History of cardiac trauma surgery

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The ancient Egyptians, although realising the anatomical importance of the heart, were largely responsible for the aura of mysticism and superstition that enveloped the heart for centuries. The Egyptian Book of the Dead (*c.* 1567 BC) describes how, on entry to the underworld, the jackal-headed Anubis weighed the heart of the deceased against a statue of the goddess of truth and justice.[1,2] If the heart weighed the same, the dead person was admitted 'to the company of Osiris and the blessed; if not, if his heart was heavy and laden with sin, it was cast to the devouring beast Ammit'.[3]

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Homer was the first author to narrate a cardiac injury in the *Iliad* (*c.* 950 BC), when the Greek commander, Idomeneus, killed the Trojan, Alkathoos.[4]

> 'Idomeneus smote him with a thrust of his spear full upon the breast, and clave his coat of bronze around him, that aforetime ever warded death from his body, but now it rang harshly as it was cloven about the spear. And he fell with a thud, and the spear was fixed in his heart, that still beating made the butt thereof to quiver.'

The *Iliad* and the *Odyssey* contain numerous references to cardiac injuries.[5-7] Achilles' best friend, Patroclus, killed Sarpedon, the son of Zeus, with a spear to the heart.

> 'The prostrate prince, and on his bosom trod; Then drew the weapon from his panting heart, The reeking fibers clinging to the dart; From the wide wound gush'd out a stream of blood, And the soul issued in the purple flood.'

Hippocrates recognised that cardiac injuries were invariably fatal. 'A severe wound of the bladder, of the brain, of the heart, of the diaphragm, of the small intestine, of the stomach and of the liver is deadly.'[8,9] Aristotle (384 - 322 BC) wrote that 'The heart again is the only one of the viscera, and indeed the only part of the body, that is unable to tolerate any serious affection. This is but what might reasonably be expected. For, if the primary or dominant part be diseased, there is nothing from which the other parts which depend upon it can derive sucour.'[10,11] Celsus (1st century AD) recognised the clinical features of shock associated with a cardiac injury when he wrote in *De Medicina* that, 'When the heart is wounded much blood is lost, the pulse weakens, pallor becomes extreme, a cold and foul sweat arises from the stricked body, the extremities become cold and speedy death follows.'[9,12] Pliny the Elder (AD 23 - 79) felt that the heart 'is the only one among the viscera that is not affected by maladies, nor is it subject to the ordinary penalties of human life; but when injured, it produces instant death.'[9,13]

Claudius Galen (AD 130 - 200) expressed his sentiment of the hopelessness of a cardiac wound:

> 'When a perforation penetrated in one of the cardiac ventricles, they (the gladiators) died on the spot, mainly by blood loss, and even faster if the left ventricle was injured. When the penetrating object did not pass through the cardiac cavity but stopped at the cardiac muscle, some of the wounded gladiators lived through the very day on which they were wounded as well as the following night; they eventually died later because of an inflammation.'[3]

The teaching of Hippocrates, Aristotle and Galen that all heart wounds were fatal was followed until, in 1604, Cabriolanus found healed scar tissue in the hearts of individuals who had died by hanging.[14,15] The idea that not all cardiac wounds were fatal was also suggested by Holerius.[9,16]

Morgagni (1761) was the first to recognise cardiac tamponade from an injury of the coronary artery and that blood in the pericardial sac could compress the heart and restrict its movement.[17]

The nihilism surrounding cardiac injuries continued and in 1804 John Bell published his *Discourses of Nature and Care of Wounds,* declaring that 'there is so little to be done … and the signs and consequences are so clear, that it is a waste of time to speak longer of wounds of the heart'.[5,18]

There is dispute over who should be named as the first modern cardiac surgeon. The two contenders are the extremely well-known Baron Larrey and the almost unheard of Catalonian surgeon called Francisco Romero. These two men apparently performed the first open pericardiotomy at approximately the same time. Francisco Romero of Barcelona performed an open pericardiotomy on a patient with a pericardial effusion around 1810. He presented his memoir, *Observatio experimentis confirmata, pro hydrope pectori, pulmonum anasarca, et hydropericardio cognoscendis; et nova methodus dittos morbos operandi,* to the Society of the School of Medicine in Paris in 1815. An incision was made over the costal cartilage of the 6th rib and after opening up the pericardial sac the fluid was allowed to drain into the pleural space. These open surgical procedures were viewed at the time as being unnecessarily aggressive and the Society did not endorse his ideas.[19]

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Baron Dominique Jean Larrey, the Surgeon-in-Chief of Napoleon's imperial guard, made a number of contributions to trauma surgery. He invented the 'flying ambulance' to rescue the wounded from the

scene of battle. Previously, casualties were considered to be a nuisance. He introduced a system of triage to manage patients according to the severity of their wounds and also successfully decompressed the pericardial sac of a patient by catheter drainage. The pericardiotomy that was performed by Baron Larrey was conducted on Bernard Saint-Ogne, a 30-year-old infantryman who had attempted suicide by stabbing himself in the chest after being accused of an offence that he did not commit, on 18 March 1810.[20]

'In the left side of the chest, the pericardium and the left lung were wounded, the knife passed through the fifth costal cartilage and was still in the wound when he was brought into hospital. Frothy blood escaped in jets with each systole. The knife was withdrawn and the wound dressed with plaster; the patient tore off the dressing and it was reapplied. The pulse was rapid and there was grave dyspnoea. Bleeding gave some relief. Some improvement took place, but later on he became worse, and in great distress requested Larrey either to open his chest or to give him a narcotic strong enough to send him to sleep. Operation 45 days after injury, incision through the skin and cellular tissue in the fifth space below the nipple, carefully carried deeper until pericardium felt. With the left index finger on the pericardium as a guide an incision into the pericardium was made with a bistoury, the finger inserted, and the apex of the heart felt. About a liter of fluid with some blood clot escaped. Great relief. In ten days the wound closed and the symptoms recurred. Wound reopened with a probe, 4 oz of pus escaped. Considerable improvement. Death 68 days after injury and 23 after the operation. Autopsy: suppurative mediastino-pericarditis.'[14]

Despite the advent of these open surgical approaches, the management of cardiac injuries in the beginning of the 19th century consisted of venesection, leeches, absolute quiet and an attempt to evacuate fluid by passing a sound into the wound. In 1875 Billroth condemned both pericardiocentesis and any surgical attempts at repairing the wounded heart. 'Paracentesis of the pericardium is an operation which, in my opinion, approaches very closely to that kind of intervention which some surgeons would term a prostitution of the surgical art and other madness.'[21] He also remarked that 'A surgeon who tries to suture a heart wound deserves to lose the esteem of his colleagues.'[22-24] In 1896 Paget wrote that 'The surgery of the heart has probably reached the limits set by nature to all surgery; no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart. It is true that heart suture has been vaguely proposed as a possible procedure and has been done on animals, but I cannot find that it has ever been attempted in practice.'[25]

Between 1912 and 1914 there were more than 75 cardiac operations and the mortality rate appeared to be diminishing, with an overall rate of around 45%.

However, there was about to be a radical shift to surgical management. In 1876 Gottard Bulau of Hamburg developed the system of the underwater drainage of the pleural cavity. This was a huge milestone in the progress of managing penetrating chest trauma and overcoming the inherent problem of the associated haemopneumothorax and allowing for re-expansion of the lung. De Vecchio demonstrated the feasibility of cardiac repair in dogs by showing a healed wound in the heart of a dog to the Eleventh International Medical Congress in Rome in 1895.[26] Ansel Cappelan of Norway then performed the first suture of the human heart in 1895.[27] The patient was a 24-year-old male who had been stabbed in the left chest in the 4th intercostal space and had presented with symptoms of cardiac tamponade. He was anaesthetised with chloroform and a 4th and 5th rib resection was performed, showing that the pericardium was distended with blood. This was opened and a 2-cm injury to the left ventricle was sutured with chromic catgut and the left anterior descending coronary artery was ligated. The patient died 2 days later from what was considered to be a pericarditis and anaemia.[9,28-30] Dr Guido Farina of Rome sutured the right ventricle in a 30-year-old man who had been stabbed in the left chest with a fine dagger at the Spedale della Consolazione in March 1896. The 5th costal cartilage and rib were removed and five silk sutures were placed into a 7-mm wound of the myocardium. On the 8th postoperative day the patient died from a bronchopneumonia, but at autopsy the heart was found to be perfectly healed.[31,32]

The first successful cardiac repair was performed by Dr Ludwig Rehn of Frankfurt on 9 September 1896. [33] A 22-year-old man, Wilhelm Justus, was brought to the hospital in a state of collapse after sustaining a penetrating wound in the fourth interspace. Stimulants were administered, which was followed by improvement, but 24 hours later his condition was so much worse that the patient was operated upon. Ether was used for narcosis.[34] A resection of the 5th left rib was undertaken and the pleura was cleared of blood. Dr Rehn describes the operation further: 'There is continuous bleeding from a hole in the pericardium. This opening is enlarged. The heart is exposed. Old blood and clots are emptied. There is a 1.5 cm gaping right ventricular wound. Bleeding is controlled with finger pressure ... I decided to suture the heart wound. I used a small

intestinal needle and silk suture. The suture was tied in diastole. Bleeding diminished remarkably with the third suture, all bleeding was controlled.'

The postoperative period was complicated by a pneumothorax and chronic infection but the patient made a complete recovery and returned to work.[11,35]

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In his address to the German Society of Surgery, Rehn said 'the feasibility of cardiorrhaphy no longer remains in doubt ... I trust that this case will not remain a curiosity, but rather, that the field of cardiac surgery will be further investigated. Let me speak once my conviction that by means of cardiorrhaphy, many lives can be saved that were previously counted as lost'.[3,35]

Duval described the median sternotomy in 1897 and much of the French success in dealing with thoracic injuries during the great war was due to this technique.[36] A number of extraplural approaches to the heart were developed because entry into the pleural cavity had to be avoided.

Walter Kirchner, a surgeon from St Louis, successfully repaired a stab to the left ventricle using an extrapleural approach via a left sternal flap. He reported to the Southern Surgical and Gynecological Association in 1909 that 'one must be convinced that injuries to the heart can no longer be considered as invariably fatal, but that the heart may be manipulated and treated surgically just as any organ of the body'.[37] In 1909 Charles H Peck of New York reported the successful suture of an injury to the right auricle in a 24-year-old girl. She presented with cardiac tamponade, her pulse returning after the pericardial sac was excised and 300 cc of blood evacuated. He tabulated 161 cases of primary suture of the heart in the medical literature from America, France, Germany, Spain, Italy, Canada and England. No previous surgeon had reported more than 3 cases. The overall operative mortality of sutured heart wounds was in the order of 64%.[38]

Brewster in 1911 defined the term cardiac tamponade 'as the haemorrhage increases, the pericardial opening sometimes becomes occluded and the condition known as cardiac tamponade arises'.[39] Luxembourg emphasised the clinical feature of cardiac tamponade – a patient with symptoms of air hunger, shortness of breath and pain will obtain relief by adopting a sitting posture.[40] Between 1912 and 1914 there were more than 75 cardiac operations and the mortality rate appeared to be diminishing, with an overall rate of around 45%.

A United States surgeon based in London, Dr Dwight Harken, removed 134 missiles from the mediastinum, including 13 from the heart, during World War II without any mortality.[41] He wrote of his experience: 'To remove the missile, the heart was often split wide open, with tremendous blood loss. Rapid, massive, blood transfusions were needed to keep the patient alive. Whole blood was often administered, under pressure, at rates up to 1.5 litre per minute. Penicillin, which was just beginning to make an impact on thoracic surgery, was often given in 10 000 unit injections'.[11,42]

Cardiac tamponade was noted by Paul Samson, an American surgeon based at a forward hospital during World War II, to be an unusual presentation in war wounds, in stark contrast to civilian cardiac injuries, as the missiles were larger and the wide pericardial tears allowed for drainage of the pericardial sac into the chest.[43] World War II saw a step back towards conservative management of cardiac wounds. This was due to the perception of a high mortality associated with cardiac repair (between 25% and 30%) and the fact that a number of selected patients recovered without operative intervention. An era of conservatism returned to the surgical management.[44,45] Dr Alfred Blalock introduced pericardiocentesis as the definitive treatment for cardiac wounds presenting with tamponade. In 1943 Blalock and Ravitch described the survival of 3 out of 4 patients treated conservatively.[46] In 1949 they reported the survival of 7 patients with cardiac tamponade with aspiration of the pericardial sac.[47] Blau in 1945 reported 27 cases of penetrating cardiac injuries. The mortality rate of 17% achieved with aspiration alone compared favourably with the operative intervention rate of 24%.[48] The majority of surgeons adhered to this conservative view, operating only when there was external haemorrhage into the thoracic or peritoneal cavity, when there was failure of pericardiocentesis to relieve symptoms, or when the tamponade recurred. There was, however, a small body of surgeons that maintained that there should be immediate surgical intervention in these injuries regardless of the circumstances.[49-51]

In 1951 Elkin from Atlanta, Georgia, was still recommending a trial of aspiration of the pericardial sac in all cases of cardiac injury while the operating room was being prepared. In selected cases careful observation would be continued if the patient responded positively to the pericardiocentesis. They managed 18 patients with stab wounds to the heart with this protocol and surgery was only undertaken in one patient. Of the 17 patients treated conservatively there was one death, a

mortality rate of 6%.[45] Cooley *et al.* in 1955 wrote that they were in complete agreement with Ravitch, Blalock and Elkin in their recommendation that the initial treatment of a penetrating injury to the heart should be non-operative and that attempted cardiac repair should be reserved for those patients that do not respond.[52]

In the early 1950s a patient was seldom operated upon in most centres until there had been several attempts made at pericardiocentesis.[53] Towards the end of the decade there was an increasing tendency to early thoracotomy in unstable patients after a single aspiration of the pericardial sac. This move towards early operation may well be attributed to the advent of cardiac surgery and the beginnings of the development of a trauma service in the USA.

In the 1960s mandatory surgical exploration versus conservative management with pericardiocentesis remained a controversial issue.[54] In 1966 in the *Journal of the American Medical Association*, Wilson reviewed 200 penetrating wounds of the pericardium from Wayne State University College of Medicine in Detroit and concluded that cardiac repair should be performed rapidly on all patients except those who maintain normal vital signs after pericardiocentesis. In their series, 9 patients out of the 200 (4.5%) had sufficient improvement after pericardiocentesis to avoid any further surgery. One of these 9 patients died.[55] The majority of surgeons were convinced at this time that the best form of therapy for severe haemorrhage from a cardiac wound was cardiorrhaphy, but doubt still remained about the management of cardiac tamponade. Many felt that those patients with the diagnosis of what was termed a 'pure' tamponade could be reasonably managed with pericardiocentesis alone. A 'trial of therapy' was starting to be adopted by a number of centres. However, several series then showed that the outcome of patients was poor if they had undergone cardiac repair only after responding poorly to pericardiocentesis.[56]

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A number of studies in the 1960s stressed the danger of a delay in cardiac surgery. In Wilson's study the patients operated on within 30 minutes had a mortality of 10% versus 26% in those who had surgery later. Beall *et al.* reported a dramatic increase in mortality from 27% to 63% if pericardiocentesis failed to relieve a tamponade and surgical intervention was delayed.[53,57] In 1968 Yao *et al.* published their series of 80 penetrating cardiac injuries. They had managed cardiac injuries from 1959 to 1965 with pericardiocentesis. If the patient responded then nothing else was done. Only when there was no clinical response to pericardiocentesis or recurrent accumulation was a thoracotomy undertaken. This management protocol changed dramatically after 1965 when all patients with the diagnosis of stab wound to the heart were managed with an emergency thoracotomy. Nineteen out of their 80 patients died (24%) and this mortality dropped to 5% between 1965 and 1967 when all patients were taken to thoracotomy with or without pericardiocentesis. They attributed this drop in mortality to more rapid triage with the development of a trauma service and an increased interest in traumatic injuries. This is indicative of the dramatic shift in the management of penetrating cardiac trauma from pericardiocentesis to operative intervention.[54] Symbas *et al.* compared the management of their penetrating cardiac injuries between 1964 and 1974 and found that the mortality rate for patients presenting with cardiac tamponade was 5% in patients operated on immediately versus 17.5% in patients managed initially with pericardiocentesis and where surgery was reserved for patients who did not respond or where the tamponade recurred.[57]

This shift from conservative to surgical management is beautifully illustrated in the three papers published from Baylor University (1955, 1966 and 1972). The mortality from stab wounds to the heart decreased from 22% to 13%.[3,51] By the 1970s the continued advances in cardiovascular surgery and presence of trained personnel, combined with the reduction in mortality, resulted in immediate cardiorrhaphy becoming the universal treatment of choice.[58]

References available at www.cmej.org.za

In a nutshell

- The ancient Egyptians were largely responsible for the myth and superstition surrounding the heart.
- It was not until the late 19th century that cardiac surgery was recognised as an acceptable approach to cardiac injury.
- A shift in management from conservative to surgery occurred with the advances in cardio-thoracic surgery and the presence of trained surgeons.