THE MATTER OF THE HEART

A History of the Heart in Eleven Operations

THOMAS MORRIS

THE BODLEY HEAD
LONDON

1. BULLET TO THE HEART

Stowell Park, Gloucestershire, 19 February 1945

A few minutes' drive south of the pretty market town of Northleach, in the heart of the Cotswolds, is a pub called the Inn at Fossebridge. If you park here, as I did one blustery spring afternoon, and climb a steep hill, you'll soon come to a small wood that lies beside a Roman road, the Fosse Way. It's a peaceful spot filled with birdsong, and as you tramp through the undergrowth it seems scarcely possible that this was the scene of one of the great feats of modern medicine. But seventy years ago this unremarkable little wood was the birthplace of modern heart surgery.

The trees, although tall, were planted only a few decades ago, and beneath them some relics of what used to be here are still visible. Dozens of low brick structures protrude through a light covering of moss and dead branches: these are the bases of long-demolished Quonset huts,* and just off the footpath I found one still intact, preserved – or so I hoped – as a reminder of what happened here in wartime.

In late 1944 you would have seen lines of these huts, hundreds of them, covering several acres of the Stowell Park estate. This was a

* A prefabricated structure of American design, based on the British Nissen hut.

huge military hospital, with its own airstrip, constructed in haste to cope with the flood of casualties expected to follow an Allied invasion of continental Europe. In April that year it became the headquarters of the 160th General Hospital of the US military, a unit specialising in chest injuries which at its peak had 500 patients under treatment[1] – and in an improvised operating theatre in one of these huts, a young Iowan surgeon called Dwight Harken removed bullets and shell fragments from the chests of 134 soldiers without experiencing a single fatality.[2] This was impressive in itself, but what makes his unblemished record all the more remarkable is that he extracted many of these pieces of twisted metal from inside a beating heart.

A metal hut is not the ideal environment for heart surgery. Sixteen feet wide by twelve high, Harken's ramshackle operating theatre had a roof of corrugated iron and was poorly insulated: the summer sun turned it into a stifling furnace, while in winter it was heated by a small stove. But the cold was the least of his concerns as he prepared for surgery on 19 February 1945. He already knew his patient well: Leroy Rohrbach, an infantry sergeant who had been involved in the Normandy landings the previous summer, a tricky case who had been in Harken's care for some time. A month after D-Day he had been caught up in the fierce fighting which obliterated the town of Saint-Lô, and an exploding shell had sent a piece of shrapnel through the lower part of his chest.

He was evacuated to England, where an X-ray showed a small piece of metal lodged inside his heart. On the fluorescent screen it could be seen pulsating gently with the throb of his heartbeat, indicating that it had passed through the outer wall of the organ and was now inside one of the cardiac chambers. On 15 August Harken operated and came desperately close to removing it: after making a small incision in the heart he managed to grasp the metal fragment with a pair of forceps, but it was jerked from his grasp as the organ contracted, and slipped back into the bloodstream. He made frantic attempts to find it, but it had vanished from view and could not be felt through the heart's thick walls. Three months later he tried once more. Again he

found it; and again it defied him, slipping from his forceps just as success seemed assured.

Yet despite these failures his patient continued to improve. This was not unheard of: soldiers with similar injuries might never need an operation, living quite happily with pieces of shrapnel – or even bullets – inside them as permanent reminders of their military service. The sergeant showed no signs of infection, and electrocardiograms revealed that his heart rhythm, which had been disturbed by the injury, was slowly returning to normal. Given that his patient had already endured two major and fruitless operations, Harken was reluctant to risk a third: it would be dangerous and possibly unnecessary.

But there was another consideration. Although many soldiers lived active lives after such injuries, others developed crippling anxiety about the alien shard of metal lodged deep inside their chests. They became depressed, fretful, and lived in perpetual fear of sudden death, terrified that a single careless movement could be enough to dislodge the shrapnel and kill them. This phenomenon was well known by 1945, and had been given a name: cardiac neurosis. Indeed, Harken's patient had become increasingly nervous about the inch-long shell fragment inside his body and begged the surgeon to persevere. Appreciating that such distress constituted a significant clinical consideration, Harken agreed to make a final attempt.

At thirty-four, Dwight Harken was already one of the most highly regarded surgeons in the US medical corps. A tall and muscular redhead, he had been born into medicine, delivered by his father, a doctor who ran the small Harken Hospital in Osceola, Iowa, and had grown up in a basement flat in the building. During his childhood the antiseptic smell of the wards had never been far away, and his father's hope was that he would eventually take over the family business; but small-town life had little appeal, and he left to study at Harvard. A few years later he moved to Britain to work with the country's leading chest surgeon, Arthur Tudor Edwards, at the Brompton Hospital in London.[3] During the war Tudor Edwards had an immense impact on military medicine, training surgeons and developing new techniques

in his treatment of air-raid casualties. Given this pedigree, and despite his youth, Harken was a natural choice to run the new specialist thoracic unit in Gloucestershire.

Although Harken's operating theatre was little more than a shack, he was otherwise in a fortunate position. By February 1945 he had state-of-the-art equipment and drugs, including the new antibiotic penicillin, and a close team of surgical colleagues who had assisted him in over a hundred operations. Charles Burstein, the anaesthetist, had been with him since the beginning;[4] he now put the patient to sleep, administering a mixture of ether and air through a facemask. Today the hut was more than usually cramped. Word had got around about this remarkable young American doing wondrous things in a field in Gloucestershire, and a delegation of eminent British surgeons, including Tudor Edwards, had come to watch Harken at work. Above the operating table a cameraman was lying on a scaffold, ready to film proceedings for the benefit of medics in America.[5]

The sergeant's body bore obvious scars from the first two operations, one a snaking line across his back from shoulder blade to hip, the other a smaller curve around his left nipple. Harken chose to renew his attack through the chest, using a scalpel to reopen his earlier incision. With a pair of Tudor Edwards retractors, an instrument named after his mentor, he separated the patient's ribs and exposed the heart by cutting through the pericardium, the tough sac around it. He could see the scar in the cardiac wall left by his first operation, and elsewhere the tissue appeared flabby and discoloured, evidence of trauma. By gently squeezing the beating heart he was able to locate the foreign body, a small area of hardness in the right ventricle, near the organ's base.

Now the shell fragment had been found, the delicate task of removing it could begin. Harken held it in place with a finger placed firmly on the outside of the heart, while inserting two rows of catgut sutures on either side, an otherwise straightforward procedure rendered more difficult by the constant contraction and relaxation of the muscle. In the event of catastrophic bleeding these could be pulled

together, a simple but effective way of staunching the flow of blood. As Burstein watched the electrocardiogram nervously, looking for signs that this manipulation was disturbing the heart's rhythm, Harken's assistant picked up the loose ends of the catgut and waited for a signal. This was the critical moment.

Working as quickly as he could, Harken now made a small incision in the heart wall and inserted a pair of forceps to widen the opening. Through this aperture he introduced a clamp and fastened it around the elusive piece of metal. For a moment all was quiet. And then, as he related in a letter to his wife, 'suddenly, with a pop as if a champagne cork had been drawn, the fragment jumped out of the ventricle, forced by the pressure within the chamber. Blood poured out in a torrent.'[6] His assistant pulled the control sutures taut, but the wound continued to bleed. Harken put a finger over it, and picking up a needle started to sew it shut. The opening was closed, but when he tried to remove his finger he discovered that he had sewn his glove to the wall of the heart. Finally his assistant cut him loose, and the job was done. Opening the heart, removing the shell fragment and repairing the incision had taken three minutes. His distinguished guests were deeply impressed: this was surgery of a sophistication and audacity which none had seen before.

Some of Harken's operations were still more dramatic. Sometimes when he cut into the heart the resulting jet of blood entirely obscured his view, and he was forced to fish around blindly for the metallic fragment in a churning scarlet sea. The degree of haemorrhage was often so severe that patients had to be given rapid transfusions. Today, blood comes pre-packed in plastic bags which are hooked on a drip stand, and enters the body under atmospheric pressure; in 1945 the blood bag had yet to be invented, and so it was instead poured into a bottle into which air was then pumped to create the high pressure necessary to force it into the patient's veins. Most of the time this worked without any problems, but every so often the bottle would explode, showering the entire operating theatre and its staff with blood and shards of glass.[7]

On another occasion Harken tried a novel method of removing foreign objects. During the First World War several surgeons had realised that since many bullets were made of iron it should be possible to remove them magnetically. Harken took up this idea, ordering a huge mains-powered electromagnet which was mounted above the operating table. After the patient's chest had been opened it was turned on. The bullet remained stubbornly in place, but every surgical instrument in the room flew lethally through the air and landed on the surface of the electromagnet with an alarming metallic clink.[8]

In an age when open-heart surgery takes place in thousands of hospitals all over the world every day, it is difficult to appreciate quite what a momentous achievement Harken's work was. He was not the first to remove bullets from the heart, but never before had a surgeon operated on so many patients without a single death, or made a terrifying procedure look almost routine. The magnitude of the accomplishment is noted in the official account of British surgery in the Second World War: 'His outstanding success, his daring interventions, and his brilliant results underline one of the most striking chapters of surgical achievement in any war, and in a symposium of this type all British surgeons will unite in offering their tribute to him.'[9]

Such hyperbole is easier to understand if you consider that less than half a century earlier heart surgery was widely regarded as impossible. In 1896 the author of the most widely read British textbook on chest surgery, Stephen Paget, wrote, '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.'[10] One of his contemporaries, the American Benjamin Merrill Ricketts, observed gloomily that 'there is probably no organ or disease about which so much has been said and written, with so little accomplished, as the heart with its diseases.'[11]

By the end of the nineteenth century surgery had made great strides, thanks to two recent discoveries: anaesthesia and antisepsis. The first anaesthetic agents, ether and chloroform, were discovered in

the 1840s and made it possible to undertake quite radical procedures without inflicting excruciating pain. Twenty years later Joseph Lister showed that if instruments and dressings were sterilised, infections could be prevented, and the age of modern surgery had begun. It was now possible to operate at leisure on an unconscious patient, and to be reasonably confident that they would not then succumb to gangrene.

Progress was rapid. Within a few decades surgeons were operating on virtually every part of the human body. By 1890 detailed surgical textbooks were available for the skeleton and its muscles,[12] the mouth and jaw,[13] the ear,[14] the eye,[15] the kidney,[16] the reproductive organs,[17] the urinary system,[18] the intestines[19] and the rectum.[20] Not even the brain was out of bounds: in 1884 Rickman Godlee successfully removed a tumour from inside the skull of a twenty-five-year-old man in an operation in London, prompting editorials in national newspapers.[21]

So why was the heart, alone among the major organs, still taboo? There were certainly practical difficulties: its position beneath the ribcage made it inaccessible, and operating inside the chest could cause the lungs to collapse as air entered the space around them, causing catastrophic respiratory failure. And then there was the fact that if the patient were to remain alive the heart had to keep pumping: how could you possibly operate on an organ that wouldn't stay still?

But there was something else, too: a reverence for the heart rooted in centuries of tradition. It was not merely another organ, but an object far more mysterious and freighted with significance. This was eloquently expressed in the sixteenth century by the French surgeon Ambroise Paré, who described the heart as 'the chief mansion of the Soul, the organ of the vitall faculty, the beginning of life, the fountain of the vitall spirits'.[22] This attitude is even apparent in the oldest surviving medical texts, those from ancient Egypt. The heart was then believed to be the seat of the intelligence, the emotions and the soul, and was preserved after death: admission to the afterlife could only be granted when it had been weighed by the god Anubis. Later, Greek scholars agreed on the fundamental importance of the heart. In the fourth century BC Aristotle pointed out that it was the first organ

to form, and the last to die; it occupied a central position; it moved; and it communicated with all other parts of the body. He also saw the heart as the source of the 'animal heat', the life force inherent to all organisms.[23]

Given the fundamental importance assigned to the heart by early thinkers, it was natural to assume that injuries to it must necessarily be fatal. In his great 37-volume encyclopaedia *Natural History*, compiled in the first century AD, Pliny described the heart as 'the primary source and origin of life'. He claimed that it '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'.[24] A century later the most celebrated surgeon of the ancient world, Galen, was able to describe the effect of cardiac injuries at first hand. For a few years he was the official doctor to the gladiators of his hometown of Pergamon, and witnessed many die from the effects of a stab wound to the heart. He noted that such a death was often instantaneous, but that the length of survival depended on the location of the wound:

> When a wound pierces the ventricle of the heart, they die immediately with great flow of blood, and especially so if the ventricle of the left part has been wounded; but if it does not reach the ventricle, but the wound stops in the substance of the heart, some of those affected can survive not only the day on which they were wounded but as long as the following night.[25]

Galen's writings remained the foundation of medical education until superseded by Renaissance scholarship almost 1,500 years later, so it is unsurprising that his conclusions went undisputed for centuries. In a wince-inducing treatise on the treatment of wounds, the seventh-century Byzantine physician Paul of Aegina gave a vivid description of a cardiac injury and its fatal consequences: 'When the heart is wounded, the weapon appears at the left breast, and feels not as if in a cavity, but as fixed in another body, and sometimes there is a

throbbing motion; there is a discharge of black blood if it can find vent, with coldness, sweats … and death follows in a short time.'[26]

That description was echoed eight hundred years later by Paré, the greatest surgeon of the Renaissance. Like Galen he had seen such injuries for himself, having spent many years as a military surgeon on the battlefields of France: 'If the heart be wounded, much blood gusheth out, a trembling possesseth all the members of the body: the pulse will be small and weak: the colour of the face will become very pale: a cold sweat, and frequent swooning will assault the wounded party: and when the limbs grow cold, death is at the door.'[27] But Paré also pointed out that death was not necessarily instant. He had witnessed a duel in Turin during which one of the combatants had been stabbed through the left breast; he nevertheless continued to fight, chasing his enemy for two hundred paces before falling down dead. When Paré examined the body he found a wound in the heart so large that he could insert his finger into it.[28]

Yet by the end of the sixteenth century surprising discoveries were being made which threatened to challenge the dogma that cardiac wounds were inherently fatal. Barthélémy Cabrol, physician to the French king Henry IV, described conducting an autopsy on two men and finding scars on their hearts. One had 'a lesion the size and width of a myrrh leaf, which penetrated quite deeply; and lest anybody think that these injuries were the cause of death, both men had been hanged: one for thieving, the other for producing counterfeit coin'.[29] Still more perplexing was the discovery of Johann Dolaeus, who wrote of a 'bullet of lead found in the heart of a boar, covered with flesh, that no way endangered his life: for he was a large boar, and when it was taken out with a huntsman's knife, any one might observe that the wound was not made two or three days, but a long time before'.[30]

Though many physicians continued to insist that cardiac wounds spelled death, the body of evidence to the contrary continued to grow. In 1778 Henry Thomas, a marine on board HMS *Foudroyant*, slipped off a gangplank while the ship was in dock at Portsmouth and fell on his bayonet. He removed the blade and declared himself fit to resume

his guard duty, before collapsing in a faint. He died nine hours later, and when they opened his body doctors were amazed to find that after impaling his colon and liver the bayonet had passed right through his heart.[31] A few years later a similar injury was seen at the same hospital in Gosport; in this case the soldier survived for two days, but died suddenly while defecating. At a post-mortem the surgeon concluded that a clot had formed in the wound, blocking the escape of blood from the heart, but had been dislodged as the soldier strained to empty his bowels.[32]

Throughout medical history some of the greatest advances in surgical knowledge have been made in the theatre of war. Military surgeons encountered injuries so numerous and terrible that they were tested to the limits of their ingenuity, devising new therapeutic approaches if existing techniques proved unequal to their needs. During the Napoleonic Wars, for instance, the Frenchman Dominique Larrey devised the modern process of triage, prioritising casualties according to the urgency of their condition, and introduced ambulances to the battlefield. His British counterpart George Guthrie, meanwhile, introduced new treatments for gunshot wounds of the legs – in particular, early amputation – that drastically reduced mortality. But one of the most celebrated cases of that conflict was one in which the surgeon did nothing at all.

At the Battle of Corunna in northern Spain in January 1809, a private in the Queen's Royals, Samuel Evens, was shot in the chest. His comrades carried him off the battlefield and he was put on a troopship back to England. It was crowded with wounded and ill soldiers and the only treatment he received was a plaster, but he was still in a fair condition when taken to hospital in Plymouth a few days later. Evens told the Scottish doctor who examined him, John Fuge, that a musket ball was still lodged in his chest, and begged him to remove it, saying that he was sure it was in easy reach. Fuge inserted a probe into the wound, but it was so deep that the entire instrument disappeared into it, and he abandoned the attempt. Three days later Evens died. His body, when Dr Fuge examined it, contained a huge

surprise. The musket ball had ripped through the wall of the heart, leaving an inch-long tear, and had lacerated one of the heart valves. This was a catastrophic injury, and yet the soldier had lived for a fortnight after receiving it. Fuge's report of the case, illustrated by an engraving of the preserved heart in a jar, was widely circulated in Europe and America – graphic evidence of the resilience of an organ hitherto believed to be uniquely fragile.[33]

Several similar cases came to light over the next few years, and doctors were now confronted with the question of how to treat them. From a twenty-first-century perspective, the emergency care received by Victor Janson in 1828 leaves a lot to be desired. Aged sixteen, he had been messing around with a friend in the cellar of his parents' house, and while play-fighting had stabbed himself with a knife. He felt no pain and assumed he had only cut his waistcoat, but ten minutes later noticed his clothes were covered in blood. He was taken to hospital, where doctors bandaged the wound, put him on his back and bled him. For the next three days they repeated this bleeding at regular intervals. The results were evidently unsatisfactory, because a few days later the therapy was intensified and twenty leeches were applied to his anus. Apparently intent on killing his patient, the doctor then inserted a probe into the wound, whereupon 'the blood sprung to the height of several feet'. Unsurprisingly, the boy soon died.[34]

Venesection, bleeding a patient by opening a vein, is one of the oldest therapies known to medicine. It was widely practised in the ancient world, when physicians believed that disease was caused by an imbalance of the four fundamental fluids or 'humours' of the human body: blood, phlegm, yellow bile and black bile. According to the humoral system, removing blood was a simple way of restoring the natural balance between the four fluids. By the nineteenth century most physicians had abandoned this antiquated notion, yet many retained an evangelical belief in the powers of bloodletting. It was often used in cases where the heart seemed to be under strain: doctors reasoned that reducing the amount of blood in the body was a simple way to reduce its workload.

Baron Guillaume Dupuytren, who was appointed chief surgeon of the hospital of Hôtel-Dieu in Paris in 1815, was a passionate advocate of venesection, and had no doubt that heart wounds could be survived. He advised treating patients as if the organ had not been injured: doctors should dress the wound, bleed the patient regularly and keep them cold.[35] Some took this last measure to extremes, packing the patient in bags of ice and cooling the room to sub-zero temperatures, while in summer they might resort to using a cellar.[36] This was intended to depress the circulation and reduce the strain on the heart; but others believed that stimulation was the key to survival. Rather than chilling their patients, they enveloped them in warm blankets and piled hot water bottles all over them.[37] There was also little agreement about what they should be given to eat or drink. Baron Dupuytren suggested acidulated drinks,[38] while hot brandy and water,[39] barley water,[40] and water-gruel and strawberries[41] were also tried. The patient in the last of these cases was a student who survived for six weeks after being stabbed in the heart; his attending physician, a Dr Lavender, concluded that the strawberries had contributed to his demise.

The first indication that more positive surgical intervention was possible came in 1872, when a thirty-one-year-old pewterer became involved in a pub brawl in London. After the tussle he noticed that a needle he had been carrying in his coat had disappeared, and he wondered whether it had entered his chest. The following day he was in some pain, and went to St Bartholomew's Hospital. The doctors could find no evidence of injury, so he went back to work; but nine days later he returned, still in pain and troubled by palpitations. He was examined by a surgeon called George Callender, who noticed a tiny bump between two of the ribs. He decided to investigate further, and after the patient had been given chloroform made a small incision into the pectoral muscle. To his surprise this revealed a small metallic object which vibrated with every heartbeat. With great delicacy he pulled at it with a pair of forceps, and a needle almost two inches long emerged from the man's chest, having apparently been lodged inside

the cardiac muscle. The patient made a good recovery, and when the details of the procedure were made public it quickly became the talk of medical London. It even earned the surgeon the rare distinction of becoming an eponym: 'Callender's operation' was notable as the first occasion on which a patient had recovered after surgery to remove an object from the heart.[42]

While a few early textbooks refer to Callender's operation as the first heart surgery, he had not actually needed to expose the organ or make an incision into its surface. The first person to do this deliberately – albeit not on a human patient – was Dr Block, a surgeon from Danzig. At a meeting of the German Surgical Society in 1882 he began a presentation of his work by brandishing a rabbit's heart. Some weeks earlier, he explained, he had cut open the animal's ribcage and created an artificial wound in the surface of the organ. He had then repaired the damage with three stitches, and a few days later the rabbit had completely recovered. To make sure this outcome was not a one-off he repeated the experiment, on the same animal and others.[43]

What particularly surprised Block was the organ's resilience. In order to insert sutures into the rabbit's heart he had to lift it out of the ribcage. He noticed that when he did this it stopped beating, and all breathing ceased. But as soon as it was released into its normal position all function resumed. Surgeons had long been terrified of touching the heart, fearing that even gentle manipulation might be enough to disturb its rhythm and cause instant death. But a much earlier writer, working in the seventeenth century, had already shown that it was quite a robust organ which would easily withstand careful handling.

The seventeenth-century English physician William Harvey contributed more than anybody to our understanding of what the heart is and what it does. He devoted years to his study of the movement of blood around the body, experimenting on an extraordinary range of creatures including dogs, rabbits, toads, lizards and crabs. Cold-blooded animals proved particularly useful, because they had a slow metabolism and therefore a slow heartbeat, allowing him to see more clearly what was going on. When Harvey began his work,

most authorities still subscribed to Galen's version of the action of the blood, a rather convoluted theory according to which arterial blood was manufactured in the heart and cooled by the lungs, while the liver produced the blood found in the veins. So great was Galen's reputation in the seventeenth century that dissent from his views amounted to medical heresy; it says much for Harvey's dedication to scientific truth that he was prepared to brave the consequences. His great discovery, laid out in his 1628 book *De Motu Cordis* ('On the Movement of the Heart'), was that blood travelled around the body in a closed circuit, propelled by the heart.

For over a decade Harvey was physician to Charles I, who took an interest in his work, allowing him to conduct dissections on deer in the royal parks. In the 1640s Harvey met a young nobleman, the son of Viscount Montgomery, who had suffered a serious accident in childhood. This left him with a cavernous wound in his side which had failed to heal. When Harvey examined the opening, he found a large open space in the thorax, into which he could easily fit three of his fingers. Looking more closely, he noticed 'a protuberant fleshy part' which, he realised with astonishment, was the young man's heart. He knew that his employer would be fascinated:

> I carried the young man himself to the king, that his majesty might with his own eyes behold this wonderful case: that, in a man alive and well, he might, without detriment to the individual, observe the movement of the heart, and with his proper hand even touch the ventricles as they contracted.

Charles inserted the royal fingers into the gaping chasm in the youth's flank and held the heart for himself, noting that this caused no pain or visible disturbance.[44] Here was clear evidence that the organ could be handled without danger; yet strangely this knowledge had already faded from view two centuries later.

Block was not the only researcher of the 1880s to suggest that it might eventually be feasible to stitch a human heart. An American

surgeon, John Roberts, raised the possibility in 1881, although the main subject of his article was the pericardium, the fibrous sac that surrounds it. Sometimes when the heart is injured this natural envelope fills with blood, preventing the organ from beating effectively. This condition, known as cardiac tamponade, is potentially fatal, and at least two surgeons of the early nineteenth century are believed to have treated it by inserting a sharp probe to puncture the sac, allowing the blood to drain away. Roberts suggested that it might even be safe to open the pericardium to retrieve foreign objects, or to enable minor repairs of the heart muscle: 'The time may possibly come when wounds of the heart itself will be treated by pericardial incision, to allow extraction of clots, and perhaps to suture the cardiac muscle.'[45]

It was a decade before this prediction was proved correct. On 6 September 1891, a young man in St Louis, Missouri, was stabbed in a fight. He was taken to the city hospital, where his wound was dressed, but ten hours later his condition had deteriorated and he was taken into the operating theatre. No anaesthetic was used, presumably because time was of the essence – a decade later one prominent surgeon still thought anaesthesia 'improper' for such a procedure,[46] and it would not be routinely used for such major surgery until after the First World War.[47] When the dressings were removed, blood and air gushed from the wound. Henry Dalton, the surgeon in charge, opened the patient's chest and turned him on his side in order to drain the blood. The incision revealed a two-inch wound in the pericardium which he managed to repair, after many attempts and with great difficulty: 'I had no precedent to guide me, no authority to uphold me in attempting to sew up this wound over a heart that was beating at the rate of 140 per minute.'[48]

At several points in the operation the patient appeared close to death, but on each occasion he was injected with a cocktail of strychnine and whiskey, which improved his condition. Strychnine is a highly toxic compound which was once used as rat poison, but at this date it was believed to be a useful stimulant which in small doses would elevate the heart rate. Whiskey also enjoyed something of a

vogue in American operating theatres at the turn of the century: in 1900 John DaCosta recommended enemas of hot coffee and whiskey when treating heart injuries,[49] while the post-operative medication of a stab victim in Georgetown nine years later included three pints of whiskey administered in a single day.[50] European surgeons preferred Old World drinks: during an operation in the 1890s, Charles Ballance injected his patient with a mixture of brandy and saline, which had so dramatic an effect that by the end of the procedure, 'he no longer seemed dead, but was so drunk and obstreperous that five men were required to hold him down'.[51]

Dalton's patient made a rapid and uninterrupted recovery; an impressive success, but he had not interfered with the heart itself. That remained a threshold that few were willing to cross. From a modern perspective it can be difficult to understand what it was that deterred surgeons from taking the decisive final step, when they had already come so close. Writing a few years later, the American surgeon Charles Elsberg explained why he and his colleagues were so petrified of touching the beating heart:

> We must remember that we have to deal with an organ of first importance which is in constant motion, and which, moreover, was believed to be very sensitive to the smallest mechanical insult or injury. It was feared that during the slightest manipulation the heart might suddenly stop, that the mere passage of a needle might be followed by the direst results.[52]

What changed their minds? A flamboyant piece of theatre staged by the Italian researcher Simplicio Del Vecchio in 1894 may have been the catalyst. At a conference of surgeons in Rome he appeared on stage with a dog on a lead and proceeded to tell his colleagues that he had operated on this animal forty days earlier, puncturing its heart and repairing the wound by stitching. Two days later it was killed, and members of the audience were able to see for themselves that the wound had healed perfectly, leaving only a small scar. Del Vecchio

was cautious about the prospects for human heart surgery, acknowledging that there were still important questions to be answered, such as whether it would be possible to administer an anaesthetic. But, he concluded, 'I am confident that in the not too distant future surgery will answer all these questions, and that with the protection afforded by asepsis it will surmount still more serious obstacles.'[53]

He did not have long to wait, for within a matter of months a surgeon in Norway had the courage not only to open the pericardium, but to attempt an operation on the structure of the heart itself – and even to insert a needle through its pulsating muscle. In the early hours of 4 September, a young man was rushed to the National Hospital in Oslo in a taxi, having been found at home lying in a pool of blood. He had been stabbed in the chest. When the thirty-seven-year-old duty surgeon, Axel Cappelen, examined him he found his unconscious patient 'pale as a corpse'. The man briefly stopped breathing, and an hour later his pulse was barely detectable. Cappelen decided to operate. Once the patient had been put to sleep with chloroform and his chest opened, Cappelen found massive internal bleeding. There was a wound about three-quarters of an inch long in the left ventricle of the heart, which he sutured with catgut, timing each stitch to avoid the violent leaps of the organ as it contracted. This delicate job was eventually completed, and when the patient awoke the next day he said he felt much better. But his recovery was only temporary: he died on the morning of 7 September, having succumbed to blood loss from an undetected arterial wound.[54]

Cappelen felt that his patient had been unlucky: the position of the wound concealed the fact that the heart had been injured in two places. If this had been spotted, and the operation had begun more promptly, he might have been successful. A second attempt to repair a cardiac wound took place in Rome in March 1896 when Guido Farina placed three silk sutures in the heart of a man who had been stabbed with a stiletto; his patient died two days later from an infection.[55] But there was something encouraging even in these failures, a hint of greater deeds to come, and the mood began to change. The *Journal*

of the American Medical Association declared bullishly: 'The opinion seems warranted, that "the citadel of life" itself will no longer be exempt from the incursions of the surgeons.'[56]

Indeed, disaster would soon be followed by triumph. Six months after Farina's disappointment, a surgeon from Frankfurt, Ludwig Rehn, achieved lasting fame and the adulation of his colleagues when he conducted the first successful operation on a human heart. On the last day of August 1896 a twenty-two-year-old gardener was discharged from the army – ironically, as it turned out, because he had been diagnosed with a heart problem. A week later he was stabbed and collapsed, unconscious. He was taken to hospital in the early hours, drenched in blood. When Rehn saw him the following day his initial assessment was that the man was dying. A colleague inspected the wound and concluded the heart was injured, so the decision was taken to operate.

When Rehn reached the chest cavity he could see a small wound in the pericardium. He opened the sac further; blood and clots were being continuously discharged from the area around the heart. He soon noticed a wound half an inch long in the surface of the cardiac muscle. He was able to control the bleeding by putting a finger over this aperture, although every time the heart contracted his finger slipped off and more blood gushed out. Rehn quickly decided to suture the laceration with silk thread, a material which was easy to handle and which – unlike catgut – would not be absorbed by the body. In the pause between heartbeats he passed his needle through both sides of the wound, and was alarmed to find that the heart halted for a moment before resuming its movement. When three stitches had been inserted the bleeding stopped; 'the heart continued to work, and we could breathe freely.'[57]

The worst was over, and all that Rehn now needed to do was wash the remaining blood and clots from the chest cavity and replace a rib which had been sawn through in order to reach the heart. These tasks were completed without alarm, and the patient returned to the ward. His condition remained a cause for concern for some weeks, but his

life was out of danger and he eventually made a full recovery. When Rehn described the operation to a meeting of surgical colleagues in Berlin the following April, he concluded his speech by bringing his patient on to the stage to demonstrate that he was in perfect health. This caused a sensation. Within hours telegraph wires were humming with the news, which was reported all over the world. Foreign correspondents were in too much of a hurry to check the spelling of Rehn's name: the front pages of newspapers in America and New Zealand attributed the triumph to a 'Dr Rehe',[58] while British readers were treated to breathless accounts of the operation performed by 'Herr Relin'.[59] Rehn had shown that while operating on the heart was daunting, the hazards were not insurmountable; emboldened by his example, many younger surgeons chose to intervene where once they had stood by impotently.

Most of the earliest attempts to emulate him took place in Europe. When an Italian surgeon reported a second successful operation in 1897, the physician G. S. Brock remarked: 'Happily it is only in Italy that surgeons have many opportunities of practising cardiac surgery – opportunities they owe to the terrible frequency with which the dagger is resorted to in this country in the quarrels of the lower orders.'[60] It was another five years before a surgeon in the US would follow suit, and in conditions far removed from the modern operating theatre. Luther Leonidas Hill's patient was Henry Myrick, a boy from an impoverished black family in Alabama, and the operation took place on their kitchen table, illuminated by kerosene lamps. Hill was assisted by his brother, who held the heart steady while stitches were inserted.[61] The case seized the attention of national newspapers, one of which headlined the story 'Lived with Stabbed Heart'.[62]

All these early cases involved patients with stab wounds; the American surgeon Rudolph Matas was not alone when he stated in 1899 that this was the only type of injury which could be treated: 'As to the gunshot perforations of the heart, they will continue, for obvious reasons, to spare the surgeon even the contemplation of his helplessness

to relieve them.'[63] Like many of the pessimistic predictions made by surgeons, this was both emphatic and completely wrong. On 3 March 1902, a twenty-six-year-old man was admitted to hospital in Paris after being shot with a revolver. The surgeon, M. Launay, operated and found that the bullet had passed right through the heart, leaving entry and exit wounds. The first of these was easily sutured, but the second, on the underside of the organ, was less easy for the surgeon's hands to reach and so caused more difficulties. Nevertheless, the operation took only thirty-five minutes and the patient was out of bed ten days later.[64]

Launay's task was simplified by the fact that the bullet had not lodged in the cardiac tissue but passed through it; removing a foreign body from inside the heart represented an altogether more formidable challenge. The evidence suggested that such injuries were always fatal, although there were records of a few fascinating cases where a victim survived for days or even weeks. The first surgeon to accept the challenge – the forerunner of Dwight Harken forty years later – was an Estonian, Werner von Manteuffel. A well-heeled young woman, Marie Plavsona, had fallen in with a bad crowd and been shot during an argument a short distance from his hospital in Dorpat on 12 September 1903.[65] When he uncovered the heart a wound came into view, out of which a fountain of blood half a metre high splashed with every beat. He closed the opening and found the bullet, which was embedded in the wall of the right ventricle, but by lifting the heart he was able to cut out the missile and repair the wound. Plavsona remained in hospital for several months, but survived.[66] For an obscure surgeon working in Estonia's second city this was a remarkable feat, and it was reported widely; von Manteuffel was rewarded with a prestigious position as personal physician to Tsar Nicholas II.

Manteuffel's description of a 'fountain of blood' gives some hint of the gory challenges faced by these brave pioneers. One spoke of being confronted by 'a lake of blood in which were churned bubbles of air',[67] another found himself 'operating in a mass of bloody foam, which is not conducive to equanimity'.[68] 'If it is in plain view', one

surgeon remarked sardonically, 'the stream spurting from a ventricle strikes the eyes of the operator with surprising accuracy.'[69] The blood in a contracting heart is at surprisingly high pressure, comparable to that at the bottom of a five-foot-deep swimming pool. Like a hairline fracture in a hot-water tank, even a minor puncture can rapidly produce startling amounts of fluid. The average human body contains around five litres of blood, and the heart pumps that entire volume every minute – making it quite possible for a large stab wound to kill a patient in a matter of seconds. But Charles Ballance, the first eminent British surgeon to venture into such territory, offered bracing encouragement to his colleagues: 'The surgeon having this job in hand will take it all in the day's work, and just as he plunges his hand into the abdomen into a mass of blood in a case of ruptured spleen . . . so he will now plunge his hand into the pericardium and seize the heart.'[70]

The First World War confronted surgeons with new and more horrible sights. The rapid evolution of military technology resulted in wounds more catastrophic than anything seen on the battlefields of the Crimea or the Boer War: machine-gun bullets tore through flesh with unprecedented power, and high-explosive shells riddled bodies with shrapnel or lacerated them with blast wounds. Ballance was one of several surgeons whose new prowess in cardiac surgery was invaluable in these circumstances. The apparently endless flood of casualties prompted a new manual on the treatment of war wounds, written by Henry Gray, a Scottish surgeon who spent most of the war at hospitals in northern France. As well as being an expert in gunshot injuries he was also an innovator who realised that for some procedures it was not always necessary to put the patient to sleep. His use of the newly discovered local anaesthetics meant that serious wounds could be treated quickly while the patient was spared the worst of the pain, saving time and allowing him to get through more operations each day.

While local anaesthetic is not obviously a method applicable to cardiac surgery, in 1915 Gray removed a bullet from the heart of a

soldier who remained awake throughout the operation. The patient in question could count himself doubly unlucky, having been shot by a round which passed straight through the man in front of him. After giving him morphine, Gray made a large incision into the man's chest; at this point the patient became anxious and complained that he was breathless, but 'settled down in about one minute, after being reassured by the surgeon'. Gray must have had a wonderfully calming bedside manner: in order to remove the bullet he had to lift the heart out of the man's chest, make an incision and extract the missile with forceps, and then stop the considerable bleeding that ensued. The patient lived another four days, but again died from an infection.[71]

Cardiac surgery was a major undertaking and rarely attempted during the war, but surprisingly successes outnumbered such failures. When the French surgeon Pierre Duval attempted to compile a list of every heart operation undertaken during the conflict he found that 23 of 26 patients had survived[72] – a triumphant result. One reason for this improvement was the increasingly sophisticated use of radiography, which gave surgeons a clear idea of what to expect before they made the first incision. X-rays, a form of high-energy electromagnetic radiation, had been discovered in November 1895 by the German physicist Wilhelm Röntgen, who also found that they could be used to visualise the internal structures of the human body. X-ray radiation is absorbed by bone and other dense materials, but passes through soft tissue virtually unaltered. Röntgen demonstrated this effect by getting his wife to place her left hand on a photographic plate and then exposing it to a burst of X-rays: when the plate was developed it revealed a skeletal image of her fingers and wedding ring. This had such obvious application to medical practice that within only a few months the technique was being used clinically to locate fractures, gallstones and bullets. Twenty years later X-ray machines were commonplace in military hospitals and even as mobile installations on the battlefield – and were often used to do more than simply take a picture.

One new technique was stereoscopic radiography, in which two images were combined to produce a three-dimensional picture. This provided invaluable information when foreign bodies were involved, because it enabled surgeons to work out whether a shrapnel fragment was actually inside the heart or sitting a few inches in front of it. If the patient were placed between the X-ray machine and a fluorescent screen it was also possible to produce moving images, a technique known as fluoroscopy. When objects were lodged inside the heart they pulsated in time with the heartbeat, or danced hypnotically as they were buffeted by the bloodstream. Alphonsus d'Abreu, a British surgeon who served in Africa and Italy during the Second World War, remarked that these swirlings and gyrations were watched 'with the same interest that astronomical observers bestow on minor planets'.[73] A particularly ingenious use of the fluorescent screen was made by a French medic, Petit de la Villéon. Instead of making an eight-inch incision through flesh and bone to remove shrapnel from the heart, he operated through a tiny opening between two ribs, using an X-ray screen to guide a pair of forceps to the site of injury. This was the first keyhole heart operation, but it horrified de la Villéon's colleagues, one of whom stated that 'no matter how satisfactory this method had proved in the lung and in other parts of the body, it had no place in the surgery of the heart.'[74] The remark is revealing, since it shows that the old, quasi-religious belief in the exceptional status of the organ still lingered; it would be many decades before minimally invasive cardiac surgery was contemplated again.

One of the more mystifying experiences for a surgeon was opening up a patient only to find that a bullet clearly visible in X-rays was nowhere to be found. Usually this meant that it had been swept away by the bloodstream and lodged elsewhere. Foreign objects could travel quite surprising distances: in one particularly dramatic example, two British surgeons found themselves in marathon pursuit of a jagged shell fragment as it migrated around the body of a teenage soldier. It had entered a vein in his chest but soon moved ominously towards his heart, where the surgeons managed to seize it briefly; but before

it could be extracted it was sucked into the cardiac chambers, eventually coming to rest in an artery behind his bladder, from which it was finally removed.[75]

In 1921 Rudolph Matas, one of the titans of early twentieth-century medicine, described these extractions of foreign bodies from the heart as 'one of the crowning triumphs of surgery'.[76] But there was little need for such expertise in peacetime, and it was not until the Second World War and the feats of Dwight Harken that any surgeon would again regularly experience the exhilaration and terror of rummaging inside a beating heart.

On the evening of 18 February 1945, Harken wrote to his wife Anne from his quarters in Gloucestershire. The following morning he would operate on Leroy Rohrbach, and he was anxious: 'If I kill this man, I shall be regarded as foolhardy rather than bold, and heart surgery could be set back by decades. If I succeed, heart surgery may well be on its way.'[77] Why such trepidation? Removing a bullet from the heart was, after all, nothing new, and Harken had himself done it many times before. But this time was different: word had got around about the young American who made cardiac surgery so safe that it was almost routine, and the pick of London's surgeons would be watching intently to find out if the rumours were true. This was not just another case, but one by which he and the future of his specialism would be judged. As it turned out, it was a triumph: two years later in America a hall full of Harken's colleagues would watch awestruck as the drama of his operation unfolded on a cinema screen in front of them. Many of them would be inspired to follow his example.

Harken's tour de force in a hut in the Cotswolds was the culmination of half a century's progress, in the course of which surgeons had overcome ancient fears about the heart and learned to treat it as one of the ordinary tissues of the body. They now knew that it could be held, manipulated and even repaired without fatal result. But heart injuries are rare, even in wartime; what of the millions living with faulty

heart valves or blocked arteries, or the thousands of babies born every year with congenital cardiac deformities? These were challenges crying out for a surgical revolution. As it happened, that revolution had already begun a few months earlier, in an operating theatre on the other side of the Atlantic; and Dwight Harken would continue to play a leading role.