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Blunt Cardiac Rupture Caused by Zip Gun Backfire

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A 16-year-old boy who sustained right ventricular rupture after backfiring of a homemade zip gun is reported. The unusual nature of this case together with the mechanisms and management of blunt cardiac rupture are briefly discussed.

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Blunt cardiac rupture occurs in 0.5% of patients sustaining blunt trauma [1]. The overall mortality rate of myocardial rupture is between 76% and 93%, whereas it is between 29% and 50% for hospital patients [1-4]. Most reported cases have followed motor vehicle accidents. More than half the patients have a delay in intervention of 1 hour after arrival in the hospital, and in 5% of all cardiac ruptures this delay is 6 or more hours, emphasizing that awareness of the condition is important to prevent morbidity associated with delayed diagnosis [1].

A 16-year-old boy was admitted to a peripheral hospital at 4:40 PM after the misfiring of a zip gun. Apparently,

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when the weapon was test fired, the bolt recoiled back into his chest and struck him over the left fifth costal cartilage adjacent to the sternum. On admission he was shocked with no recordable blood pressure, distended neck veins, and soft heart sounds. He was resuscitated and started on a regimen of dopamine for inotropic support with a diagnosis of cardiac contusion. An electrocardiogram showed ST segment elevation over chest leads V₁ to V₃, and his chest roentgenogram showed a globular heart shadow.

He was transferred to Groote Schuur Hospital, and on arrival at 8 PM he was shocked and was assessed as having cardiac tamponade. A central venous catheter was placed and the central venous pressure was recorded at 34 cm H₂O. Immediate ultrasound measured 16 mm of pericardial fluid anterior to the heart. Of particular interest was the hexagonal bruise about 1.5 cm in diameter at the site of the injury.

The patient was transferred to the operating room immediately. Before induction of anesthesia, the patient was prepared and draped. With induction of anesthesia the patient's blood pressure became unrecordable. A sternotomy was performed immediately. The pericardium, which was intact, was opened in the midline, and 300 mL of dark blood and clot in the pericardium was evacuated. An actively bleeding 3-cm longitudinal tear was noted in the anterior right ventricle immediately adjacent to the interventricular septum. A small surrounding area of myocardial bruising was noted. With decompression of the cardiac tamponade, the sluggish cardiac activity improved rapidly without the need to give further inotropic support or internal cardiac massage. The hole was closed with interrupted 4-0 Prolene (Ethicon, Somerville, NJ) horizontal mattress sutures with pledgets. Of note was the firm texture of the surrounding myocardium, suggesting freedom from injury. There was no sign of any fractures of the adjacent costal cartilages. The patient's wound was then closed in routine fashion with mediastinal and pericardial drainage after thorough inspection of the heart for associated injuries. At completion of the operation the patient was normotensive and breathing without assistance and was extubated.

The patient was well for the first 48 hours after the operation but had progressive respiratory distress and bilateral pulmonary infiltrates with hypoxemia without evidence of cardiac failure or fluid overload clinically or on invasive monitoring. The diagnosis of adult respiratory distress syndrome was made, necessitating reintubation on day 2 and ventilation for 4 days. He was successfully weaned from ventilation and extubated. Hospital discharge was on the 10th postoperative day, with complete resolution of his adult respiratory distress syndrome and no electrocardiographic evidence of residual injury. Follow-up 10 days later revealed a sinus tachycardia with signs of mild right ventricular failure requiring administration of diuretics. At later follow-up his cardiac failure had resolved.

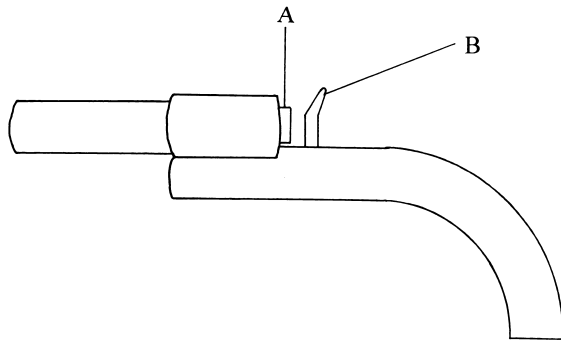


Fig 1. Line diagram of a zip gun showing (A) the bolt head, which was a free-floating firing pin mounted in the "breech," and (B) the sprung hammer, which was mounted in the lower piece of piping, which also served as a handle.

Comment

Although most cases of blunt cardiac rupture follow motor vehicle accidents in which the patients were either occupants or pedestrians, any direct trauma to the chest can result in cardiac rupture [1-4]. The magnitude of such trauma is usually evident from the history and from multiple associated injuries. About 50% of all cardiac rupture victims have associated chest injury with fractured ribs and lung contusion, whereas head injury occurs in 50% to 80% [3, 5]. Abdominal and long bone fractures occur in a significant proportion of patients as well.

Zip guns are crude homemade guns, the main components of which are illustrated in Figure 1. Usually they are made from metal piping bent to create a handle, which is then fixed to another piece of piping to fashion a breech and barrel [6]. Most of these weapons do not employ a trigger but use a sprung hammer, which is pulled back manually and released. The hammer then hits the head of a shortened bolt or nail, which acts as a primitive, free-floating firing pin. When the weapon backfired in this case the bolt was exploded backward into the patient's chest, causing his myocardial rupture.

Myocardial rupture after highly localized relatively minor precordial injury such as described here is very rare. The diagnosis was delayed in this patient even though he manifested typical signs of cardiac tamponade because of the seemingly benign local external appearance of his injury. The lack of precordial bruising can occur after a direct kick from an ungulate in young patients who have compliant chest walls [5]. Similarly, the flexible costal cartilage of our patient reduced the probability of fracture of adjacent osseous structures.

The importance of echocardiography in confirming the diagnosis is clear in this particular case. Echocardiography is reliable in detecting intracardiac injury as well as the presence of pericardial fluid [5, 7]. Tamponade remains a clinical diagnosis, however, and investigation can delay timely surgical intervention in the clear-cut case.

Several mechanisms of myocardial rupture have been reported. Compression injury to the heart occurs as the tissues are compressed at the point of impact, such as

occurs with steering wheel injury or in vehicular-pedestrian impacts [8]. Stress injury is the acceleration-deceleration type injury in which the relatively mobile heart tears itself away from the fixed points of entry of the great veins into the pericardium. An indirect mechanism of blunt cardiac rupture is the hydraulic ram effect, in which sudden compression of the abdomen and lower limbs acutely raises the hydrostatic pressure in the right atrium with resultant rupture [3, 4]. In our patient we postulate that the heart was in end-diastole at the time of impact and that the concussive force was transmitted directly to the full heart. Consequently the myocardium was compressed between the overlying costal cartilage and the incompressible blood in the heart, with tearing apart of the myocardial fibers with minimal surrounding trauma. Delayed cardiac rupture may follow myonecrosis after traumatic coronary occlusion and subsequent infarct softening [4]. Blast injury causing cardiac rupture is well documented in military practice [4]. Sudden death after local precordial trauma is usually due to arrhythmia (commotio cordis) and not cardiac rupture.

Right atrial rupture occurs in about half of the patients reaching the hospital, whereas right ventricular rupture occurs in less than 20% [1, 2, 4]. In postmortem studies both left and right ventricular rupture appear to occur at least as frequently as right atrial rupture, indicating that ventricular rupture is more lethal than atrial rupture. In addition, there may be greater force necessary to rupture the thick ventricular chamber, which would increase the possibility of associated injuries. The right ventricular rupture in our patient was large, and his survival was influenced by the absence of significant associated injuries that may have accompanied another mechanism of cardiac rupture.

Surgical management of cardiac rupture is straightforward with direct repair of the laceration with pledgeted nonabsorbable sutures. Occasionally patch repair of the cardiac rupture may be necessary if the surrounding myocardium is soft and sutures tear out. This and extensive myocardial ruptures require cardiopulmonary bypass, as do intracardiac injuries.

In conclusion, this case draws attention to the importance of having a high level of suspicion in patients with direct precordial chest trauma to rule out blunt cardiac rupture even in the absence of significant associated injuries.

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Right Ventricular Infarction During Left Ventricular Assist System Support

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Left ventricular assist devices are frequently used to bridge patients to cardiac transplantation. As this experience grows, new and unanticipated complications will occur. This report describes a 50-year-old man with ischemic cardiomyopathy being bridged to cardiac transplantation who suffered an acute right ventricular infarction during the interval of support.

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A 50-year-old man with a strong family history of coronary artery disease suffered an anterior myocardial infarction in July 1995. He was initially treated with tissue plasminogen activator and subsequently underwent cardiac catheterization with coronary arteriography. He was found to have severe triple-vessel disease involving the left anterior descending, right coronary, and first obtuse marginal arteries. He underwent coronary artery bypass grafting that same month.

In October 1995, severe angina once again developed, and repeat coronary arteriography showed four of the five bypass grafts occluded. Therefore, in November 1995 he underwent redo coronary artery bypass grafting. Throughout 1996 he had multiple hospitalizations for severe angina, usually to rule out acute myocardial infarction. His ventricular function began to deteriorate, and by late 1996 he had severe refractory congestive heart failure. In December 1996 he had two transient ischemic attacks, which were thought to be embolic (intracardiac) in origin.

On January 24, 1997, he was admitted to St. Louis University with angina and severe congestive heart fail-

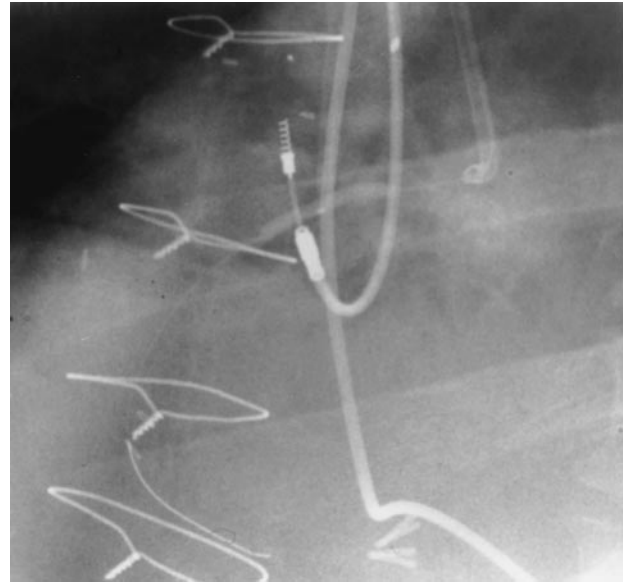


Fig 1. Mid-right coronary artery thrombus before angioplasty.

ure. Dobutamine and nitroglycerin drips were started, and cardiac catheterization showed occluded grafts to the obtuse marginal, posterior descending, and diagonal coronary arteries. His heart failure continued to be unresponsive to $10 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ of dobutamine, so an intraaortic balloon pump was placed. His cardiac index remained low at $1.7 \text{ L} \cdot \text{m}^{-2} \cdot \text{min}^{-1}$ with a pulmonary capillary wedge pressure of 24 mm Hg. His pulmonary artery pressure was 58/28 mm Hg. He was evaluated and accepted for cardiac transplantation. Due to his deteriorating condition a Novacor (Baxter Healthcare Corp, Oakland, CA) left ventricular assist system (St. Louis University Institutional Review Board protocol 8770) was implanted. His postoperative course was complicated by multiple thromboembolic events even though he was anticoagulated with warfarin and aspirin. After several events we decided to maintain his prothrombin time international normalized ratio at 3.5 to 4.5. (The international normalized ratio had been maintained at 2.5 to 3.0.) He was receiving 325 mg/day of aspirin and 100 mg/day of dipyridamole.

On February 19, 1997, substernal chest pain radiating to the left jaw, left arm, and shoulder developed. This pain was not relieved by sublingual nitroglycerin. In addition, the left ventricular assist system flows dropped from 5.4 to 4.0 L/min. The patient was transferred to the intensive care unit from the step-down floor, a dose of morphine sulfate was given, and a nitroglycerin drip was started. His angina was relieved with the intravenous nitroglycerin; however, he had electrocardiographic changes suggestive of subendocardial lateral ischemia. For this reason, he was taken to the cardiac catheterization laboratory, where selected arteriography showed a mid-right coronary artery thrombus, the result of a ruptured ulcerative plaque (Fig 1). This lesion underwent angioplasty; however, the distal right coronary artery remained partially occluded with fresh thrombus (Fig 2).

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