8
Elective Amputation: From 1846 to Recent Times

". . . that, while the surgeon endeavours to avoid Scylla, he may not unwittingly run into Charybdis, mutilating a limb that might have been saved, and endangering life by the retention of one that should have been promptly amputated."

Gross, 1862[1]

"For it is not necessary . . . that pus should be generated in wounds. No error can be greater than this."

Theodoric, c. 1267[2]

Revolutionary changes in the past 150 years have rendered operative surgery acceptable to patients, previously terrorised by pain, hazarded by blood loss and uncontrollable debilitating and lethal wound infections. At the same time, operative capabilities have spread an ever-widening net of endeavour to all parts of the body, from foetuses in utero to the elderly, severely injured and moribund, and although amputation remains a final solution for some, this now produces better functional stumps backed by increasingly sophisticated prostheses, often facilitating near-normal activity for amputees.

The Control of Pain

The acceptance of ether inhalation anaesthesia in 1846 is a watershed in the history of medicine, assuring patients the balm of pain relief and providing surgeons more time to perform operations accurately. Its success spread like wildfire, on a worldwide scale, in contrast to the halting application of antisepsis and asepsis, equally important to the development of safe surgery, to be debated later. No attempt is made to detail the development of general anaesthesia, a major subject in its own right, yet it is appropriate to discuss earlier attempts to relieve pain during major operative procedures including amputations.

Today's patients, familiar with aspirin and anaesthesia, have difficulty comprehending the acceptance of pain by our forbearers, especially in assenting to major operations such as lithotomy and amputation, even if we understand that patients were making a choice between impending death and possible survival. Doubtless there were many who could not countenance such operations and awaited inevitable death[3] Nevertheless, our ancestors, and indeed some nonindustrialised societies today, appear to have resigned themselves to a life attended by pain and suffering, perhaps bolstered by a philosophy based on religious or tribal convictions. Meschig who observed trepanation, in 1980, without anaesthesia among certain tribes in Kenya for persistent headache, with locally made tools, extending over many hours, and often over many sessions, concluded:

"Africans are more capable of withstanding pain than Europeans, for they do not expect sympathy or pity from their fellows even if they complain."[4]

In Christian communities, many believed St. Paul's words in the Bible, literally:

"Beareth all things, believeth all things, hopeth all things, endureth all things."[5]

A late 18th-century manuscript described the reaction of Laura, a 9-year-old girl of an aristocratic family, who underwent thigh amputation

for a painful tuberculous knee bearing this without a murmur, holding a bunch of flowers throughout, until the femoral artery was ligated when she cried "Oh!" She maintained two texts supported her ordeal: "*. . . through much tribulation you must enter into the Kingdom of Heaven*" and "*. . . if we suffer with Him we shall reign with Him.*" She also expressed great delight to think amputation took place on Maundy Thursday in Passion Week, by suffering thus to be tested like her Saviour.[6] And in 1844, Harriet Martineau when an invalid wrote on this theme, stating the:

"*. . . supposition—indispensable and, I believe, universal,—that pain is . . . ordained for, or instrumental to good.*" and acute pain can be: "*. . . vivifying and cheering.*"[7]

Knowledge of pain-relieving plant remedies has a long history; for example, the mandrake (mandragora bark in wine) was known to Dioscorides in the 1st century A.D. as safe in moderate doses "*. . . but being too much drunk, it drives out ye life.*"[8] Similar remedies and mind-blowing botanical drugs are still known among hunter-gatherer communities. By the 12th century A.D., a concoction of drugs was recommended as a soporific sponge by Michael Scott, who wrote:

"Take of opium, mandragora and henbane, equal parts. Pound and mix them with water. When you want to saw or cut a man, dip a rag in this and put it to his nostrils; he will soon sleep so deep that you may do as you wish."[9]

Sadly, the patient often slept too well and perished. Hugh of Lucca's similar remedy was described by Theodoric as:

"A decoction of opium, unripe mulberry, hyoscyamus, spurge flax, mandragora, hemlock, lapathum, ivy and lettuce seed, sponge soaked and dried, moistened with warm water and vapour inhaled by nostrils; resuscitation by another sponge dipped in fresh vinegar."[10]

Unfortunately, these remedies lacked accurate control of the dosages, for chemical assay did not exist until the 19th century. Further, many components were imported laboriously, especially to Northern European countries, leading to deterioration and possible adulteration of the products, or substitution, as Morson, a 19th-century authority on the manufacture of morphia from opium indicated; on purchasing opium cakes in the London docks, he took the precaution of thrusting a knife into them to exclude any substitution with wood.[11] Uncertainty about opium's efficacy condemned Horatio Nelson, whose right arm was amputated at Santa Cruz in 1797, to its prescription after his operation, not before (Fig. 8.1). His surgeon Thomas Eshelby reported:

"Compound fracture of the right arm by a musket ball passing through a little above the elbow and artery divided. The arm was immediately amputated and opium afterwards given."[12]

However, Watt has reported that some 18th-century naval surgeons employed opium liberally, including preoperative use.[13]

Even so, other surgeons stated preoperative prescription, sufficient to allay pain, usually induced nausea and vomiting which interfered with operative procedures. Moore, a civilian surgeon claimed that for amputations:

Fig. 8.1. Painting of Lord Nelson dressed after a scalp wound sustained at the Battle of the Nile, in 1798, also showing his right arm stump following injury at Teneriffe in 1795; blood has dripped from the scalp onto his right shoulder. (© National Maritime Museum, London, UK)

"The strongest dose we dare venture, has little or no effect in mitigating the sufferings of the patient during the operation."[14]

In the 20th century, the surgeon Wangensteen confirmed that, in addition, individual sensibility might vary considerably after a standard dose when he wrote:

"The senior author has seen a man of seventy-five remain in coma for four days after administration of one quarter grain (16 mg) of morphine."[15]

Alcohol is frequently mentioned in connection with amputations, opinions varying as to its object and any efficacy. Moyle, a naval surgeon when performing amputation on a sailor, wrote in 1693:

". . . give him a Spoonful of Cordial to cherish him . . ." and also: *". . . have a Cordial Bottle ready at hand to relieve men when they faint."*[16]

In the Royal Navy, patients were often given a tot of rum and a piece of leather to bite on before an operation, suggesting the alcohol was to stiffen resolve rather than diminish pain. Dionis wrote in France that patients were much encouraged by half a glass of wine.[17] Alcohol may be better than nothing, especially when the British garrison at the siege of Lucknow in 1857 ran out of anaesthetic agents and were able to turn, apparently, to liberal stocks of champagne from the officer's mess. Cox mentions port wine for a disarticulation at the hip in 1842 (Fig. 8.2). Immediately after surgery he reported:

". . . and though the patient had drunk a full half pint of port wine, she was now in an extremely collapsed condition;"[18]

Another recorded example concerned a successful Caesarian section in Uganda, witnessed in 1879 by Felkin, under banana wine inebriation.[19]

In 1363, Chauliac mentions bandages or fillets to arrest haemorrhage and for their numbing effect, sufficient to ameliorate the pain of amputation. Gersdorff's leg amputation (see Fig. 1.5) shows a length of cord binding above and a shorter length below the line of section but makes no mention of its numbing effect. In 1676, Wiseman considered a "ligature," that is, a bandage tourniquet, essential for major amputations and wrote:

Fig. 8.2. Disarticulation of the hip showing Signorigni compressor over the femoral artery and the formation of flaps by transfixion with a long, narrow, double-bladed knife, 1844. (From Cox WS. *A Memoir on Amputation of the Thigh at the Hip Joint*. London: Reeve, 1845.[18]) (See Fig. 9.4)

". . . by this ancient way of Ligature the Vessels are secured from Bleeding, the Member benummed, and the Flesh held steady, ready to receive the impression of your crooked Knife . . ."[20]

An extension of this approach to numbing the operative site was discussed by Moore in 1784 when he introduced the application of specially constructed screw compressors (Fig. 8.3) to stupefy individual nerves. After trials these devices were abandoned as the numbness was variable and accompanied by severe and objectionable neuralgic pain. Following observations on shattered limbs exposed to freezing conditions during the French retreat from Moscow, deliberate refrigeration of limbs with ice was found to relieve pain during amputation. Unfortunately, sources of ice were not readily available until much later. By contrast, Cooper considered that warming and oiling the instruments would reduce pain.[21]

Attempts by Elliotson and others to interest the profession in the benefits of hypnosis in the 1840s, helpful to susceptible patients, fell on deaf and

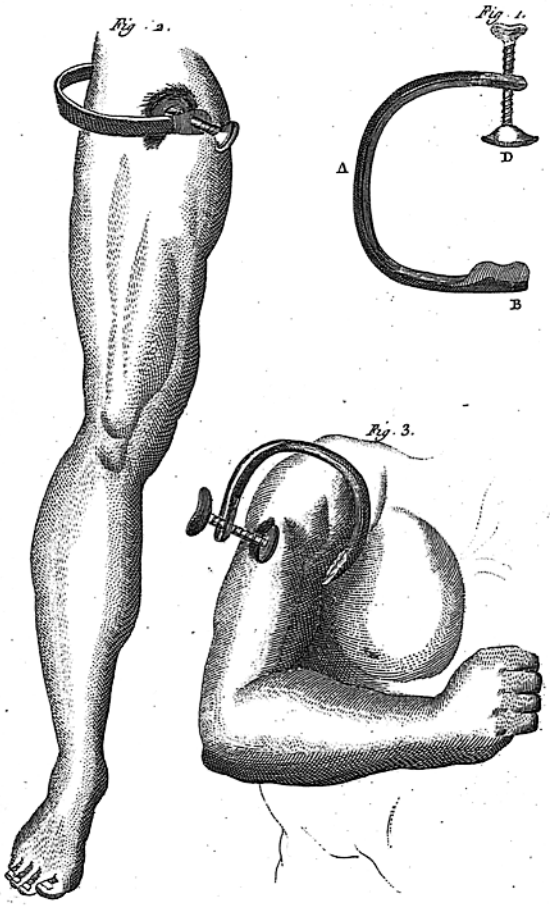

Fig. 8.3. Nerve compressor to induce loss of sensation; applications combining femoral and sciatic trunks, and combining cutaneous nerves of the arm with nerve trunks in the axilla. (From Moore J. *A Method of Preventing and Diminishing Pain in Several Operations of Surgery.* London: Cadell, 1784.[14])

derisory ears, being considered fakery by most practitioners. In India, Esdaile reported on his wide experience of hypnotic techniques at a native Indian hospital, having studied hypnosis already practised by the Hindu population. He performed over 950 operations, including amputations, relieved of pain, being endorsed by many European witnesses. His results arrived too late to influence surgeons in Britain for, very shortly after, ether anaesthesia was announced.[22] In practice, all that most surgeons offered was a speedy operation based on accurate anatomical knowledge. In 1822, Cooper believed:

"Modern practitioners have materially simplified all the chief operations of surgery, accomplished by better anatomical science, by devising less painful methods and by improving the construction of instruments."[21]

Commenting on hypnosis, Velpeau stated in 1840:

". . . these practices are a chimera, for it is better to have sharp scalpels, detailed knowledge and confidence, and the resignation of the patient; " adding: *"Immersing the instruments in hot water may reduce the pain."*[23]

Liston emphasised the importance of speed and wrote in 1838:

"The . . . parts should be divided by a single incision, rather than that the patient should be tormented . . . by a slow and tedious procedure, bit by bit." and for amputations he added: *". . . incisions from within outwards . . . give much less pain than those in the opposite direction."*[24] (Fig. 8.4).

We have mentioned (see Chapter 5) attempts at speedy amputation by axe, chisel and mallet, massive bone nippers and Fabry's "guillotine" of wooden timbers weighted with lead, usually ending with badly splintered bone, all of which were abandoned.

The timing of amputation was also considered important. Wiseman when employed in the Spanish navy complained that some colleagues undertook amputation too readily and unnecessarily, yet was convinced that immediate amputation for battle trauma was often best, and least painful when the victim was heated by the action, that is, full of adrenaline and endorphins. He commented:

"And then it must be done in its proper time, that is to say, suddenly upon receipt of the Wound, before the Patient's Spirits be over-heated either with Pain or Fever, etc." And: *"Therefore you are to consider well the Member, and if you have no probable hope of Sanation, cut it off quickly, while the Souldier is heated and in mettle."*[25]

Evidence of this "heating" is displayed by a seaman who, after arm amputation, was found by Wiseman helping to traverse a gun (see Chapter 6). On another occasion Wiseman was offered a drink by a sailor who pleaded for an immediate amputation.[25] Other military surgeons were also aware of this euphoric state exhibited by some but by no means all those severely injured.

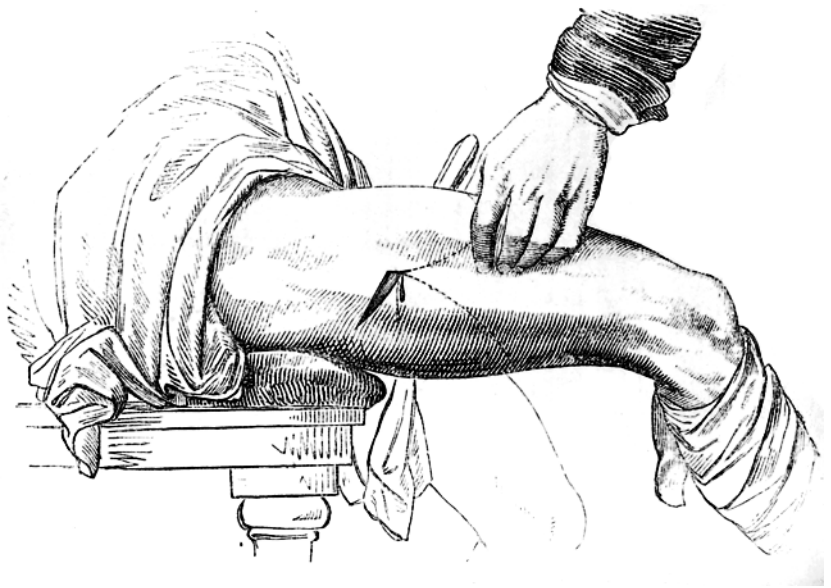

Fig. 8.4. Transfixion method of forming flaps for a midthigh amputation, Liston, 1837. (From Liston R. *Practical Surgery*, vol 7. London: Churchill, 1837.[24])

Yet beyond this state, evidence of remarkable self-control in accepting pain is reported as in the case of a boy aged 9 years who demanded thigh amputation to relieve his misery (see Chapter 3) and Thomas Main, a sailor at the battle of Trafalgar, having his arm amputated at the shoulder whilst he sang "Rule Britannia" *". . . with great composure, smiling and with a steady clear voice."*[26]

Even when anaesthesia was available, some patients were capable of submitting to major operations without its help. MacCormac related the story of an old French soldier injured at the battle of Sedan who underwent joint excisions of both a shoulder and an elbow, without anaesthesia, for he wished to monitor the operations and ensure amputation was not performed against his wishes.[27] During World War I, Leriche when asked to perform amputations on two Cossack soldiers, sent for his anaesthetist, only to be told by Russian colleagues that it was useless to give these soldiers anaesthesia for they felt no pain. With considerable repugnance, Leriche disarticulated three fingers and their metacarpals (half the hand) of one Cossack and the foot of the other:

"Neither one man nor the other showed the least tremor, but turned the hand or raised the leg when asked to do so, without showing even the slightest sign of momentary weakness, just as if under the most perfect local anaesthesia."[28]

Leriche pondered whether physical pain is influenced by a "mental factor," by energy or free will, either acting as a brake on the expression of pain or by actually diminishing painful perceptions. He emphasised further research was necessary, despite convictions that differences in racial and national responses existed, as in the case of the Cossacks, and that modern man's resolution had been weakened by familiarity with analgesics and anaesthetics.

After the first public demonstration of ether anaesthesia in the Massachusetts General Hospital on October 16, 1846, its use spread rapidly. Remarkably, Liston who was among the first to employ it in Britain on December 21, 1846, undertaking a midthigh amputation, still operated at breakneck speed to sever the limb in 25 seconds, by one account, or 28 seconds in another (Fig. 8.5); after wound suppuration the patient returned home 53 days later.[29] Such urgency increased surgical errors, but eventually the calm offered by freedom from the patient's screams and struggles ensured safer, more-deliberate work. Yet, a few established surgeons were reluctant to embrace anaesthesia, for example, in 1847 Professor John South, then aged 50 years, expressed reservations on the employment of ether, concluding:

". . . I have considerable doubt of the propriety of putting a patient into so unnatural a condition as results from

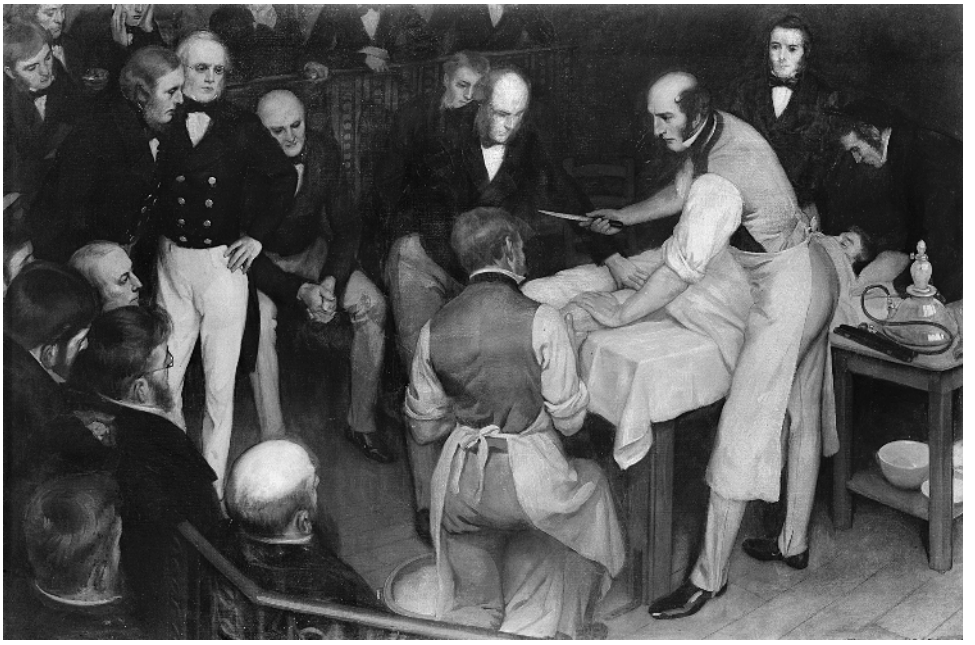

Fig. 8.5. Reconstructed painting of the first amputation performed in Britain under anaesthesia, December 1846, showing Robert Liston, Spencer Wells and Joseph Lister as a student; only Liston was definitely present. (Copyright Wellcome Trust Medical Photographic Library.)

inhaling ether, which seems scarcely different from severe intoxication, a state which no Surgeon would be desirous of having a patient who was about to be submitted to a serious operation."[30]

In January 1847, at the suggestion of David Waldie, James Simpson employed chloroform anaesthesia, and this and nitrous oxide gas were added to ether as potent pain-relieving agents.

The Control of Infection

Cleansing wounds with water, wine, balsams and other herbal lotions has a long history and is comprehensible with respect to fresh, dirty wounds which doubtless encouraged, long before any knowledge of the causes of putrefaction, instinctive distrust of obvious foreign material. Any effect of cleansing is uncertain for even macroscopically clean wounds became infected, and was accepted by many as inevitable and, indeed, a necessary requirement for healing and recovery, leading to the description "laudable pus."[31] Among those convinced that pus formation was not necessary for healing was Theodoric, who made his views clear in the 13th century, as the quotation heading this chapter demonstrates. Sadly, his proposition only became a reality post Lister, six centuries later. Meanwhile, surgeons continued to apply water dressings, dry lint, absorbent cotton wool or none at all, leaving the wound open to glaze over, assuming haemorrhage had been controlled, or various chemicals ad hoc, or cautery to cleanse wounds, doubtless being pleased if healing occurred without putrefaction. In Chapter 7 we noted the healing of Alanson's 35 consecutive amputations due to his isolation policy and open delayed wound closure, and also the avoidance of amputation by Crowther who applied dressings of wood tar (later shown to contain cresol and phenol) to 28 consecutive severe compound fractures. Yet these reports and the advice of Semmelweiss in 1847, who successfully prevented puerperal fever in obstetric wards by hand-scrubbing with soap and chlorine water, failed to alert any material change in surgical practices.

In 1834, Runge isolated carbolic acid (phenol), which was employed to sweeten dissecting rooms and to treat infected wounds. Both Lemaire and

Declat in Paris investigated the properties of phenol intensively and recommended its use for many infected conditions including suppurating wounds, disputing priority of application with Lister.[32] They and others demonstrated that phenol promoted the healing of putrefied wounds, sinuses and ulcers, yet they failed to initiate its prophylactic function. Lister in Glasgow, who experienced a depressing mortality rate of 45% for major amputations performed in his unit during 1864–1865, heard from a chemist colleague, Anderson, of Pasteur's experiments on fermentation and his proof against spontaneous generation, and wondered if something floating in the air was responsible for wound infections. Anderson, who knew that carbolic acid eliminated the odour of sewage, supplied Lister with a crude sample; in retrospect it is strange that Lister, apparently, had not heard of the investigations in this field of Lemaire, Declat and others. As pure phenol proved very irritating to wound tissues and his own hands, he changed to an oily solution of 5% phenol in 1865, which proved an efficient prophylactic against infection of fresh wounds.[33] In 1867 he described the successful management of 11 compound fractures treated with phenol dressings, without an amputation; at the same time he undertook 7 inevitable amputations for severe injury without a death.[34] As his system evolved, Lister performed elective surgery soaking the patient's skin, his hands, instruments and dressings, and from 1871 spraying the air around wounds, with phenol, to achieve a high ratio of wound healing without sepsis.[35] Amputation deaths of 45% before this regimen fell during the years 1867–1869 to 15%[36]; at the same time many patients with compound fractures, formerly candidates for amputation, healed without suppuration to preserve their limbs.

Many critics claimed failure to repeat Lister's results, almost certainly because they omitted to follow his precise instructions, and many were content to pursue old ways without attempting chemical antisepsis; if some immersed their instruments and dressings in phenol, they denied any relation to Listerism! Criticism by London practitioners was often damning and even when Lister became Professor of Surgery at King's College, London, in 1877, many students ignored his lectures and operating sessions initially. At a symposium conducted by William MacCormac in 1879, 14 well-known surgeons, all but 3 from London, debated antisepsis over two evening discussions. Five, all London surgeons, remained opposed to Listerism, 1 sat on the fence, but 8 supported antisepsis. A flavour of the opposition was expressed by Wood, a colleague of Lister at King's College Hospital, when he complained the hospital committee demanded personal funding to purchase antiseptic materials in his wards, adding:

"This was not unnatural, for my surgical colleagues, and notably Sir W. Fergusson, were of opinion (still shared by many) that the pure waters of Damascus were as good or better than all the carbolised waters of Israel for purifying influence."[37]

Schultze of Berlin, who visited Lister in 1874 and was converted to antisepsis, also visited many other medical centres in Britain and observed:

". . . in London Lister has few adherents. The principal surgeons have nothing to do with it, because they say they do not obtain from it any better results, and, speaking generally, the whole affair is too complicated for them. Precise objections you do not hear; the details of practice are usually unknown to them."[38]

In Paris too there was much opposition and even callous demonstrations in front of students. As late as 1892, Terrillon reported Dépres opening an abscess with a folding bistoury and then asking for a drain:

"The nurse fetched one from a neighbouring ward. Depres took the drain immersed in phenol, put it on the floor, rolled it under his foot and then placed it in the wound."[39]

Considerable opposition was also expressed in America where little notice was taken of antiseptic surgery until Lister spoke at the International Medical Congress, Philadelphia, in 1876. Thereafter, acceptance was slow and, as Watson's quotation in Chapter Ionpage 8 indicates, opposition or indifference was still common in 1883. Fortunately, Lister's pupils, house surgeons and many impartial visitors witnessed the remarkable changes indisputably linked to Lister's practice to disseminate his views. Important foreign visitors who supported Listerian antisepsis included Saxtorph of Copenhagen, Lucas-Championniere of Paris and Reyher of Dorpat; Lucas-Championniere was to write the first book on

antiseptic surgery in 1876[40] and Reyher, serving in the Russian army during the Russo-Turkish war, was the first to demonstrate that antiseptic management was possible during battle conditions, reversing sepsis from 62.9% to 10.5%.[41] It was principally German surgeons who embraced Lister's practice with energy and scientific thoroughness to demonstrate its superiority over other regimens, usually without visiting him, by simply digesting his publications. In 1872, Volkmann of Halle, faced with many cases of pyaemia and erysipelas after elective operations, instituted Listerian practice as an experiment and was amazed at the transformation of his wards, to become *"Lister's most devoted disciple."*[42] Similarly, Nussbaum of Munich, who had experienced a hospital gangrene rate of 80% in 1872, was amazed to find this drop to zero.[43]

Pasteur stated in 1874:

"If I had the honour of being a surgeon, I would never introduce into a human body an instrument that had not been passed through boiling water and better that a flame, just before an operation, and rapidly cooled."[44]

He amplified this in 1878, recommending careful hand-washing and flaming, the use of dressings subjected to heat at 130°–150°C and water to 110°–120°C. Regrettably, surgeons were extremely slow to seize on these revolutionary instructions, although it is believed Macewen in Glasgow began to boil his instruments in a fish-kettle during the late 1870s.[45] Primed with the science of bacteriology and knowledge of Pasteur and Koch's laboratory autoclaves, surgical heat sterilisation emerged in France and Germany between 1883 and 1893.

Neuber of Kiel was probably the first to autoclave operating gowns in 1883 and then to advocate sterile caps and rubber shoes in 1886.[46] By 1887, Tripier of Lyon was autoclaving wound dressings and perhaps instruments.[47] Redard in Paris, having shown that simple boiling did not always sterilise the inside of tubular instruments and needles, commenced autoclaving instruments and dressings before 1888[48] (Fig. 8.6E). Von Bergmann of Berlin claimed in 1890 that for 2 years he had operated with autoclaved swabs and sutures, and boiled instruments, continuing to employ antiseptics for the patient's skin, his hands and for catgut.[49] This aseptic scheme, clarified by von Bergmann's assistant Schimmelbusch, in his monograph of 1892, reported a range of autoclaves and boilers, special drums for autoclaving linen, swabs, dressings and sutures, and also novel glass and metal operating furniture[50] (see Fig. 8.6F), constituting the basis of modern surgical practice.

In the 20th century, bacteriological knowledge, chemotherapy, antibiotics and ventilated clean-air operating theatres have all diminished the risks of infection, although modern management has induced a growing problem with drug-resistant organisms. Reduced bone and joint infection rates, after operations in specially ventilated clean air enclosures, confirm Lister's suspicions about organisms floating in the air, although he was persuaded to abandon his phenol spray in 1887.

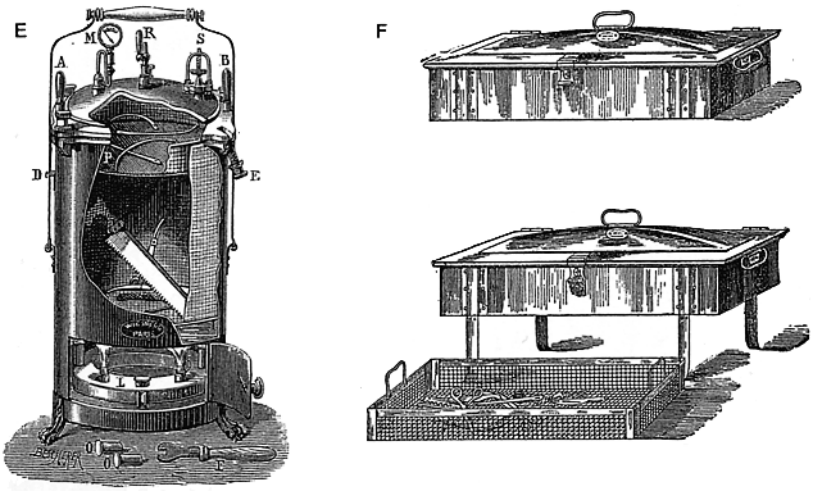

Fig. 8.6. *E*, Redard's autoclave for sterilising instruments, 1888[48]; *F*, Schimmelbusch's portable boiler, packed and opened to show legs beneath which heat was applied, and also the removable tray for instruments, 1893.[50]

Critics still diminish Lister's contribution, believing that heat sterilisation is the keystone of modern surgery, overlooking that the patient's skin, the surgeon's hands and many instruments such as endoscopes cannot be submitted to heat sterilisation, whilst the march of resistant bacteria often relates to poor observance of simple Listerian prophylaxis. Inescapably, operative surgery's struggle against infection continues, dependant on both rigorous aseptic and antiseptic measures.

Amputation During Warfare

After the battles of the Napoleonic era, Europe experienced a lull for several decades until broken by the Crimean campaign, followed by the Franco-Prussian and other European Wars, and also the American Civil War, culminating in the savage 20th-century disasters of the two World Wars. If battlefields accelerated the number of amputations, this was accompanied by growing numbers of major industrial accidents, rapid transport injuries and rampant joint tuberculosis to test civilian surgeons similarly.

During the Crimean War (1854–1856), France, Turkey and Britain fought Russia, unprepared for the diseases which killed most soldiers and also frostbite, caused by severe winters, and hence a source of amputations. The British made some use of chloroform while the French employed it widely, although the crowded hospitals were overwhelmed by hospital gangrene, eventually diminished by Florence Nightingale's regime. French surgeons achieved some success with dressings of ferric chloride, and also cautery.[51] Due to hospital infection, Scrive advised immediate amputations, noting however that of 9 disarticulations at the hip, all died. Of 4698 amputations by the French, 27% died, but Scrive does not indicate what percentage of 1512 thigh amputations (32% of the total) or 912 leg amputations (19.5% of the total) were mortal.[52] British amputation mortality ranged from 0.5% to 1.8% for fingers and the forearm, from 22.9% to 27.2% for the arm and shoulder, and from 50% to 86.8% above the knee.[53]

The American Civil War of 1861–1865 produced huge numbers of casualties and many amputations, those undertaken by the Union army being meticulously recorded in six substantial volumes. Again the use of general anaesthesia was available but antisepsis remained primitive; Wangensteen draws attention to some control of hospital gangrene by a few officers, employing bromine, turpentine and nitric acid, respectively.[54] However, Keen observed:

"We used only the ordinary marine or toilet sponges. After an operation they were washed in ordinary water to cleanse them of blood and pus, and were used in subsequent operations. . . . If one fell on the floor it was squeezed two or three times in ordinary water and used at once! . . . Practically every serious wound was bathed in pus, many times abscesses followed, or erysipelas, or blood poisoning, or hospital gangrene, or lockjaw."[55]

The overall mortality rate of 29,980 amputations performed by the Union army was 26.3%, ranging from 2.9% for fingers and hand, to 5.7% for toes and feet, to 33.2% for shin amputation, to 54.2% for thigh amputation and to 83.3% for hip disarticulation. It is estimated the Confederate Army sustained 25,000 amputations.[56]

The siege of Paris during the Franco-Prussian War of 1870–1871 is notorious for deprivation, famine and a high mortality after amputation. Although many wounds were treated conservatively, the mortality after expectant treatment, by excision or by amputation was equally severe. The French surgeon, Nelaton, performed 70 amputations resulting in 70 deaths, and other surgeons in Paris had similar experience. Lister wrote a paper on antiseptic management expressly to help military surgeons in this conflict, without serious response.[35] In the fighting outside Paris, Lucas-Championniere, who as we have observed keenly supported Listerian antisepsis, was prevented by his chief from bringing carbolic acid to his field hospital where patients were dying from septic conditions, and it was taken back unopened to Paris.[57] However, despite the appalling mortality from wounds, volunteers such as Sims from America and MacCormac from Britain were able to perform some antiseptic surgery.

World War I introduced trench warfare on an unprecedented scale, precipitating massive artillery bombardments, resulting in 77% of all gunshot wounds being caused by shell fragments,[58] a complete reversal of the predominance of bullet wounds typical of former wars. Shell fragment wounds were often multiple, causing

ragged destruction of soft tissues and underlying bone, as well as retention of the metal fragment or fragments with contaminated in-driven clothing remnants. A further common aggravating factor stemmed from delay in evacuating the injured from flooded and muddy terrain, and particularly from dangerous no-mans-land, before definitive surgical treatment could begin in a Casualty Clearing Station some 25 miles or so behind the front line. This delay was most significant for gunshot wounds of the thigh with open femoral fractures, for evacuation on a stretcher was the only method of transport from no-mans-land where stretcher bearers often became casualties in attempting evacuation.[59] Compound fractures of the femur had a depressing reputation, and the number who died before evacuation remains unknown. Of those rescued, Hurley and Weedon recorded an average delay in reaching their surgical station of 3 to 4 days, often with gas gangrene, and that within 48 hours of reception 38% were dead despite treatment.[60] Such victims were usually candidates for amputation and before blood transfusion and the Thomas splint became mandatory, the mortality remained high; in addition there were no antibiotics. In one analysis of 144,264 British troops with upper or lower limb injuries, 4,236 (2.9%) underwent amputation, of which 75 (6.5%) upper and 344 (11.15%) lower limb amputations died.[61] American statistics for 4,057,101 soldiers who fought in World War I indicate that 4,403 underwent major amputations. Of the 60 million combatants of all nations, 7 million were killed, 19 million were wounded and half a million underwent amputations.[62] One benefit stimulated by these large numbers of amputees was an obligation to improve prosthetic services (see Chapter 13).

World War II revealed another type of war with large numbers of civilians directly involved, especially subject to heavy aerial bombardment, and with military battles proving largely mobile contests, involving heavy armaments due to tanks, planes and sophisticated artillery; shell wounds were common except in jungle warfare. Civilians and others trapped in collapsed buildings often sustained crush injuries of their limbs and died of renal failure due to damaged muscle producing metabolites blocking kidney function,[63] even if amputation was performed. Early evacuation, good splintage, transfusion of plasma or blood, occasional arterial repair and the availability of penicillin late in the war often saved limbs from amputation. However, the severity of tissue damage by landmines and the more destructive power of weaponry generally often made conservative measures unavailing, to produce an incidence of amputation at 5.3% which overtook the 2% of World War I.[64] Commenting on major conflicts involving American forces, Aldea and Shaw demonstrated that from the American Civil War to the Vietnam War, overall wound mortality dropped from 13.3% to 1.8% whilst paradoxically the amputation rate increased from a low figure to 13.5% (Table 8.1), suggesting firstly, that weaponry had become more destructive with time and secondly, that improved evacuation methods and basic wound care enabled victims formerly destined to die to be saved by amputation.

Table 8.1. Military statistics during recent wars.

War	Wound mortality	Amputation rate
American Civil	13.3%	Not known
WW I	8.0%	2.0%
WW II	4.5%	5.3%
Korea	2.5%	13.0%
Vietnam	1.8%	13.5%

Source: From Refs. 56, 58.

Amputation During Civil Life

In contrast to battlefield indications centred on gunshot injury, and ignoring occasional gunshot wounds due to hunting and shooting accidents, civil indications for amputation were linked to diseased joints, leg ulceration and to industrial and traffic injuries. In the 19th century, not many lived long enough to develop degenerative arterial disease, unlike the aging population of the 20th century, especially those over 70 years of age whose failing circulation dominates current indications for amputation in civil life. Diabetes mellitus is a potential source of gangrene, but an association between the two does not appear to have been made until the mid-19th century (see Chapter 2), and without insulin it is doubtful whether amputation was feasible.

At the beginning of the 19th century, scrophulous joints due to bovine tuberculosis, the "white swelling" or "tumor albus," were common and, in Britain at least, proved a frequent indication for amputation, to rid patients of painful swollen joints which eventually ulcerated to form permanent sinuses and secondarily infected bone, associated with spread elsewhere and death. That amputation could resolve both local and more general spread seems to have taken place, according to Lloyd who described two amputees as follows:

"The first case is a little boy, about eight years old, who had a scrophulous affection of his knee joint, who was terribly reduced, and who had symptoms of mesenteric disease, and yet perfectly recovered after the limb was removed. The next is the case of a little boy, eleven years of age, whose limb was amputated on account of scrophulous disease of the tarsus and metatarsus, who perfectly recovered, although he was so ill before hand, from the irritation of the foot, that it was debated whether the operation would give a chance of recovery."[65]

Many however were not considered suitable for surgery or died after amputation. As noted in Chapter 7, the alternative operation of joint excision was essayed in the late 18th century by Park and Moreau, taken up in the early 19th century by Syme and a few others, but was not established generally until after ether anaesthesia became available.[66] Subsequently, most joints were excised, including the hip and, as a result of Lister's enterprise, the wrist to save the hand.[67] Towards the end of the 19th century, the development of efficient splintage, for example, by Hugh Owen Thomas,[68] and adequate provision of long-stay beds in sanatoria reduced operative solutions even further. As the Industrial Revolution and factories motivated by machinery developed, increasing numbers of trapped limbs, especially involving children, and particularly the hand and arm necessitated amputation. Legs were frequently run over by wagons, coaches and railway stock as the latter burgeoned after 1840. Eventually, legislation reduced work-related injuries but other high-velocity accidents proliferated as bicycles, motorcycles, motor vehicles and eventually aeroplanes added their toll.

Warfare and scientific advances in the 20th century have added blood transfusion, resuscitation techniques, arterial reconstruction, skin and bone grafting, and antibiotics to the surgical arsenal, resulting in the reconstruction of injured limbs previously subject to amputation. As we discuss in Chapters 12 and 13, some believe the pendulum has swung too far towards prolonged programmes of repair when modern amputation techniques and prostheses may provide better function.

Summary

Amputees before anaesthesia recorded amazing examples of sangfroid during surgery, including that of children, often buttressed by strong religious convictions. Others admitted to real pain and terror. In 1846, general anaesthesia not only relieved patients but gave surgeons time to operate more accurately and also pursue alternative operations which avoided amputation. Despite this miraculous advance, surgery remained hazarded by lethal wound infections until prophylactic chemical sterilisation commenced in 1867, to be further reinforced by thermal sterilisation about 1890. Sadly, the 20th century saw warfare on an unprecedented scale, stimulating, however, splintage systems, transfusion, antibiotics, evacuation methods, arterial repair and intensive patient care. Many severe limb injuries are now remediable, although there are limits to the pursuit of reconstruction.

References

1. Gross SD. *A Manual of Military Surgery, or Hints on the Emergencies of the Field, camp and Hospital practice*. Philadelphia: Lippincott, 1862.
2. Campbell E, Colton J (editors). *The Surgery of Theodoric ca. 1267*, vol 2. New York: Appleton, 1955–1960: Chapter 27.
3. Stanley P. *For Fear of Pain, British Surgery, 1790–1850*. Amsterdam: Rodopi, 2003:261–281.
4. Meschig R, Schadwalt H. Schadeloperationen in Kenia. *Dtsch Med Wochenschr* 1981;106:157.
5. *Holy Bible*. First Epistle of Paul the Apostle to the Corinthians, Chapter 13, v. 7.
6. Agnew LRC. An eighteenth century amputation. *Lancet* 1983;ii:1074–1075.
7. An invalid [Harriet Martineau]. *Life in the Sick Room*. London: Moxon, 1844:7, 109. Cited by Stanley

P. *For Fear of Pain, British Surgery, 1790–1850*. Amsterdam: Rodopi, 2003:288.
8. Cited by Wangensteen OH, Wangensteen SD. *The Rise of Surgery*. Folkestone: Dawson, 1978:290.
9. Cited by Kirkup J. Surgery before general anaesthesia. In: Mann RD (editor) *The History of the Management of Pain*. Carnforth: Parthenon, 1988:17.
10. Campbell E, Colton J. *The Surgery of Theodoric ca. A.D. 1267*, vol 2. New York: Appleton-Century-Crofts, 1955:212–213.
11. Morson AC. Memorials of Lord Lister. *Proc R Soc Med* 1971;64:1060–1063.
12. Lloyd C, Coulter JLS. *Medicine and the Royal Navy 1200–1900*, vol III. Edinburgh: Livingstone, 1961 (1714–1815):144.
13. Watt J. Surgery at Trafalgar. *J R Nav Med Serv* 2005;91:283–291.
14. Moore J. *A Method of Preventing and Diminishing Pain in Several Operations of Surgery*. London: Cadell, 1784:13.
15. Wangensteen OH, Wangensteen SD. *The Rise of Surgery*. Folkestone: Dawson, 1978:292.
16. Moyle J. *Chirurgus Marinus*. London: Tracey, 1693: 48–52.
17. Dionis P. *Cours d'Opérations de Chirurgie*. Paris: d'Houry, 1750:747.
18. Cox WS. *A Memoir on Amputation of the Thigh at the Hip Joint*. London: Reeve, 1845:33.
19. Felkin RW. *Notes on Labour in Central Africa*. Edinburgh: Edinburgh Medical Journal, 1884:9–10.
20. Wiseman R. *Several Chirurgical Treatises*. London: Royston, 1686:452.
21. Cooper S. *A Dictionary of Practical Surgery*. London: Longman, 1822:50.
22. Stanley P. *For Fear of Pain, British Surgery, 1790–1850*. Amsterdam: Rodopi, 2003:289–292.
23. Velpeau AALM. *Lecons Orales de Clinique Chirurgicale*. Paris: Baillière, 1840:66.
24. Liston R. *Practical Surgery*, vol 7. London: Churchill, 1837:300.
25. Wiseman R. *Several Chirurgical Treatises*. London: Royston, 1686:420.
26. Stanley P. *For Fear of Pain, British Surgery, 1790–1850*. Amsterdam: Rodopi, 2003:104.
27. Leriche R. *The Surgery of Pain* (translated by A. Young). London: Baillière, 1939:56.
28. Leriche R. *The Surgery of Pain* (translated by A. Young). London: Baillière, 1939:2–3.
29. Merrington WR. *University College Hospital and Its Medical School: A History*. London: Heinemann, 1976:33–34.
30. Chelius JM. *A System of Surgery*, vol 2 (translated by J. South). London: Renshaw, 1847:1009.
31. Garrison FH. *An Introduction to the History of Medicine*. Philadelphia: Saunders, 1929:152.
32. Declat Dr. *Manuel de Médecine Antiseptique*. Paris: Doin, 1890:467–472.
33. Godlee RJ. *Lord Lister*. London: Macmillan, 1917: 1182–1184.
34. Lister J. On a new method of treating compound fracture, abscess, etc. *Lancet* 1867;i:326, 357, 507; ii:95.
35. Lister J. A method of antiseptic treatment applicable to wounded soldiers in the present war. *Br Med J* 1870;ii:243.
36. Lister J. On the effects of the antiseptic system of treatment upon the salubrity of a surgical hospital. *Lancet* 1870;i:4, 40.
37. MacCormac W. *Antiseptic Surgery*. London: Smith Elder, 1880:72.
38. Godlee RJ. *Lord Lister*. London: Macmillan, 1917: 343.
39. Terrillon M. *Asepsie*. Paris: Baillière, 1948:15.
40. Lucas-Championnière J. *Chirurgie Antiseptique: principes modes d'application du pansement de Lister*. Paris: Baillière, 1876.
41. Cited by Wangensteen OH, Wangensteen SD. *The Rise of Surgery*. Folkestone: Dawson, 1978:597 (ref. 22).
42. Godlee RJ. *Lord Lister*. London: Macmillan, 1917:336–337.
43. Lister J. An address on the effect of the antiseptic treatment upon the general salubrity of surgical hospitals. *Br Med J* 1875;ii:769.
44. Cited by Wangensteen OH, Wangensteen SD. *The Rise of Surgery*. Folkestone: Dawson, 1978:692 (ref. 30).
45. Bowman AK. *The Life and Teaching of Sir William Macewen*. London: Hodge, 1942:62–63.
46. Neuber G. *Die Aseptische Wundbehandlung in meinen chirurgischen Privat-Hospitalern*. Keil, Lipsius, 1886.
47. Tripier L. De la stérilisation d cotton, de la gaze et de l'eau servant au pansement des plaies. *Progres Med* 1887;6:483.
48. Redard P. De la désinfection des instruments chirurgicaux et les objets de pansement. *Rev Chir* 1888;8:360, 494.
49. Von Bergmann E. Die aseptische Wundbehandlung in der konigl. Chirurg. Klinik zu Berlin. *Jahrb Klin* 1889;1:147–166.
50. Schimmelbusch C. *The Aseptic Treatment of Wounds*, 2nd Ed (translated by A.T. Rake). London: Lewis, 1894.
51. Wangensteen OH, Wangensteen SD. *The Rise of Surgery*. Folkestone: Dawson, 1978:323.
52. Scrive G. *Relation Medico-Chirurgicale de la Campagne de l'Orient*. Paris: Masson, 1857:461–469.

53. Wangensteen OH, Wangensteen SD. *The Rise of Surgery.* Folkestone: Dawson, 1978:505.
54. Wangensteen OH, Wangensteen SD. *The Rise of Surgery.* Folkestone: Dawson, 1978:507–510.
55. Keen WW. The contrast between the surgery of the Civil War and that of the present war. *N Y Med J* 1915;101:817.
56. Aldea PA, Shaw WW. The evolution of the surgical management of severe lower extremity trauma. *Clin Plastic Surg* 1986;132:549–569.
57. Godlee RJ. *Lord Lister.* London: Macmillan, 1917: 354–355.
58. Mitchell TJ, Smith GM. *History of the Great War Based on Official Documents: Medical Services. Casualties and Medical Statistics.* London: HMSO, 1931.
59. Kirkup J. Fracture care of friend and foe during World War 1. *A N Z J Surg* 2003;73:453–459.
60. Hurley V, Weedon SH. Treatment of cases of fractured femur at a base hospital in France. *Br J Surg* 1919;6:351–376.
61. Mitchell TJ, Smith GM. *History of the Great War Based on Official Documents: Medical Services. Casualties and Medical Statistics.* London: HMSO, 1931:284.
62. Aldea PA, Shaw WW. The evolution of the surgical management of severe lower extremity trauma. *Clin Plastic Surg* 1986;132:563.
63. Bywaters EGL, McMichael J. Crush syndrome. In: Cope Z (editor) *Surgery.* London: HMSO, 1953:673–688.
64. Aldea PA, Shaw WW. The evolution of the surgical management of severe lower extremity trauma. *Clin Plastic Surg* 1986;132:564.
65. Lloyd EA. *A Treatise on the Nature and Treatment of Scrofula.* London: Anderson, 1821:169–170.
66. Butcher RGH. *On the Excision of the Knee Joint.* Dublin: Hodges & Smith, 1855.
67. Lister J. *The Collected Papers.* Oxford: Clarendon Press, 1909:417–440.
68. Thomas HOT. *Diseases of the Hip, Knee and Ankle Joint.* Liverpool: Dobb, 1875.