CASE REPORT

Penetrating cardiac injury: sustaining health by building team resilience in growing civilian violence

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SUMMARY

Penetrating cardiac injury (PCI) is gradually increasing in developing countries owing to large-scale manufacturing of illegal country-made weapons. These injuries are associated with significant morbidity and mortality. Logistically it is difficult to have all organ-based specialists arrive together and attend every critically injured patient round-the-clock in developing countries. It is therefore important for doctors (physicians, surgeons and anaesthetists) to be trained for adequate management of critically injured patients following trauma. We report the approach towards 2 cases of haemodynamically unstable PCI managed by a team of trauma doctors. Time lag (duration between injury and arrival at hospital) and quick horizontal resuscitation are important considerations in the treatment. By not referring these patients to different hospitals the team actually reduced the time lag, and a quick life-saving surgery by trauma surgeons (trained in torso surgery) offered these almost dying patients a chance of survival.

CASE PRESENTATION

Patient-1: A 19-year-old man presented to the emergency department (ED) following a stab injury in the precordium. On arrival his airway was patent and air entry was reduced on the left side of the chest. His heart rate was 156 bpm and blood pressure (BP) was 72/38 mm Hg. Glasgow Coma Scale (GCS) was 15/15 with bilateral pupils reacting to light. Chest X-ray suggested pneumomediastinum and left-sided pneumothorax. Focused assessment with sonography in trauma (FAST) was positive (presence of fluid) in the pericardial window. The patient was resuscitated with 2 L of Ringer's lactate and a left-sided intercostal drainage tube (ICDT) was inserted due to pneumothorax. Postresuscitation, his air way was patent, air entry was bilaterally equal to left ICDT draining minimal serosanguineous fluid; his heart rate was 160 bpm and BP was 60/34 mm Hg. GCS was 14/15 with normal pupils reacting to light. He was immediately shifted to the operating theatre (OT) from the ED as he was haemodynamically unstable and did not respond to fluid resuscitation. He underwent clamshell thoracotomy and pericardiotomy to relieve cardiac tamponade. A 200 mL of blood with clots was evacuated. Digital tamponade was maintained over the rent in the left ventricle (LV) to prevent blood loss (figure 1), and rent in the anterior wall of LV was repaired by interrupted sutures reinforced using pericardial pledgets (figure 2). He developed

Figure 1 Digital tamponade maintained to prevent blood loss.

Figure 2 Cardiorrhaphy with reinforcement of sutures performed using pericardial pledgets.

two episodes of bradycardia and cardiac arrest during surgery that was reverted by cardiac massage. The thoracotomy wound was closed after placing a bilateral ICDT. The duration of surgery was 45 min. Nine units of blood products were transfused in the ratio of 1:1:1 (packed red blood cells (PRBC): platelets: fresh frozen plasma (FFP)) in the OT. He was then shifted to the intensive care unit (ICU). Three units of blood products were transfused in the ratio of 1:1:1 (PRBC: platelets: FFP) in the immediate postoperative period in the ICU. As he recovered completely, he was discharged on post-operative day-9; there was no episode of cardiac arrhythmia in the postoperative period and during the follow-up period of 42 months.

Patient-2: A 22-year-old man presented to the ED following gunshot injury to the lower one-third

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Figure 3 Arrow showing entry wound of bullet through the lower third sternum.

sternum (figure 3). His airway was patent and air entry was equal in bilateral chest. His heart rate was 142 bpm and BP was 78/42 mm Hg. GCS was 15/15 with bilateral pupils reacting to light. Chest X-ray suggested pneumomediastinum and left-sided pneumothorax. FAST was positive (presence of fluid) in the pericardial window and in the four areas of the abdomen (perihepatic, perisplenic, pelvis and paracolic). The patient was resuscitated with 2 L of Ringer's lactate and a left-sided ICDT was inserted due to pneumothorax. Postresuscitation, his air way was intubated, breathing bilaterally equal with left-sided ICDT draining the serosanguineous fluid; his heart rate was 188 bpm and BP was 40/24 mm Hg on inotropic support. GCS was 13/15 with normal pupils reacting to light. He was immediately shifted to the OT from the ED as he was haemodynamically unstable and did not respond to resuscitation. He underwent clamshell thoracotomy and pericardiotomy to relieve cardiac tamponade. A 300 mL of blood along with clots was evacuated. Digital tamponade maintained over the rent in the right ventricle (RV) to prevent blood loss, rent in the posterior wall of RV was repaired by interrupted sutures. During laparotomy, 2700 mL of blood was evacuated and obviously visible major bleeding vessels within the lacerated left lobe of the liver were ligated. Perihepatic packing of the shattered left lobe of the liver was performed to achieve haemostasis. Stomach laceration and diaphragmatic rent were repaired and bag laparostomy (temporary closure of abdominal wall) performed. The thoracotomy wound was closed after placing a bilateral ICDT. The duration of surgery was 75 min. Twelve units of blood products were transfused in the ratio of 1:1:1 (PRBC: platelets: FFP) in OT. He was then shifted to the ICU. Twenty-one units of blood products were transfused in the ratio of 1:1:1 (PRBC: platelets: FFP) in the immediate postoperative period in the ICU. On POD-3 the perihepatic packs were removed and on POD-16 the laparostomy wound was approximated. The patient was discharged on POD-23. Prolonged hospital stay was due to multiple organ injury (cardiac, liver, stomach and diaphragm), coagulopathy and temporary closure of abdomen. There was no episode of cardiac arrhythmia in the postoperative period and during follow-up period of 10 months.

GLOBAL HEALTH PROBLEM ANALYSIS

Global health problem list:

- Growing civilian violence in developing countries

- Easy availability of craft-made firearms
- Impact on the health services and measures taken to avert gunshot injuries
- Health and social services adaptation by building team resilience to deal with such injuries

Growing civilian violence in developing countries

PCI is uncommon in developing countries.¹ Wani *et al*² documented 6% (26/386) of cardiac injury over a period of 12 years. Even though India has stringent rules for granting gun licences, it still has large number of civilian firearms. PCIs are gradually increasing in northern India owing to increased large-scale illegal manufacturing of craft-made firearms and the rising anti-social behaviour among criminals or paradox in behaviour among civilians in certain communities (ceremonial firing or celebratory firings, honour killing, irrational practices of superstitions and black magic, caste conflicts, etc). As per the National Crime Records Bureau (Ministry of Home Affairs, India), deaths that resulted from unlicensed firearms are seven times more common than those by the licenced guns.³ Most violent gun crimes (eg, homicide) occur in cities and urban communities.⁴

Easy availability of craft-made firearms

Kattas (popularly known as 'Desi-Kattas') are handmade unlicensed weapons that are made of scrap materials, they are cheap, readily available, fire single shots and can be easily dismantled and discarded after the crime.⁵⁻⁷ Criminals are found to procure such firearms and ammunition by illegal means as they do not require a licence, they are sold secretly and sometimes are available on rent. They contain non-standard calibre cartridges and are devoid of characteristic rifling marks, therefore tracing gun ownership is almost impossible. Some procure guns or desi kattas for self-protection (as status symbols) and others use them for criminal activity ('supari killing' or 'contract killing'). Gang leaders use firearms to secure siphoned territory (also known as 'Dabangs') and intimidate people or political rivals in semiurban and urban areas. Corruption and poor law enforcement is one of the major reasons for the widespread availability of kattas.

Impact on the health services and measures taken to avert gunshot injuries

Firearm-related injury is a serious threat to the health services of the nation. It incurs huge cost to the victims, their family and society. The cost of PCI is high due to treatment (surgery, ICU and hospital stay, reoperation when needed, investigation for diagnosis and anticipated complications, blood transfusion, etc) and rehabilitation. Maintaining a trauma centre is costly because they function round-the-clock with state of readiness to receive patients. Government policy on armed violence requires political commitment and coordination between the government and civil society. The government has taken several steps to prevent the proliferation of illegal weapons and unearth unlicensed/illegal arms. Constant patrolling and surveillance teams are maintained at international borders to check illegal smuggling of arms. Several coordination meetings are held among paramilitary forces, army and the state police forces. Several strategies are designed to interrupt the connection between three essential elements such as the 'host' (the injured person), 'agent' (weapon or perpetrator) and 'environment' (conditions under which the injury occurred). Regular upgradation of intelligence network is a continuous process. Both the state and the central

licencing authorities have been instructed by the Ministry of Home Affairs to update all the details of arms licences issued at National Database on Arms Licence (NDAL). Arms that are not registered in this database will be considered as illegal and will be subjected to legal action.

Health and social services adaptation by building team resilience to deal with injuries

Firearm injuries cause significant morbidity (long-term physical and psychological disability for individuals and families) and mortality.⁸ The true incidence of cardiac trauma is not known as it often goes under reported because of high fatality. Only 6% of the patients who sustain PCI reach hospital alive, and in those receiving cardiopulmonary resuscitation only 17% survive.^{9 10} Stretch compliance of pericardium does not work in acute PCI as the pericardium has the property of elasticity that limits expansion with progressive accumulation of fluid leading to diastolic collapse. Pericardiocentesis in PCI is time consuming, performed through trial and error resulting in incomplete drainage.¹¹ Therefore, surgical drainage of pericardial blood and repair of the underlying cardiac chamber injury (cardiorrhaphy) will usually restore normal cardiac function.¹²

The lack of properly structured prehospital care, unawareness of these injuries at peripheral health centers and availability of few appropriate hospitals in the centre (district hospitals and tertiary health care centre in the metropolitan cities) are well-known facts about the developing or underdeveloped nations.¹³ India is no exception to these facts.¹³ All these factors eventually lead to time delay in the transfer of a patient from the site of injury to the hospital resulting in fatality.¹⁴ Generally, when a patient arrives in tertiary care hospitals he is assessed by a resident bachelor of medicine and surgery (MBBS) doctors or duty medical officer initially in the casualty and then the information is conveyed to the specialists. It is then followed by the arrival of organ-based specialists, who assess the patient and orders for the investigations. The overall time spent in the casualty is in hours. The patient has to pay for all the investigations and doctors consultation fees in private hospitals. Many patients who sustain injury are poor and are not covered by health insurance. Private tertiary care centres perform basic emergency care (non-operative management) and refer these patients to the government hospitals, thus increasing time lag. Blood bank facilities in most of the private tertiary care hospitals are inadequate, not all the doctors are certified in Advanced Trauma Life Support (ATLS) and these hospitals rarely receive patients following trauma as they are medicolegal cases. Only a few government hospitals in India have modern equipment and are supported by trained specialists (available round-the-clock for in hospital patients).

Despite increased awareness of the impact of trauma injury, the field of trauma care and emergency medicine has progressed slowly in developing countries and prehospital care is still at a primitive stage in a few developing countries when compared to UK trauma system. A regionalised network of trauma care forms the basis of UK trauma network and has evolved significantly over past 30 years. Trauma networks in UK comprise one or more major trauma centres (MTCs) linked to a number of trauma unit (TUs). Patients with major injuries are taken directly to MTCs or to the nearest TUs for rapid initial stabilisation and subsequently transferred to the MTCs for specialty care. MTCs have a policy of automatic acceptance of patients requiring MTC care referred from TUs or in case patients present to MTCs by themselves. There are three types of MTCs—those

that treat only adults, those that treat only children and those that treat both adults and children. MTCs are designed to deliver high-quality specialist care to patients of all ages starting from admission (initial patient assessment, diagnostics tests, surgery and critical care management) to rehabilitation. A consultant will be involved in surgical decision-making and all emergency life-saving or limb-saving interventions are performed by a consultant of the respective specialty or in the presence of a consultant in the operating room. Organ-based consultants from various departments (viz, neurosurgery, spinal and spinal cord surgery, vascular surgery, general surgery (adult or child), orthopaedic surgery, cardiothoracic surgery, plastic surgery, maxillofacial surgery, ear, nose and throat surgery, anaesthetics, interventional radiology and intensive care specialists) are available within 30 min when required. For children requiring MTC care, a consultant is always available between 08:00 to midnight for emergency care, and at all other times they are available within 30 min. After adequate treatment patients will be sent back to their locality hospital or host TUs or specialty rehabilitation centre once deemed medically fit. The entire healthcare services in UK is provided free from 'cradle to grave' funded by the government. Intense training is provided to the successive generation of specialists within the British ED, to achieve correct disposition of all patients.

Even though India produces large number of qualified MBBS doctors in a year, still there is severe shortage of organ-based specialists both for its rural and urban services. Logistically it is difficult to ensure all organ-based specialist doctors are available round-the-clock to deal with acute care trauma surgery in developing countries. Lack of adequate numbers of subspecialty postgraduate seats and training centres; lack of established posts and career opportunities; inadequate facilities in the government hospital and poor salaries are major reasons for emigration of doctors from India.¹⁵ To overcome these circumstances we approach trauma patients as a team in our trauma centre. Lack of adequate numbers of specialists in our healthcare system can be solved by training a team of existing doctors, who on gaining the skills perform life-saving surgeries and reduce mortality. All the doctors working in the trauma centres are trained and certified in the ATLS course. A trauma team in the ED consists of a trained trauma physician, one consultant of respective specialty (neurosurgery, orthopaedic surgery and trauma general surgery), one resident of respective specialty and nurses trained in assisting trauma patient management. Entire horizontal resuscitation is supervised by a consultant of the respective specialty. The trauma surgical team in the OT consists of one consultant of respective specialty, consultant anaesthesia, residents of respective specialties and nurses. Depending on the case, a trauma general surgery consultant operates on neck injuries, torso and non-orthopaedic extremity injuries that include cardiovascular injuries, visceral and vascular injury. A critical care team in ICU consists of one critical care consultant, one consultant of respective specialty, one physician, one resident of respective specialty and nurses trained in assisting critical care management of the patient. In total there are four teams each in ED, ward, OT and ICU. Teams work in shift duties. The first shift works between 08:00 to 14:00, second shift works between 14:00 to 20:00 and third shift works between 20:00 to 08:00. One team will be at rest for 24 hours after the night shift. Consultants of respective specialties shift every 24 hours. The trauma centre is headed by chief of trauma centre, and is supported by several faculties and resident doctors in the respective departments and nursing staff. All India Institute of Medical Sciences New Delhi

(AIIMS) trauma centre is funded by central government. Our trauma centre functions similarly to the MTCs in UK's trauma network, but it is not interconnected with the TUs or specialty rehabilitation centres or teams providing prehospital care during transportation. A continuous process of training for doctors and nurses is set in place. The institution has started a Magister Chirurgiae (M.ch) degree course in trauma and critical care services for postgraduate doctors since January 2016. It consists of 3 years of senior residency training programme in the department of trauma surgery (2 months of training in the department of cardiothoracic and vascular surgery, 6 months of training each in neurosurgery and orthopaedic surgery, respectively). All the doctors working in the trauma centre undergo ATLS and AIIMS Ultrasound Trauma Life Support (AUTLS) courses. Advanced trauma course for nurses (ATCN) are conducted for training nursing staff. A training programme within the department of trauma surgery is also available for doctors not pursuing their M.ch course for a minimum period of 1 year. This consists of training in the ED, ward, ICU and OT. Resident doctors rotate duties every 3 months, from ED to ward, ward to ICU and ICU to OT. Teaching programmes are held in the respective departments within the trauma centre. Resident doctors present and discuss on several topics during seminars that include discussion on recent advances and research articles. Weekly morbidity and mortality meeting provides an opportunity to learn from the mistakes, acquire correct approach and learn new skills. Consultants from the respective department teach the various steps of surgery to all the residents assisting in the surgery and ensure

that they acquire skills before completion of training. The institute conducts an annual conference that provides a common platform for various doctors (national and international faculties) to discuss research ideas and share clinical experiences.

Chest injury is evaluated based on the site of injury, mechanism, clinical manifestations and findings on FAST.¹⁶ Patients of PCI can be reasonably stable or absolutely moribund, often they present in two ways; cardiac tamponade or haemorrhagic shock.¹⁷ Cardiac arrest at presentation in ED is associated with increased risk of mortality.¹⁷ However, Beck's triad (hypotension, low distended neck veins and muffled heart sounds) is not frequently noticed, and muffled heart sounds may not be heard in a noisy ED. Controversies exist regarding utility of biochemical diagnosis and no single test is universally accepted to confirm diagnosis.¹⁸ However, FAST or transthoracic echocardiograph in the absence of haemothorax has 100% sensitivity and 96% specificity for evaluating PCI.¹⁹ In our patients FAST being positive in the pericardial window suggested cardiac injury. FAST being positive in the abdomen suggested abdominal visceral injury. FAST being positive both in the chest and abdomen in penetrating injury suggested diaphragmatic injury.²⁰ Once an indication for chest exploration is made, selecting an appropriate chest incision is very important because four to five compartments are required to be considered. For example, the right chest, left chest, mediastinum, abdomen (in case abdominal organ injury is suspected) and neck (in case innominate vessels, carotid artery or subclavian vessels injury is suspected). We suggest an algorithm (figure 4) for selecting a chest incision in

Figure 4 Algorithm for selecting a chest incision for penetrating chest injury in postresuscitated haemodynamically unstable patients. FAST, focused assessment with sonography in trauma; ICDT, intercostal drainage tube.

patients presenting with penetrating chest injury in postresuscitated haemodynamically unstable patients. One should remain flexible and insist on adequate exposure of the injury. The algorithm may have to be curtailed based on the requirement of optimum exposure. For example, in a few left parasternal injuries or in cases with uncertain diagnosis, a posterolateral thoracotomy is generally beneficial as it offers excellent visualisation of the posterior aspect of the heart (especially LV), the great vessels (such as the subclavian artery or aorta) and in cases of air embolism or massive air leak. Decision to operate is arrived at after adequate resuscitation and selection of chest incision is based on the presenting signs and symptoms.

Cardiac injuries no doubt have high mortality rates but survival happens only if these patients reach the hospital in time. Time lag (time between injury and arrival at hospital) is an important determinant of survival. Immediate surgery for definitive cardiac repair with continuing cardiorespiratory efforts is a major life-saving step of resuscitation and outcome. Persons with PCI reaching the hospital alive will rarely have sustained complex cardiac injuries. Cardiopulmonary bypass (CPB) and a specialist cardiac surgeon may be required in the management of complex cardiac injuries (eg, valvular rupture, papillary muscle injury, proximal lesion of coronary arteries, multiple-cardiac chamber injury, etc).^{21 22} Persons with PCI reaching the hospital in a deteriorating haemodynamic status will usually have sustained minimal cardiac injury (eg, rent in the ventricle or atrium and require surgical evacuation of tamponade and cardiorrhaphy). Arrhythmia and/or cardiac arrest prior or during the surgery should not deter the treating team of doctors in providing critical care to these patients, as these patients usually recover after the repair of cardiac rent.²³

Development of an emergency medical services system, improving quality and infrastructure at peripheral health centres and necessary measures to reduce brain drain are no doubt policymaking decisions of the government, but it is also necessary for doctors (physicians, surgeon, anaesthetists and critical care specialists) to become trained and be determined to save a life. Proper initial assessment of the patient in ED, appropriate resuscitation pertaining to the case, quick diagnosis, essential surgery and adequate critical care are important considerations in the treatment. For example, in our patient who has sustained penetrating chest injury, early adequate assessment was performed, appropriate resuscitation provided; a decision to operate was taken when indicated and damage control surgery (thoracotomy and cardiorrhaphy) was performed to relieve cardiac tamponade.²⁴ Cardiac tamponade and/or haemorrhagic shock are definitive indications for cardiac surgery in PCI. Cardiac arrest during or prior to surgery is associated with increased risk of mortality and is a marker of poor prognosis. One should also be ready to tackle patients who sustain multiple site injuries especially in the setting of limited availability of personnel (eg, organ-based specialist surgeon) and equipment (eg, CPB) where time cannot be lost and quick decisions need to be made. An organised approach with quick life-saving decisions by a trained torso surgeon can offer these almost dying patients a chance of survival. Improvement in outcome of treatment delivery is likely to improve as prehospital and trauma triage protocols mature, interhospital transfer protocols evolve and the trauma centres themselves become more organised, experienced and better resourced.

Learning points

- ▶ Penetrating cardiac injuries are gradually increasing due to widespread proliferation of illegal manufacturing of handmade guns and increasing civilian violence.
- ▶ Possibility of cardiac trauma must be kept in mind when injury is within the anatomical area of the heart.
- ▶ Time-consuming non-therapeutic investigations in the event cardiac tamponade or haemorrhagic shock (moribund patients) should be avoided. Focused assessment with sonography in trauma has good diagnostic accuracy for detecting fluid in the pericardium and is the most useful tool in penetrating cardiac injury (PCI).
- ▶ Trauma surgeons trained in torso surgery should take initiative in the evaluation and in deciding about appropriate management of patients who sustained torso trauma. By not referring to different hospitals the team can actually reduce time lag and a quick life-saving surgery in persons with PCI can offer these almost dying patients a chance of survival.
- ▶ Internationally trauma systems have developed differently, particularly in the provision of physician delivered prehospital care in the UK. Assigning life-saving skills to paramedics and lay people is a key factor for efficient prehospital trauma system in low-resource communities as well.

Contributors MMP conceived the design and was the first operating surgeon; KSKP and VD were first and second assistant surgeons, respectively. MU received the patient initially in the emergency department; patient was evaluated, resuscitated and discussed with MMP on telephone. The patient was operated by MMP, KSKP and VD. MU took the operating steps photographs and video. Demography of the patient and clinical details (data) were collected by KSKP and VD, further it was analysed by MMP. The manuscript was prepared by MMP, KSKP, VD and MU. Editing of image and video was performed by MU. Case report was critically analysed, revised and uploaded by MMP. Final approval of the case report is provided by MMP, KSKP, VD and MU. Overall responsibility and corresponding author is MMP.

Competing interests None declared.

Patient consent Obtained.

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