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scattered reports of palliation with radiotherapy and/or chemother apy, the response of cardiac sarcomas to these therapies is generally poor. The one exception appears to be cardiac lymphosarcomas, which may respond to a combination of chemo- and radiotherapy. Primary cardiac lymphoma is the most chemotherapy-sensitive primary cardiac malignancy, with long-term survival achieved in ~40% of treated individuals. ■ ■TUMORS METASTATIC TO THE HEART Metastatic cardiac tumors are much more common than primary cardiac tumors, and their incidence is likely to increase as the life expectancy of patients with various forms of malignant neoplasms is extended by more effective therapy and improved imaging modalities allow earlier identification of metastatic disease. Although cardiac metastases may occur with any tumor type, the relative incidence is especially high in malignant melanoma and, to a somewhat lesser extent, leukemia and lymphoma (Fig. 282-4). In absolute terms, the most common primary sites from which cardiac metastases originate are carcinoma of the breast and lung, reflecting the high incidence of these malignancies. Cardiac metastases almost always occur in the set ting of widespread primary disease; most often, there is either primary or metastatic disease elsewhere in the thoracic cavity. Cardiac metastases may occur via hematogenous or lymphangitic spread or by direct tumor invasion. While they generally manifest as small, firm nodules, diffuse infiltration also may occur, especially with sarcomas or hematologic neoplasms. The pericardium is most often involved, followed by myocardial involvement of any chamber and, rarely, by involvement of the endocardium or cardiac valves. Cardiac metastases are clinically apparent only ~10% of the time, are usually not the cause of the patient’s presentation, and rarely are the cause of death. The vast majority occur in the setting of a previously recognized malignant neoplasm. As with primary cardiac tumors, the clinical presentation reflects more the location and size of the tumor than its histologic type. When symptomatic, cardiac metastases may result in a variety of clinical features, including dyspnea, acute pericar ditis, cardiac tamponade, ectopic tachyarrhythmias, heart block, and CHF. Importantly, many of these signs and symptoms may also result from myocarditis, pericarditis, or cardiomyopathy induced by radio therapy or chemotherapy, and a high index of suspicion for cardiac involvement should be maintained for patients with malignant disease who develop these symptoms. Electrocardiographic (ECG) findings are nonspecific but may reveal features consistent with pericarditis or may demonstrate low QRS volt age and electrical alternans in the setting of a large pericardial effusion. On chest x-ray, the cardiac silhouette is most often normal but may be enlarged or exhibit a bizarre contour. Echocardiography is useful for Met RV LV LA FIGURE 282-4 Large metastatic lesion (Met) in the left ventricle (LV) of a patient with diffusely metastatic bladder cancer. The mass arose from the interventricular septum and prolapsed into the aortic outflow tract during systole.

identifying and assessing the significance of pericardial effusions and visualizing larger metastases, although CT and radionuclide imaging may define the tumor burden more clearly. Cardiac MRI offers superb image quality and plays a central role in the diagnostic evaluation of cardiac metastases and cardiac tumors in general. Pericardiocentesis may allow for a specific cytologic diagnosis in patients with malignant pericardial effusions with a reported sensitivity of 67–92%. Angiogra phy is rarely necessary but may help to delineate discrete myocardial lesions.

CHAPTER 283 Cardiac Trauma TREATMENT Tumors Metastatic to the Heart Most patients with cardiac metastases have advanced malignant disease; thus, therapy is generally palliative and consists of control ling symptoms and treatment of the primary tumor. Symptomatic malignant pericardial effusions should be drained by pericardiocen tesis. For patients with refractory or recurrent malignant pericardial effusion, the surgical creation of a pericardial window allowing for drainage of the effusion to the adjacent pleural or peritoneal space may prevent recurrent pericardial tamponade. Prolonged drainage (3–5 days) and concomitant instillation of a sclerosing agent (e.g., bleomycin) can be considered as a palliative measure in terminally ill patients. Given the overall poor prognosis of these patients, dis cussions regarding goals of care and involvement of palliative care services are often appropriate. ■ ■FURTHER READING Bussani R et al: Cardiac tumors: Diagnosis, prognosis and treatment. Curr Cardiol Rep 22:169, 2020. Mousavi N et al: Assessment of cardiac masses by cardiac magnetic resonance imaging: Histological correlation and clinical outcomes. J Am Heart Assoc 8:e007829, 2019. Shapira O et al: Tumors of the heart, in Sabiston and Spenser Surgery of the Chest, 9th ed, FW Sellke et al (eds). Philadelphia, Elsevier, 2016, pp 1849–1857. Tamin SS et al: Prognostic and bioepidemiologic implications of papil lary fibroelastomas. J Am Coll Cardiol 65:2420, 2015. Young PM et al: Computed tomography imaging of cardiac masses. Radiol Clin N Am 57:75, 2019. Alexandra R. Pipilas, Eric H. Awtry

Cardiac Trauma ■ ■CARDIAC TRAUMA Traumatic cardiac injury may be caused by either penetrating or nonpenetrating trauma; the latter is often referred to as blunt cardiac injury (BCI). Penetrating injuries most often result from gunshot or knife wounds, and the site of entry is usually obvious. Blunt cardiac injuries most often occur during motor vehicle accidents, either from rapid deceleration or from impact of the chest, but can also result from falls from heights, crush injuries, blast injuries, violent assault, or significant physical contact during sporting events. Importantly, rapid deceleration following motor vehicle accidents may be associated with significant cardiac injury even in the absence of external signs of thoracic trauma. ■ ■BLUNT CARDIAC INJURY Myocardial contusion is a nonspecific term that has been used to describe a broad spectrum of nonpenetrating cardiac injuries that

TABLE 283-1 Spectrum of Cardiac Abnormalities Following Blunt Cardiac Injury ABNORMALITY COMMENTS ECG abnormalities Sinus tachycardia, RBBB, heart block, ST-T wave abnormalities, atrial and ventricular arrhythmias PART 6 Disorders of the Cardiovascular System Elevated cardiac biomarkers Troponin I or T are most specific Focal wall motion abnormality or hematoma Most commonly involving RV free wall, LV apex, and interventricular septum Valvular insufficiency Most commonly involving mitral and tricuspid valves and occasionally the aortic valve Myocardial rupture Ventricular septal defect or free wall rupture Coronary artery injury Most commonly involving the LAD; usually presents as STEMI Pericardial effusion and tamponade Resulting from free wall rupture or coronary artery laceration Abbreviations: ECG, electrocardiogram; LAD, left anterior descending coronary artery; LV, left ventricle; RBBB, right bundle branch block; RV, right ventricle; STEMI, ST-segment elevation myocardial infarction. result in abnormalities on electrocardiogram (ECG), elevation in cardiac biomarkers, and acute structural cardiac abnormalities (Table 283-1). Importantly, the cardiac injury may initially be overlooked in trauma patients as the clinical focus is directed toward other, more obvious injuries. Unfortunately, there is no one sign or symptom that confirms the diagnosis of BCI, and clinical, laboratory, and radiographic find ings may be nonspecific in the setting of significant trauma. The physi cal examination may be challenging in the setting of chest wall injury; however, patients should be carefully examined to detect pericardial rubs, cardiac murmurs, and evidence of pericardial tamponade (Chap. 281). The mechanism of injury and the presence of other chest trauma should be considered when determining the index of suspicion for BCI; however, there is no proven association between sternal or rib fractures and the presence of BCI, and significant cardiac injury may be present in the absence of chest wall abnormalities. Chest pain is common following thoracic trauma, and while it can indicate cardiac ischemia or pericardial injury, it often reflects mus culoskeletal trauma. Nonetheless, myocardial necrosis may occur as a direct result of the blunt injury or as a result of traumatic coronary laceration, dissection, or thrombosis. The injured myocardium is pathologically similar to infarcted myocardium and may be associ ated with atrial or ventricular arrhythmias, conduction disturbances including bundle branch and atrioventricular (AV) nodal block, or abnormalities on ECG resembling those of infarction or pericarditis. Thus, it is important to obtain an ECG in all patients presenting with chest trauma. Serum creatine kinase, myocardial band (CK-MB) isoenzyme levels are increased in ~20% of patients who experience blunt chest trauma but may be falsely elevated in the presence of massive skeletal muscle injury and should not be relied upon to confirm the diagnosis of BCI in the setting of trauma. Cardiac troponin levels are more specific for identifying cardiac damage; patients with normal serial troponin levels after chest trauma are very unlikely to have sustained cardiac injury. When combined with a normal ECG, a normal troponin level at 6–8 h after chest trauma essentially excludes BCI. Echocardiography is the most useful modality for the detection of structural and functional sequelae of BCI, including regional wall motion abnormalities (most commonly involving the right ventricle, interventricular septum, or left ventricular apex), pericardial effusion, valvular dysfunction, and ventricular or ventricular septal rupture. A transthoracic echocardio gram (TTE) should be performed in all patients with suspected BCI, especially in those with an abnormal ECG, elevated troponin, or hemo dynamic instability; transesophageal echocardiography should be con sidered for patients in whom adequate TTE images cannot be obtained. Traumatic rupture of the cardiac valves or their supporting struc tures, most commonly of the tricuspid or aortic valves, leads to acute valvular incompetence. This complication is usually heralded by the development of a loud murmur, may be associated with rapidly

progressive heart failure, and can be diagnosed by either TTE or trans esophageal echocardiography. BCI may also result in dissection, occlu sion, or laceration of the coronary arteries. ST elevation may be seen on the ECG, and prompt intervention is often required. The most serious consequence of nonpenetrating cardiac injury is myocardial rupture. Free wall rupture may result in hemopericar dium and tamponade while a ventricular septal rupture can result in significant intracardiac shunting. Although generally fatal, up to 40% of patients with cardiac rupture have been reported to survive long enough to reach a specialized trauma center. Hemopericardium also may result from traumatic rupture of a pericardial vessel or a coro nary artery. Additionally, pericarditis and/or pericardial effusion may develop weeks or even months after blunt chest trauma as a manifesta tion of the post–cardiac injury syndrome, an inflammatory condition that resembles the postpericardiotomy syndrome (Chap. 281). Blunt, nonpenetrating, often innocent-appearing injuries to the chest may trigger ventricular fibrillation even in the absence of struc tural myocardial damage. This syndrome, referred to as commotio cordis, occurs most often in adolescents during sporting events (e.g., baseball, hockey, football, and lacrosse) and is an electrical phenom enon that probably results from an impact to the chest wall overlying the heart during the susceptible phase of repolarization (just before the peak of the T wave). Survival depends on prompt defibrillation. Sudden emotional or physical trauma, even in the absence of direct cardiac trauma, may precipitate a transient catecholamine-mediated cardiomyopathy referred to as takotsubo syndrome or apical ballooning syndrome (Chaps. 266–270). Rupture or transection of the aorta, usually just above the aortic valve or at the site of the tethering ligamentum arteriosum, is a com mon consequence of nonpenetrating chest trauma and is the most common vascular deceleration injury. The clinical presentation may be similar to that of aortic dissection (Chap. 291); the arterial pressure and pulse amplitude may be increased in the upper extremities and decreased in the lower extremities, and chest x-ray may reveal medi astinal widening. Aortic rupture into the left thoracic space is almost universally fatal; however, the rupture may occasionally be contained by the aortic adventitia, resulting in a false, or pseudo-, aneurysm that may be discovered months or years after the initial injury. TREATMENT Blunt Cardiac Injury The treatment of BCI depends on the specific injury sustained. Hemodynamically stable patients with a normal ECG and normal serial troponin levels are at low risk for BCI and usually do not require hospital admission for cardiac issues. Patients with an abnormal ECG, including those with conduction disturbances, and/ or elevated troponin but normal echocardiogram usually warrant 24–48 h of telemetry monitoring; however, other specific cardiac treatment is not usually required in the absence of the development of arrhythmias, as conduction disturbances are often transient. Patients with mechanical complications (acute valvular insuffi ciency, myocardial rupture) require urgent operative correction. ■ ■PENETRATING CARDIAC INJURY Penetrating injuries of the heart produced by knife or bullet wounds usually result in rapid clinical deterioration and frequently in death as a result of hemopericardium/pericardial tamponade or massive hemorrhage. Nonetheless, up to half of such patients may survive long enough to reach a specialized trauma center if immediate resuscitation is performed. Prognosis in these patients relates to the mechanism of injury, the specific cardiac chamber(s) involved, and their clinical con dition at presentation. In general, gunshot wounds are associated with a higher mortality than are knife wounds. Twenty percent of shooting victims survive versus up to 65% of stabbing victims. This is likely in part because ballistic wounds are more frequently associated with mul tichamber cardiac injury. As a result of its anterior position in the chest, the right ventricle (RV) is the most frequently injured cardiac chamber,

RV LV A B FIGURE 283-1 Transthoracic echocardiogram demonstrating a traumatic ventricular septal defect. The patient underwent emergent repair of the right ventricle following a self-inflicted stab wound to the chest. Subsequent two-dimensional imaging (A) revealed a laceration of the interventricular septum (arrow) with color flow Doppler (B) demonstrating prominent left-to-right shunting across the defect. LV, left ventricle; RV, right ventricle. followed by the left ventricle (LV); isolated atrial injury is uncommon. Some studies suggest that RV injuries may be associated with a better prognosis than LV injuries, and most reports indicate that multicham ber involvement carries a worse prognosis than single-chamber injury. Patients who are in hemodynamic collapse at presentation to the emer gency department have a particularly poor prognosis with a mortality rate approaching 90%, whereas ~75% of patients who are stable enough to be brought to the operating room will survive. Cardiac perforation of the right atrium, the RV free wall, or the interventricular septum may occur as a complication of cardiac pro cedures including placement of central venous/intracardiac catheters, insertion of pacemaker/defibrillator leads, or performance of RV endo myocardial biopsies; and coronary arterial perforation can occur dur ing deployment of intracoronary stents. These iatrogenic injuries are associated with a better prognosis than are other forms of penetrating cardiac trauma, likely related to a more limited degree of cardiac injury and the rapid availability of corrective therapies. Traumatic rupture of a great vessel from penetrating injury is usually associated with hemothorax and, less often, hemopericardium, both of which are associated with significant mortality. Local hematoma formation may compress adjacent vessels and produce ischemic symp toms, and arteriovenous fistulas may develop, occasionally resulting in high-output heart failure. Some patients with penetrating chest injuries are hemodynamically stable at presentation and without symptoms to suggest cardiac injury; however, as many as 20% of these patients will have occult penetrating cardiac trauma. As a result, there should always be a high index of sus picion for cardiac injury in any patient with penetrating chest trauma, irrespective of clinical stability. TTE should be performed in all of these patients to assess for the presence of pericardial effusion or hematoma. Occasionally, patients who survive penetrating cardiac injuries may subsequently present days or weeks later with a new cardiac murmur or heart failure as a result of mitral or tricuspid regurgitation or an intracardiac shunt (i.e., ventricular or atrial septal defect, aortopulmo nary fistula, or coronary arteriovenous fistula) that was undetected at the time of the initial injury or developed subsequently (Fig. 283-1). Therefore, trauma patients should be examined carefully several weeks after the injury. If a mechanical complication is suspected, it can be confirmed by echocardiography or cardiac catheterization.

CHAPTER 283 Cardiac Trauma TREATMENT Penetrating Cardiac Injury Penetrating cardiac injury associated with hemodynamic insta bility is a surgical emergency and requires immediate resuscita tive measures including endotracheal intubation, establishment of large-bore intravenous access to facilitate massive volume resuscita tion, and immediate thoracotomy to allow for pericardial drainage and repair of cardiac injuries. Occasionally, cross-clamping of the descending aorta is required to perfuse the heart and brain pref erentially until hemodynamic stability can be achieved. Hemody namically stable patients in whom echocardiography reveals even a small pericardial effusion require urgent surgical exploration to evaluate for occult cardiac perforation. Pericardiocentesis may be lifesaving in patients with tamponade but is usually only a tempo rizing measure while awaiting definitive surgical therapy. In some survivors of penetrating cardiac injury, the pericardial hemorrhage predisposes to the development of constriction (Chap. 281), which may require surgical decortication. ■ ■FURTHER READING Ali H et al: Clinical and electrocardiographic features of complete heart block after blunt cardiac injury: A systematic review of the literature. Heart Rhythm 14:1561, 2017. Biffl WL et at: Diagnosis and management of blunt cardiac injury: What you need to know. J Trauma Acute Care Surg 96:685, 2024. Crawford T et al: Thoracic trauma, in Sabiston and Spencer Surgery of the Chest, 9th ed, FW Sellke et al (eds). Philadelphia, Elsevier, 2016, pp 100–130. Ismailov RM et al: Trauma associated with cardiac dysrhythmias: Results from a large, matched case-control study. J Trauma 62:1186, 2007. Morse BC et al: Penetrating cardiac injuries: A 36-year perspective at an urban level 1 trauma center. J Trauma Acute Care Surg 81:623, 2016. Wu Y et al: Imaging of cardiac trauma. Radiol Clin N Am 57:795, 2019. Yousef R, Carr JA: Blunt cardiac trauma: A review of the current knowledge and management. Ann Thorac Surg 98:1134, 2014.

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