Crevelari ES, Martinelli Filho M, Carnevale FC, et al. Usefulness of preoperative venography in patients with cardiac implantable electronic devices submitted to lead replacement or device upgrade procedures. Arquivos Brasileiros de Cardiologia. 2018;**111**(5):686-696

[21] Jaroszewski DE, Altemose GT, Scott LR, Srivasthan K, Devaleria PA, Lackey J, et al. Nontraditional surgical approaches for implantation of pacemaker and cardioverter defibrillator systems in patients with limited venous access. The Annals of Thoracic Surgery. 2009;**88**(1):112-116

[22] Kirkfeldt RE, Johansen JB, Nohr EA, Moller M, Arnsbo P, Nielsen JC. Pneumothorax in cardiac pacing: A population-based cohort study of 28,860 Danish patients. Europace. 2012;**14**(8):1132-1138

[23] Scumpia A, Dekok M, Aronovich D, Bajwa G, Barros R, Katz R, et al. Acute chest pain in a patient with a non-strangulated hiatal hernia. Journal of Acute Disease. 2015;**4**(4):344-346

[24] Seo YH, Kwak JY. Spontaneous hemomediastinum and hemothorax caused by a ruptured bronchial artery aneurysm. The Korean Journal of Thoracic and Cardiovascular Surgery. 2011;**44**(4):314-317

[25] Migliore F, Siciliano M, De Lazzari M, Ferretto S, Valle CD, Zorzi A, et al. Axillary vein puncture using fluoroscopic landmarks: A safe and effective approach for implantable cardioverter defibrillator leads. Journal of Interventional Cardiac Electrophysiology. 2015;**43**(3):263-267

[26] Yang F, Kulbak G. A new trick to a routine procedure: Taking the fear out of the axillary vein stick using the 35 degrees caudal view. Europace. 2015;**17**(7):1157-1160

[27] Thomas JB, Antiga L, Che SL, Milner JS, Steinman DA, Spence JD, et al. Variation in the carotid bifurcation geometry of young versus older adults: Implications for geometric risk of atherosclerosis. Stroke. 2005;**36**(11):2450-2456

[28] Lam RC, Lin SC, DeRubertis B, Hynecek R, Kent KC, Faries PL. The impact of increasing age on anatomic factors affecting carotid angioplasty and stenting. Journal of Vascular Surgery. 2007;**45**(5):875-880

[29] Del Corso L, Moruzzo D, Conte B, Agelli M, Romanelli AM, Pastine F, et al. Tortuosity, kinking, and coiling of the carotid artery: Expression of atherosclerosis or aging? Angiology. 1998;**49**(5):361-371

[30] James HA, Wan SH, Wylam ME. Delayed post-operative cardiac tamponade manifesting as cardiogenic shock. Journal of Cardiology Cases. 2013;**8**(6):195-197

[31] Goyle KK, Walling AD. Diagnosing pericarditis. American Family Physician. 2002;**66**(9):1695-1702

[32] Yamada T, Kay GN. In: Huang SKS, Miller JM, editors. Complications Associated with Radiofrequency Catheter Ablation of Arrhythmias. Philadelphia: Content Repository Only! 2019. p. 636. DOI: 10.1016/B978-0-323-52992-1.00038-7

[33] Provaznik Z, Holzamer A, Camboni D, Rupprecht L, Resch M, Wittmann S, et al. Perforation of myocardial wall and great vessels after cardiovascular interventions-a 5-year analysis. The Journal of Thoracic Disease. 2017;**9**(12):5288-5294

[34] American College of Cardiology. 2017. Available from: https://www.acc.org/latest-in-cardiology/articles/2017/10/27/10/20/managing-pericardium-in-electrophysiology-procedures

[35] Jumper N, Radotra I, Witt P, Campbell NG, Mishra A. Brachial plexus impingement secondary to implantable cardioverter defibrillator: A case report. Archives of Plastic Surgery. 2019;**26**:594-598

[36] Harcombe AA, Newell SA, Ludman PF, Wistow TE, Sharples LD, Schofield PM, et al. Late complications following permanent pacemaker implantation or elective unit replacement. Heart. 1998;**80**(3):240-244

[37] Kolker AR, Redstone JS, Tutela JP. Salvage of exposed implantable cardiac electrical devices and lead systems with pocket change and local flap coverage. Annals of Plastic Surgery. 2007;**59**(1):26. Discussion 30

[38] Shittu M, Shah P, Elkhalili W, Suleiman A, Shaaban H, Shah PA, et al. A rare case of recurrent pacemaker allergic reaction. Heart Views. 2015;**16**(2):59-61

[39] Abdallah HI, Balsara RK, O'Riordan AC. Pacemaker contact sensitivity: Clinical recognition and management. The Annals of Thoracic Surgery. 1994;**57**(4):1017-1018

[40] Honari G, Raissi F. Hypersensitivity to cardiovascular implants: Cardiac implantable electronic devices and septal occluders. In: Chen J, Thyssen J, editors. Metal Allergy: From Dermatitis to Implant and Device Failure. Cham: Springer International Publishing; 2018. pp. 273-283

[41] Celikyurt U, Agacdiken A, Bozyel S, Argan O, Sade I, Vural A, et al. Assessment of shoulder pain and shoulder disability in patients with implantable cardioverter-defibrillator. Journal of Interventional Cardiac Electrophysiology. 2013;**36**(1):91-94

[42] Findikoglu G, Yildiz BS, Sanlialp M, Alihanoglu YI, Kilic ID, Evregul H, et al. Limitation of motion and

shoulder disabilities in patients with cardiac implantable electronic devices. International Journal of Rehabilitation Research. 2015;**38**(4):287-293

[43] Mahapatra S, Bybee KA, Bunch TJ, Espinosa RE, Sinak LJ, McGoon MD, et al. Incidence and predictors of cardiac perforation after permanent pacemaker placement. Heart Rhythm. 2005;**2**(9):907-911

[44] Cano O, Andres A, Alonso P, Osca J, Sancho-Tello MJ, Olague J, et al. Incidence and predictors of clinically relevant cardiac perforation associated with systematic implantation of active-fixation pacing and defibrillation leads: A single-Centre experience with over 3800 implanted leads. Europace. 2017;**19**(1):96-102

[45] Vanezis AP, Prasad R, Andrews R. Pacemaker leads and cardiac perforation. JRSM Open. 2017;**8**(3):2054270416681432

[46] Rajkumar CA, Claridge S, Jackson T, Behar J, Johnson J, Sohal M, et al. Diagnosis and management of iatrogenic cardiac perforation caused by pacemaker and defibrillator leads. Europace. 2017;**19**(6):1031-1037

[47] Barrett JF, Keat N. Artifacts in CT: Recognition and avoidance. Radiographics. 2004;**24**(6):1679-1691

[48] Merchant EE, Johnson SW, Nguyen P, Kang C, Mallon WK. Takotsubo cardiomyopathy: A case series and review of the literature. The Western Journal of Emergency Medicine. 2008;**9**(2):104-111

[49] Wei ZH, Dai Q, Wu H, Song J, Wang L, Xu B. Takotsubo cardiomyopathy after pacemaker implantation. Journal of Geriatric Cardiology. 2018;**15**(3):246-248

[50] Gardini A, Fracassi F, Boldi E, Albiero R. Apical ballooning syndrome (takotsubo cardiomyopathy) after permanent dual-chamber pacemaker implantation. Case Reports in Cardiology. 2012;**2012**:308580

[51] Postema PG, Wiersma JJ, van der Bilt IA, Dekkers P, van Bergen PF. Takotsubo cardiomyopathy shortly following pacemaker implantation-case report and review of the literature. Netherlands Heart Journal. 2014;**22**(10):456-459

[52] Jefferies JL, Younis GA, Flamm SD, Rasekh A, Massumi A. Chest pain and diaphragmatic pacing after pacemaker implantation. Texas Heart Institute Journal. 2005;**32**(1):106-107

[53] Shah R, Qualls Z. Diaphragmatic stimulation caused by cardiac resynchronization treatment. CMAJ. 2016;**188**(10):E239

[54] Habib A, Lachman N, Christensen KN, Asirvatham SJ. The anatomy of the coronary sinus venous system for the cardiac electrophysiologist. Europace. 2009;**11**(Suppl 5):v15-v21

[55] Shah SS, Teague SD, Lu JC, Dorfman AL, Kazerooni EA, Agarwal PP. Imaging of the coronary sinus: Normal anatomy and congenital abnormalities. Radiographics. 2012;**32**(4):991-1008

[56] Moubarak G, Bouzeman A, Ollitrault J, Anselme F, Cazeau S. Phrenic nerve stimulation in cardiac resynchronization therapy. Journal of Interventional Cardiac Electrophysiology. 2014;**41**(1):15-21

[57] Banaszewski M, Stepinska J. Right heart perforation by pacemaker leads. Archives of Medical Science. 2012;**8**(1):11-13

[58] Namazi M, Karbasi-Afshar R, Safi M, Serati A. Diaphragmatic stimulation: A case of atrial lead

dislodgement and right atrium perforation. Indian Pacing and Electrophysiology Journal. 2008;**8**(2):133-136

[59] Tanabe K, Kotoda M, Nakashige D, Mitsui K, Ikemoto K, Matsukawa T. Sudden onset pacemaker-induced diaphragmatic twitching during general anesthesia. JA Clinical Reports. 2019;**5**(1):36

[60] Semmler V, Fichtner S, Lennerz C, Kolb C. Very late perforation of an implantable cardioverter defibrillator lead: A case report. The British Journal of General Practice. 2014;**64**(619):107-108

[61] Alla VM, Reddy YM, Abide W, Hee T, Hunter C. Delayed lead perforation: Can we ever let the guard down? Cardiology Research and Practice. 2010;**2010**:741-751. DOI: 10.4061/2010/741751

[62] Refaat MM, Hashash JG, Shalaby AA. Late perforation by cardiac implantable electronic device leads: Clinical presentation, diagnostic clues, and management. Clinical Cardiology. 2010;**33**(8):466-475

[63] Chao JA, Firstenberg MS. Delayed pacemaker lead perforations: Why unusual presentations should prompt an early multidisciplinary team approach. International Journal of Critical Illness and Injury Science. 2017;**7**(1):65-68

[64] Ibrahim M, Hasan R. Pacemaker-mediated angina. Experimental & Clinical Cardiology. 2013;**18**(1):35-37

[65] Duray GZ, Israel CW, Wegener FT, Hohnloser SH. Tachycardia after pacemaker implantation in a patient with complete atrioventricular block. Europace. 2007;**9**(10):900-903

[66] Mirescu NC, Muresan L, Farcas AD. A rare case of pacemaker induced tachycardia in an elderly woman with cor triatriatum sinistrum. Oxford Medical Case Reports. 2017;**2017**(8):omx047

[67] Doppalapudi H. In: Ellenbogen KA, Wilkoff BL, Kay GN, Lau C, Auricchio A, editors. Timing Cycles of Implantable Devices. Philadelphia, PA: Elsevier; 2017. p. 961. DOI: 10.1016/B978-0-323-37804-8.00036-5

[68] Wessman DE, Stafford CM. The postcardiac injury syndrome: Case report and review of the literature. Southern Medical Journal. 2006;**99**(3):309-314

[69] Imazio M, Hoit BD. Post-cardiac injury syndromes: An emerging cause of pericardial diseases. International Journal of Cardiology. 2013;**168**(2):648-652

[70] Shvilkin A, Ellis ER, Gervino EV, Litvak AD, Buxton AE, Josephson ME. Painful left bundle branch block syndrome: Clinical and electrocardiographic features and further directions for evaluation and treatment. Heart Rhythm. 2016;**13**(1):226-232

[71] Ebrille E, DeSimone CV, Vaidya VR, Chahal AA, Nkomo VT, Asirvatham SJ. Ventricular pacing - electromechanical consequences and valvular function. Indian Pacing and Electrophysiology Journal. 2016;**16**(1):19-30

[72] Tops LF, Schalij MJ, Bax JJ. The effects of right ventricular apical pacing on ventricular function and dyssynchrony implications for therapy. Journal of the American College of Cardiology. 2009;**54**(9):764-776

[73] Virtanen KS, Heikkila J, Kala R, Siltanen P. Chest pain and rate-dependent left bundle branch block in patients with normal coronary arteriograms. Chest. 1982;**81**(3):326-331

[74] Sroubek J, Tugal D, Zimetbaum PJ, Shvilkin A, Buxton AE. Treatment

of painful left bundle branch block syndrome with cardiac resynchronization therapy or right-ventricular pacing. HeartRhythm Case Reports. 2019;**5**(6):321-324

[75] Mora B, Douard H, Barat JL, Broustet JP. Simultaneous occurrence of left heart block and chest pain during exertion. Archives des maladies du coeur et des vaisseaux. 1987;**80**(12):1807-1811

[76] Oladunjoye OO, Oladunjoye AO, Oladiran O, Callans DJ, Schaller RD, Licata A. Persistent exertional chest pain in a marathon runner: Exercise-induced, painful, left bundle branch block syndrome treated with his-bundle pacing. Mayo Clinic Proceedings: Innovations, Quality & Outcomes. 2019;**3**(2):226-230

[77] Suryanarayana PG, Frankel DS, Marchlinski FE, Schaller RD. Painful left bundle branch block [corrected] syndrome treated successfully with permanent his bundle pacing. HeartRhythm Case Reports. 2018;**4**(10):439-443

[78] Viles-Gonzalez JF, Mahata I, Anter E, d'Avila A. Painful left bundle branch block syndrome treated with his bundle pacing. Journal of Electrocardiology. 2018;**51**(6):1019-1022