WO-09 Amputation and major surgery before antibiotics: outcomes, methods and when it is right

HEALING after the FALL, research library, WO-09

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What this report does and does not give. It gives the record: who operated, on whom, with what result, and the rules by which trained people decided to cut or not to cut. It is not an operative manual, and the Protocols section covers decision, preparation, aftercare and record-keeping rather than the operation itself. A person who has read only this document should be able to judge whether an amputation is needed and what it will cost. They should not imagine they can perform one.

1. Findings

1.1 What the operation is, and the four things that kill

An amputation removes a limb or part of one. The oldest evidence is a skeleton from Liang Tebo cave in East Kalimantan, Indonesian Borneo, whose distal third of the left lower leg was removed, probably in childhood, at least 31,000 years ago. The person survived and lived another six to nine years before burial (Maloney et al. 2022). That find tells the story in miniature: the operation is technically ancient, it is survivable, and survival depends on the weeks afterwards rather than the minutes of cutting. Four things kill a patient on or after the table, and they have killed in roughly the same proportions for two centuries.

Bleeding. The large vessels of the thigh and arm will empty a person in minutes. This is controlled by a tourniquet applied before cutting and by tying each vessel as it is found. Ambroise Paré's revival of the ligature over cautery in the sixteenth century is the single change that made the operation survivable at all (THRIVING library, WO-02).

Shock. Pain, blood loss and fear together. Before 1846 the operation was done awake, which is why Robert Liston's reputed speed mattered. Popular accounts, citing the medical historian Richard Gordon, put about one in ten of Liston's University College Hospital patients dying on the table against about one in four at St Bartholomew's, with leg amputations finished in under thirty seconds (Mental Floss 2012, History Hit undated). None come from hospital records that could be checked, and all are marked [VERIFY].

Infection. This killed most of those who died. In the nineteenth century it came under four names that surgeons could not reliably tell apart: erysipelas, pyaemia, septicaemia and hospital gangrene. In the Union armies, hospital gangrene alone had a reported overall mortality of about 45.6 per cent (Medical and Surgical History, via UTHSCSA 2014). This is why amputation mortality fell by two thirds when antisepsis arrived, and fell again when antibiotics arrived.

The stump that fails. Not a cause of death but of permanent disability. A stump too short, too long, covered only in skin over bare bone, or left with an adherent scar cannot take a prosthesis, and the patient survives and never walks.

Primary Surgery states the principle plainly: "The quality of the stump is more important than its length" (Cotton 2015, chapter 60.5).

1.2 The record before antisepsis: Larrey, the hospitals and the countryside

Dominique Jean Larrey, surgeon-in-chief to Napoleon's armies, is the father of the doctrine that early amputation beats late. He built the ambulances volantes so that the wounded reached a surgeon within hours rather than the usual 24 to 36. The famous claim that he performed about 200 amputations in 24 hours after Borodino in 1812, and 300 more at the Berezina, is repeated by every secondary source and by none that cites a page of Larrey's own Mémoires de chirurgie militaire, so it is marked [VERIFY] (Royal College of Surgeons of England blog undated, Hektoen International 2017). A 2024 review states that his swift amputation cut mortality from over 90 per cent to under 25 per cent compared with delay of a week or more, a secondary summary with no visible underlying data, also marked [VERIFY] (Cureus review 2024).

The hospital was the dangerous place. James Young Simpson, the Edinburgh obstetrician who introduced chloroform, surveyed amputation outcomes by post and published Hospitalism in 1869, drawing on 374 replies from country surgeons, 3,077 cases from small and medium hospitals and 2,089 from eleven large ones. His headline finding was that major amputation in British civil hospitals killed about 41 per cent against about 11 per cent in private country practice, with Paris quoted at about 60 per cent.

Simpson's figures were attacked at once, and the attack holds up. Edmund Andrews of Chicago Medical College, writing in 1876, pointed out that Simpson had posted blank forms to an immense number of country surgeons personally unknown to him, that there were at least three sources of error all tending to understate deaths, and that in the Upper Lake States amputation mortality ran at about 19 to 20 per cent whether in hospital, private or country practice (Andrews 1876). The honest summary is that hospitals of the period were genuinely more lethal than the countryside, and that nobody knows by how much. A single institution over time tells the clearest story: at Newcastle Infirmary, major amputation mortality was about 40 per cent around 1872 and 8 per cent for 1878 to 1891 (via James Lind Library [VERIFY]).

1.3 The American Civil War: the largest dataset gathered without antisepsis

The Medical and Surgical History of the War of the Rebellion, published 1870 to 1888, records 29,980 amputations among over 174,000 shot wounds of the extremities, with a further 4,656 treated by surgical excision. The overall mortality in the table reproduced by Singer and Glynne is 7,283 deaths in 29,980 cases, 24.3 per cent. Other summaries of the same source give 26.3 per cent or about 27 per cent, the difference presumably in which cases are counted (Singer and Glynne 2005 citing Adams 1996, PBS Mercy Street undated).

Mortality rose steeply with the level of the cut. Fingers: 198 deaths in 7,902 cases, 2.5 per cent. Thigh: 3,411 deaths in 6,369 cases, 53.6 per cent. Hip joint: 55 deaths in 66 cases, 83.3 per cent. Shoulder joint: 236 deaths in 852 cases, 28.5 per cent (Keen 1905, read only as a textbook excerpt, [VERIFY]). The hip figure is worth dwelling on. Sixty-six were attempted in four years of war and eleven people survived. A hip disarticulation after the Fall is a way of letting someone die on a table instead of in a bed.

Mortality also rose with delay, but not simply. Surgeons used three categories. **Primary** meant within the first 24 hours by military convention, or within 48 hours in most modern summaries. **Intermediate** meant after that but before free suppuration was established. **Secondary** meant later still, once the wound was frankly suppurating.

The cleanest site-by-site figures come from the Confederate Surgeon-General's returns to February 1864, printed in the Confederate States Medical and Surgical Journal in May 1864, given here as primary against secondary mortality. Thigh, 507 cases: 38 per cent against 73 per cent. Leg, 464 cases: 30 per cent against 49 per cent. Arm, 434 cases: 14 per cent against 37 per cent. Forearm, 114 cases: 12 per cent against 22 per cent. The only Union figure found

that is broken out at all covers September to December 1862: 826 cases, 336 deaths, 40 per cent (Confederate States Medical and Surgical Journal 1864).

Two cautions. Civil War statistics mix hospital and field data, and the Confederate and Union sets are not interchangeable. And Andrews found intermediate amputations the most fatal category of all, worse than primary or secondary except at the hip, attributing this to operating during acute inflammation (Andrews 1876). If that is right, the rule is not "sooner is better" but "operate before inflammation or well after it, not during".

One Civil War intervention stands out as genuinely effective. Middleton Goldsmith, in the Ohio and Cumberland armies, treated hospital gangrene by debriding and then applying and injecting bromine. He reported 8 deaths among 304 patients, 2.6 per cent, against 43.3 per cent treated by other methods, and Surgeon G. R. Weeks reported 3 deaths in 104 bromine-treated patients, none from gangrene (Goldsmith 1863, via UTHSCSA 2014). These are his own retrospective statistics with a variable comparison group, but the effect size is large enough to survive a good deal of scepticism.

1.4 Lister, and what antisepsis actually bought

Joseph Lister published his antiseptic principle in the Lancet in 1867 as a series of case reports, not statistics. His first paper rested on eleven patients with compound fractures, of whom two died. The numerical comparison everyone quotes came in 1870: in the pre-antiseptic period 16 deaths in 35 amputations, about 45 per cent, and in the antiseptic period 6 deaths in 40, about 15 per cent (Lister 1870, via James Lind Library). Bull's 1959 recount gives 33 pre-antiseptic cases and 43 per cent against 15 per cent, and found the difference highly significant by chi-square while questioning whether the historical comparison was adequate.

The brief's caution that "Lister's numbers are his own" is exactly right, and Lister said so himself: the numbers were "too small for a satisfactory statistical comparison". Hamilton's 1982 reconstruction shows that Lister's wards had *higher* death rates than the Infirmary as a whole before antisepsis, and that he gave no 1865 data at all, calling the records imperfect. Longer runs of upper-limb amputation case fatality in the same institution swing between 0 and 75 per cent across the preceding decades, which is to say that 45 to 15 per cent could be noise (Hamilton 1982, via James Lind Library).

The critics were serious people. William Savory, later President of the Royal College of Surgeons of England, said in 1879 that Lister had produced no comparative statistics worth the name. Thomas Nunneley attacked antisepsis at the British Medical Association in 1869. Lawson Tait achieved 100 ovariotomies with three deaths in 1882 "without any of the Listerian details", and in 1890 called for planned prospective experiments with defined groups, which nobody ran. George Callender reported 200 operations at St Bartholomew's in 1873 with results he credited to cleanliness rather than carbolic (James Lind Library).

The honest reading is that something real happened in surgical wards between 1865 and 1890 and that carbolic was one of several things that changed at once, alongside hand and instrument cleanliness, ventilation, and the willingness to leave wounds open. This matters, because the parts of the change that were free, namely cleanliness and open wounds, are available after the Fall, while carbolic is both hard to make and dangerous (THRIVING library, WO-12, which notes that as little as 1 g swallowed can kill).

1.5 The twentieth century: the open wound and the plaster

The decisive surgical lesson of the First World War was not a drug but a discipline: excise dead tissue early, and do not close the wound. Clostridial myonecrosis was historically present in about 5 per cent of war wounds and is now about 0.1 per cent, the fall credited to wound excision and later to penicillin (orthopaedic review 2013, via search).

The Thomas splint for femoral fractures is the war's most-quoted statistic and the least reliable. Sources give the fall in femoral fracture mortality as 80 to 20, 80 to 8, 80 to 7 and 70 to 30 per cent (National Archives blog, Imperial War

Museum, New Zealand official history). The direction is consistent and the magnitude is not, and contemporary accounts also credit early wound excision and Robert Jones's training campaign rather than the splint alone. The relevance here is that a femoral fracture splinted well is often a limb that does not need amputating.

Josep Trueta, in the Spanish Civil War, combined thorough debridement with H. Winnett Orr's closed plaster. The wound was left freely open under vaselined gauze, the limb enclosed in plaster including the joints above and below, and the plaster changed only for cleanliness, position or complications. Of 1,073 open fractures, 6 died, 976 gave a satisfactory result and 91 a poor one, the poor results including secondary amputations, persistent osteitis and non-union (Rendle Short 1939). These are Trueta's own figures and the definitions are not given, but a sub-1 per cent mortality for open fractures without antibiotics is the most encouraging number in this report, and it was achieved with debridement, open wounds, plaster and time.

1.6 Modern practice without full facilities: ICRC and MSF doctrine

The doctrine used by the International Committee of the Red Cross and reproduced in Primary Surgery is the most directly transferable knowledge for a district infirmary after the Fall. Its core rules, from chapter 60 (Cotton 2015, which cites Giannou, Baldan and Molde 2013 throughout):

Never close an amputation stump at the first operation in a war wound. The risk of infection and septicaemia is very high. Leave the stump open, cover it with a bulky absorbent dressing, and leave it untouched until delayed primary closure at about four to five days.

Do not fashion definitive flaps at the first operation. Use "flaps of opportunity" determined by the injury, excising all damaged soft tissue first and cutting the flaps long, because they retract.

It is the soft tissue injury, not the bone injury, that dictates the level. A fracture proximal to the amputation level is not a reason to amputate higher, especially in children. Immobilise the fracture and amputate at the level of the soft tissue injury.

Do not change the dressing to look at it. Each change traumatises granulation tissue and exposes it to cross-infection, and the dressing is never a reliable indication of the state of the wound. The wound is doing well if the patient is smiling, eating and sitting comfortably in bed. The dressing may give off a sour ammoniacal odour, which is normal, a "good-bad smell". An infected stump has a "bad-bad smell" and the last compress slides off a layer of pus without resistance.

Guillotine amputation is not a routine procedure. It is for extricating someone from rubble or a vehicle, or for damage control in a patient dying of gas gangrene or sepsis, and a revision is almost always needed later. The same chapter's rules on level and on irrigation are set out in Protocols 5 and 6 below.

The humanitarian outcome data are thinner than the doctrine. Médecins Sans Frontières performed 936 limb amputations in 17 countries between 2008 and 2017, 75 per cent of patients male, median age 27 years, with trauma the indication in 756 cases, 81 per cent, rising to 94 per cent during active crises (Naidu et al. 2021, abstract only). Across 17 MSF surgical programmes from 2001 to 2008, operative mortality for all procedures was 0.2 per cent, 31 deaths. At Boost Hospital in Afghanistan, 5,719 operations from 2010 to 2012 gave an intraoperative mortality of 0.8 per cent, seven deaths, with 47 per cent of interventions done as emergencies.

These are not comparable to the historical amputation figures. They cover all operations, most of them minor, and count deaths in a narrow window. The one honest conclusion is that organised surgery in a resource-poor setting with trained staff and protocols is not notably dangerous in itself. What is dangerous is the injury, the delay and the infection. For a modern comparison, a systematic review of 45 studies of lower-extremity amputation found 30-day mortality from 7.1 to 51.4 per cent, mean 16.45 per cent (Cureus review 2023), but most of those patients were elderly people with vascular disease rather than young trauma patients.

1.7 When it is right, and when it is wrong

The indications given by Primary Surgery are the most usable list available (Cotton 2015, 60.1): a limb already traumatically amputated, irretrievable damage, ischaemic tissue damage from unrelieved vascular damage or crush or compartment syndrome, haemorrhage when other efforts fail, overwhelming sepsis, chronic continuing sepsis, and a finger or toe where function matters more than losing a part. For damage to one muscle group, extensive debridement and fasciotomy may be adequate.

Against these sit the warnings, which matter at least as much.

Avoid primary amputation. "As a general rule, don't amputate as a primary measure if at all avoidable. You will only be able to make a definitive assessment of the soft tissue damage in the operating theatre during the initial debridement." If debridement is likely to take more than two hours and there are many other patients, amputation may be the better option.

Scoring systems do not work. The Mangled Extremity Severity Score and its rivals "have not been shown to be useful in prospective clinical decision-making for amputation versus limb salvage, especially not for the inexperienced", and they do not predict functional recovery.

An insensate sole is not an indication. More than 50 per cent of patients recover sensation over two years.

Lean towards salvage in the arm. A lower-limb prosthesis is remarkably efficient at enabling walking, while even the most sophisticated upper-limb prosthesis is a poor substitute for a hand.

Life before limb. In an unstable polytrauma patient, do damage control only and reassess over the next 48 hours.

For the mangled limb where vascular injury coexists with severe tissue damage, the guidelines offered are: haemorrhage with an extensively comminuted fracture and bone defect, a two-finger-sized wound cavity, and entry plus exit wounds summing to more than 10 cm diameter, or transection of major nerves, or other life-threatening injuries. If vascular repair by shunt and fasciotomy with fracture immobilisation is possible, salvage is worth trying with close observation over 48 hours. If revascularisation has failed or severe sepsis ensues, amputation is necessary.

Timing in specific conditions. Gas gangrene is the one diagnosis where waiting kills within hours, and only excision or amputation cures it (THRIVING library, WO-14). In modern series with antibiotics and hyperbaric oxygen, 139 patients gave 27 deaths, all among the 67 in shock on admission, and post-traumatic extremity clostridial myonecrosis carried about 5 per cent mortality (Hart 1983, via secondary summary). A review of 50 cases found 38 survivors, 25 of whom kept their lives at the cost of a limb. Without antibiotics the village has only the knife, and the knife must be early.

Frostbite is the opposite. The old adage "frostbite in January, amputate in July" describes real practice: wait for demarcation before cutting, unless the patient becomes septic. Depth of tissue loss takes many weeks to declare itself (MSD Manual undated, North American Rescue summary of Wilderness Medical Society guidance [VERIFY]).

Crush injury sits between the two, and the evidence is genuinely contested. After the Kahramanmaraş earthquake of 6 February 2023, 233 patients gave 41 fasciotomies (17.6 per cent), 72 amputations (30.9 per cent) and 15 deaths (6.4 per cent), with the authors concluding that late fasciotomy should be avoided and that amputation is life-saving in desperate lower-limb injuries. After the Bam earthquake of 2003, fasciotomy in 70 of 200 patients with crush-induced acute kidney injury produced no excess of sepsis, dialysis, amputation or death. Nobody has run a trial and nobody will.

1.8 The other operations that were survivable

The brief asks which operations besides amputation a pre-antibiotic surgeon could do with acceptable results. The answer is: drainage, and very little else without a steep price.

Abscess drainage. The best modern reconstruction of the pre-antibiotic record found cure rates for major abscesses of 76 per cent without antibiotics (95 per cent confidence interval 71 to 80) against 96 per cent with penicillin (94 to 98), and penicillin reduced mortality by about 6 percentage points (Spellberg et al. 2009). Three quarters of people with a major abscess were cured by the knife alone. This is the operation a village can learn, and it is covered at length in the library (THRIVING library, WO-14).

Strangulated hernia. Before antisepsis this was close to a coin toss. Herniotomy statistics from St Bartholomew's, St Thomas's and Guy's up to 1884 gave 43 per cent mortality over 940 cases, and Croft's split of those cases gave 29.5 per cent in the antiseptic group of 44 against over 50 per cent in the pre-antiseptic group. Bowlby, reviewing the next decade, still found 35.8 per cent and blamed delay rather than the operation. A German aseptic series analysed by Macready showed mortality of about 12.5 per cent when strangulation had lasted a day or less, rising to about 44 per cent at four to five days. By 1927 to 1929 at Bristol Royal Infirmary, Kemm reported 10 deaths in 74 inguinal and femoral cases, 13.5 per cent, six of them moribund on admission (read as excerpts, exact citations [VERIFY]). Elective repair was a different matter: Bassini reported one death and seven relapses in 250 cases.

Caesarean section. The historical figures are grim and improve with technique rather than with drugs. Before Porro's operation of 1876, which removed the uterus, classical caesarean mortality was reported at about 90 per cent, Porro-Müller at 54 to 58 per cent, and Sänger's uterine suture of the early 1880s gave 18 survivors in 25 operations, 72 per cent. Sir John Peel told a 1962 audience that British caesarean maternal mortality a century earlier had been 60 to 80 per cent (read as excerpts, [VERIFY]).

Appendicectomy. At Cook County Hospital, 822 operated cases from November 1912 to February 1916 gave 58 deaths, a little over 7 per cent, and a collected national series of 13,445 operations gave 7.4 per cent, the deaths concentrated in perforation with general peritonitis. Before appendicectomy, Parker's practice of opening the abscess at five to twelve days reduced his mortality from 50 to 15 per cent. Wangensteen argued that the sharp fall came between 1940 and 1942, before penicillin was in general use.

Lithotomy. William Cheselden's own published figures for 213 public lithotomies at St Thomas's, given in the fifth edition of 1740, are 20 deaths, about 9 per cent, and he broke them down by age. Three deaths in 105 children aged ten or under, 4 in 62 aged eleven to twenty, and then the line turns: 4 in 7 aged fifty-one to sixty, 1 in 5 aged sixty-one to seventy, 1 in 2 aged seventy-one to eighty (Tröhler 2013). That is a young person's operation. Mortality past fifty is above 50 per cent. These are Cheselden's own numbers, published partly to defend his reputation.

Trephination. The archaeological record from Peru is the best long series anywhere. Kushner, Verano and Titelbaum examined more than 800 trepanned crania and judged survival by bone remodelling: about 40 per cent for 59 skulls from 400 to 200 BCE, 53 per cent for 421 skulls from 1000 to 1400 CE, and 75 to 83 per cent for 160 Inca-period skulls from 1400 to 1500 CE, against 46 to 56 per cent mortality for American Civil War cranial surgery. The authors believe the successful operations were shallow ones that did not pierce the dura (Kushner, Verano and Titelbaum 2018, read via secondary summaries). Trepanation is still practised in Kisii, western Kenya, chiefly for acute trauma, with mortality described as low but no numbers given (Journal of Eastern African Studies 2014, abstract only).

Cataract couching. This is the one traditional operation in this report that the evidence condemns. A Nigerian national survey of adults over 40 found 249 of 583 operated eyes, 42.7 per cent, had been couched, with 42.6 per cent of those still blind after correction. Orthodox surgery restored vision of 3/60 or better in 82.1 per cent of eyes against 58.6 per cent of couched eyes. A Yemeni series of 55 couched eyes found 1.8 per cent with good vision and 76.4 per cent still blind. A Benin City clinic series found secondary glaucoma in 61.5 per cent and no light perception in 33.3 per cent.

1.9 Who can do it, and how long it takes to learn them

This is the question the book must answer honestly, and it has better evidence than any other part of the topic. The best data come from caesarean section in Africa, where non-physician clinicians have done major surgery for forty years. Wilson and colleagues meta-analysed six non-randomised controlled studies covering 16,018 women. For maternal death the odds ratio for clinical officers against doctors was 1.46 with a 95 per cent confidence interval of 0.78 to 2.75, p = 0.24. For perinatal death it was 1.31, 0.87 to 1.95, p = 0.19, with severe heterogeneity (I^2 = 88 per cent). But for wound infection it was 1.58, 1.01 to 2.47, p = 0.05 over two studies and 4,436 women, and for wound dehiscence 1.89, 1.21 to 2.95, p = 0.005 over three studies and 6,507 women, both with no significant heterogeneity. The overall maternal mortality across the six studies was 1.2 per cent and perinatal mortality 10.7 per cent (Wilson et al. 2011).

That is the honest statement the brief asks for. Trained non-doctors did not kill noticeably more mothers or babies. They did produce about 60 per cent more wound infections and about 90 per cent more wound breakdowns. The authors concluded that this "may highlight a particular training need". For a district infirmary after the Fall, where a wound infection cannot be rescued by antibiotics, that excess is the thing to be afraid of.

The training was not short. In the six studies, Zaire and Burkina Faso used nurses with a two-year clinical officer course, with a further one to two years of surgical training in Zaire. Malawi and Mozambique required a three-year health foundation course plus a year as a hospital or surgical intern. Tanzania used three years of medical training plus two years of clinical training plus three months each in surgery and obstetrics (Wilson et al. 2011). Mozambique's técnicos de cirurgia enter with three years of basic nursing and an average of seven years of practical experience.

Retention is the argument for training locals. Almost 90 per cent of the Mozambican técnicos and assistant medical officers studied were still at their district hospitals seven years later, while all the formally trained doctors had left, and in 2002 they performed 92 per cent of the 3,246 caesareans, ruptured uteruses and ectopic operations in rural district hospitals (Pereira 2010). The mission-hospital route takes longer. The Pan-African Academy of Christian Surgeons, founded in 1996 out of David Thompson's work in a small Gabonese mission hospital, runs five-year residencies certified by the College of Surgeons of East, Central and Southern Africa, and a twenty-year analysis found 100 per cent of active graduates practising in Africa and 79 per cent in their home country, with 35 per cent long-term rural retention (PAACS 2018).

Finally, the cheapest intervention in surgery is a piece of paper. Haynes and colleagues introduced a nineteen-item WHO checklist at eight hospitals, comparing 3,733 patients before with 3,955 after. In-hospital death within 30 days fell from 1.5 to 0.8 per cent and major complications from 11 to 7 per cent, with equal reductions at high-income and lower-income sites (Haynes et al. 2009). This was a before-and-after study, not a trial, and some of the gain may be the attention that came with it. It is still the single best-evidenced thing a village dispensary could copy tomorrow.

2. Evidence grades

Practice	What the tradition says	What the record shows	Grade
Amputation for irretrievable damage or gas gangrene	Cutting saves life	Civil War 24.3% overall, far lower in ICRC settings, untreated gas gangrene near-universally fatal	B
Tourniquet before and during amputation	Controls bleeding	Standard everywhere, 5.5% neurological complications at 109 to 187 minutes, none needing amputation	B

Practice	What the tradition says	What the record shows	Grade
Open stump with closure at 4 to 5 days	War-wound doctrine	ICRC and military doctrine, consistent series, no trial	B
Primary closure of a war-wound stump	Faster healing	Repeatedly condemned, very high risk of septicaemia	X
Debridement plus closed plaster (Trueta)	Immobilisation prevents spread	1,073 cases, 6 deaths, 976 satisfactory	B
Early rather than delayed amputation	Larrey's doctrine	Confederate thigh 38% primary vs 73% secondary	B
Carbolic antisepsis	Kills the germ	Lister 45% to 15% on small numbers, contested by Savory and Tait, carbolic lethal at ~1 g	C
Cleanliness, boiled instruments, open wounds	Prevents the hospital diseases	Convergent and strong once separated from carbolic	B
Bromine for hospital gangrene	Destroys the slough	Goldsmith 2.6% vs 43.3%, 304 patients, retrospective	C
Abscess drainage without antibiotics	Let the pus out	76% cure rate without antibiotics	B
Mangled Extremity Severity Score and rivals	Objective decision aid	Not useful prospectively, not predictive of function	X
Amputation for an insensate sole	The foot is useless	More than 50% recover sensation over 2 years	X
Guillotine amputation as routine	Fast and safe	Almost always needs revision, stump cannot be fitted	X as routine, B as damage control
Waiting for demarcation in frostbite	Frostbite in January, amputate in July	Standard practice and current guidance, unless septic	B
Surgical safety checklist	Catches errors	Death 1.5% to 0.8%, complications 11% to 7%, before-and-after	B
Trained non-physicians doing major surgery	Task-shifting works	No excess maternal or perinatal death, 58% more wound infection, 89% more dehiscence	A/B
Cataract couching	Restores sight	76% of couched eyes still blind in one series, glaucoma common	X
Shallow trephination for trauma	Relieves pressure	40% to 83% survival across 1,800 years in Peru, still practised in Kisii	C

3. Means ledger

Rung	What amputation and major surgery look like	What the rung changes
Hands and knowledge alone	No operation. Recognise gas gangrene, crush and dead limb. Direct pressure, then an improvised tourniquet with the time written on the skin. Elevation, splinting, water by mouth, honest comfort.	Saves some who are bleeding. Saves nobody whose limb must come off. Prevents the error of cutting a limb that would have recovered.
Hearth (fire, clean water, salt, honey, vinegar, fat, cloth, needle, knife)	Still no planned amputation. Wound irrigation and open dressings. Removal of a finger or toe already hanging by skin. Drainage of a pointing abscess with a boiled blade. Splinting.	Abscess drainage alone cures about three in four. Clean water and open wounds prevent some infections that would otherwise have forced an amputation.
Garden and still (ethanol, beeswax, soap, scale, pressure cooker, forge)	Pressure-cooker sterilisation (THRIVING library, WO-12). Forged retractors, knife and bone saw. A tourniquet of known width. Plaster for closed treatment of open fractures. Opium or alcohol for pain, which is not anaesthesia.	Makes sterile instruments and a plaster regime possible. Trueta's 1 per cent mortality for open fractures lives at this rung if the debridement is good.
Village dispensary (300 people, trained lay healer, salvaged stock, basic instruments, microscope)	Guillotine or open amputation as damage control in a patient dying of gas gangrene, by someone taught over years, with ketamine or a regional block (THRIVING library, WO-10 and WO-11). Finger and toe amputations. Abscess drainage. Open stumps, referral upward for revision.	Turns a certain death from gas gangrene into a possible survival at the cost of a limb. Does not produce a stump that will take a prosthesis.
District infirmary (3,000 people, nurse or doctor, sterile room, ten beds, lab bench)	Planned amputation with tourniquet, flaps of opportunity, excision of dead tissue, open stump, closure at four to five days, physiotherapy from day one, interim prosthesis. Caesarean section. Strangulated hernia. Abscess.	Amputation becomes a treatment rather than a gamble. Expect infection and dehiscence above hospital rates even with good people (Wilson et al. 2011), and expect to re-amputate some.
Hospital before the Fall	Vascular repair, external fixation, free flaps, limb salvage, antibiotics, blood bank, imaging, intensive care, modular prosthetics, pain services.	Converts most of the amputations above into salvaged limbs, and most of the deaths into survivals. This is what is lost.

4. Harm test

How it kills or maims when done wrong. By bleeding, if a vessel is not secured or a tourniquet released without haemostasis. By shock, if the patient was not resuscitated first. By sepsis, above all if the stump is closed at the first operation. By cutting a limb that would have recovered. By cutting too high, removing a joint that would have carried a prosthesis. By cutting too low, in the distal third of the tibia, producing a stump that cannot be fitted.

The errors with numbers attached. Closing a war-wound stump primarily: the ICRC doctrine is absolute because the septicaemia risk is "very high". Leaving a tourniquet on: generally safe to two hours, with risks of muscle death, rhabdomyolysis and limb loss rising after three to four hours and irreversible damage common after six. In 110 battlefield applications, 5.5 per cent had neurological complications, all applied for 109 to 187 minutes, none needing amputation, against a mean of 78 minutes in those without complications. Releasing a tourniquet that has been on more than two hours causes sudden hypotension and a release of potassium and acid that can stop the heart.

Who must never receive it. Nobody who is not resuscitated, and nobody whose limb has not been assessed in the best light available. Do not amputate for an insensate sole, do not amputate higher because of a proximal fracture, and in children lean hard towards salvage and towards disarticulation over bone section, because growth will shorten a bony stump relative to the soft tissues. The old, the frail and the critically ill are the one group in whom Primary Surgery advises choosing a safer, more proximal level, to avoid a second operation.

Misidentification risks. Gas gangrene mistaken for ordinary wound infection, which costs a life. Ordinary swelling mistaken for gas gangrene, which costs a limb. The "good-bad smell" mistaken for the "bad-bad smell" of pus. Compartment syndrome, which needs fasciotomy and not amputation, mistaken for irretrievable ischaemia. Frostbite judged too early.

Signs that it is going wrong, and what to do. The patient who was smiling on day two and is now not eating, not sitting up and febrile. Severe pain under the dressing, the first sign of either a tourniquet-effect bandage or spreading infection. Pus at the dressing edge, or the bad-bad smell. The answer in every case is the same: take the whole dressing down under anaesthesia and debride again. If infected soft tissue or bone remains at the time of intended closure, amputate higher and leave the stump open.

Historical cases of harm. The intermediate amputations of the Civil War, done during acute inflammation, which Andrews found more fatal than either earlier or later operation. The 66 Civil War hip disarticulations with 11 survivors. Hospital gangrene in the Union armies at 45.6 per cent. Lister's own wards before antisepsis, which were worse than the Infirmary average. The Haitian earthquake of January 2010, where at one French team's hospital 28 of 30 operations in three days ended in amputation, because limbs had been crushed and gangrenous for days before anyone reached them. Humanity and Inclusion later judged that amputations made up an unusually large share of the surgery and that some, done in extremely difficult conditions, later needed corrective surgery.

5. Red flags

These are the signs that mean death or disability without what the village cannot give.

- **Gas gangrene with shock.** Sudden severe pain out of proportion, a racing pulse with little fever, bronze muscle, crackling under the skin, a sweetish rotten smell. In the best modern series every death was in a patient in shock on arrival. Without a surgeon the same day, this person dies. **Do anyway:** open the wound widely, get a tourniquet and the fastest available amputation above the dead muscle, give fluids, keep them warm. If no one can cut, say so, give opium, and do not leave them alone.
- **Bilateral above-knee amputation or hip disarticulation.** Survivable in a hospital, usually not in a district infirmary. **Do anyway:** control bleeding, give fluids and opium, prepare the family.
- **Crush of the thigh or pelvis after long entrapment.** Thigh injuries carried the mortality at Kahramanmaraş, renal failure follows and there is no dialysis. **Do anyway:** fluids before and during extrication, and a frank conversation.
- **A stump that breaks down twice, with infected bone.** Needs repeated high amputation and more anaesthetics than the patient has in them. **Do anyway:** one further amputation at a clean level, left open, and no more.
- **Tetanus after amputation.** Covered fully in the library (THRIVING library, WO-14). Without antitoxin, hospitalised adult case fatality is about 4 in 10 and nearly all untreated die.

- **Haemorrhage a tourniquet cannot reach.** Groin, axilla, root of the neck. **Do anyway:** direct pressure held by a person, not a bandage, and accept that it usually fails.
- **An amputee with no prosthesis in prospect.** Not fatal, but part of the answer to whether the operation was right. Primary Surgery is explicit that the decision must weigh "the accessibility of prostheses and physiotherapy". A village that cannot make a peg leg should know that before it takes a leg.

Honest comfort means saying the true thing once, clearly, and then staying. Opium of known strength, a dark quiet room, water, a turned body, and someone holding a hand.

6. The case against

Against operating at all. The strongest critic of surgery in weak hands is the record of wound infection. Wilson and colleagues found 58 per cent more wound infections and 89 per cent more wound dehiscences when clinical officers rather than doctors did caesareans, in settings that still had antibiotics. Remove the antibiotics and that excess becomes deaths. The implied conclusion is that a village should drain abscesses, splint fractures and leave the rest alone.

Against the historical numbers. Alfred Jay Bollet and others have shown that Civil War statistics mix field and hospital data and that the denominators shift. Edmund Andrews demolished Simpson's hospitalism survey in 1876 on grounds of postal self-selection. William Savory told the British Medical Association in 1879 that Lister had produced no comparative statistics worth the name, and Lawson Tait matched Listerian results without carbolic. Every headline number in this report is weaker than it looks.

Against treating the ICRC record as transferable. ICRC surgeons are trained surgeons. The 0.2 per cent operative mortality in MSF programmes was achieved by qualified staff with blood, anaesthetic drugs, oxygen, antibiotics, sterile supplies and evacuation, none of which are guaranteed after the Fall. Primary Surgery itself says the decision to amputate must account for "the availability of blood transfusion, the level of post-operative and physiotherapy care, as well as the accessibility of prostheses".

Against the romance of the old operation. Nothing here suggests that a careful reader can learn to amputate from a book. Mozambique's técnicos trained for three to four years on top of a nursing qualification, and PAACS runs five-year residencies. The honest floor is years, not weeks.

Against the romance of modern salvage. Equally, Primary Surgery warns that "the result of salvage is sadly, even in sophisticated centres, often not as satisfactory as primary amputation", that an early decision to amputate "may often reduce a victim's suffering", and that a long multi-step salvage "might overstretch the patient's financial and physiological capacity and so might be even life-threatening". Refusing to amputate is also a decision with a body count.

7. 10-line summary

1. Amputation is an operation people have survived for 31,000 years, and the surviving depends on the weeks after, not the minutes during.
2. Four things kill: bleeding, shock, infection and a stump that fails. Infection killed most of them.
3. In the American Civil War, 29,980 amputations killed 24.3 per cent overall, 2.5 per cent at the finger, 53.6 per cent at the thigh and 83.3 per cent at the hip.
4. Confederate returns show primary thigh amputation at 38 per cent against 73 per cent for secondary. Earlier is better, but operating during acute inflammation may be worst of all.
5. Lister reported 45 per cent falling to 15 per cent in 1870 on 75 cases of his own, and his critics were right that the numbers were too small.
6. Trueta's debridement plus closed plaster gave 6 deaths in 1,073 open fractures without antibiotics. Good debridement and an open wound are the cheapest lifesavers here.

7. Never close an amputation stump at the first operation in a contaminated wound. Leave it open, dress it bulkily, and do not touch it until delayed primary closure at four to five days.
8. The soft tissue injury, not the bone, dictates the level. The minimum tibial stump is 5 cm and the ideal about 15 cm. Never cut in the distal third of the tibia.
9. Trained non-doctors do major surgery without excess deaths but with about 60 per cent more wound infections and 90 per cent more wound breakdowns. Their training took three to five years.
10. Mangled extremity scores do not work, an insensate sole is not an indication, and more than half of such feet recover sensation within two years.

8. Open questions

- What does the Medical and Surgical History's own Union table give for amputation mortality by level crossed with primary, intermediate and secondary timing? Only Confederate and partial Union figures were obtained.
- Is Andrews right that intermediate amputations were the most fatal category? If so, the "operate within 48 hours or wait" rule needs restating in the book.
- Did Larrey record his Borodino results anywhere that can be checked? The 200-in-24-hours figure has no primary source that could be found.
- What is amputation mortality in ICRC hospitals, as a number? Coupland's work gives technique but the outcome series was not obtained.
- Does the "good-bad smell" versus "bad-bad smell" distinction hold up against any measured series, or is it expert pattern recognition only? And what proportion of district-level amputations by trained non-surgeons needs re-amputation higher? Neither was found.
- Was the fall in hospital gangrene mortality with bromine real, and could an equivalent be made or salvaged after the Fall? Goldsmith's 1863 report itself was not read.
- Can a village make a usable peg leg or Jaipur-type foot, and what does it cost in labour hours? That is NU-05's question and was not pursued here.

9. Sources to read in full

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10. At the bedside after the Fall

A household. A man's leg is crushed under a fallen beam. You cannot operate and you must not try. Stop the bleeding with pressure first and a tourniquet only if pressure fails, wide and tight and above the wound, and write the time on his skin. Do not loosen it to let the blood back in. Splint the leg, give him water in small amounts, keep him warm and carry him to the village. What you need to start is a wide strap, a stick, a strip of cloth, a pen and a flat thing to carry him on. The first failure to expect is a tourniquet made of cord or wire, which cuts the skin without stopping the artery. The second is putting one on when firm pressure would have done.

A village of 300. Someone has to be able to say the words "this limb is dead" and act on them. The village needs one person trained over years, a pressure cooker, instruments of forged steel, ketamine or ether, a wide tourniquet, and enough clean cloth for a bulky dressing the size of a loaf. It needs a written amputation policy agreed in advance, because the decision is made badly at three in the morning by one frightened person. It can expect to drain abscesses, remove dead fingers and toes, and perform a damage-control amputation on a patient dying of gas gangrene. It cannot expect a stump that will take a prosthesis without revision. The first failure to expect is that the stump will be closed too early by someone who thinks an open wound is a failure, and the patient will die of septicaemia a week after a successful operation.

A district of 3,000. Here the operation becomes a treatment. The district needs a room that can be cleaned, ten beds, two people who can hold an airway, sterile instruments, a tourniquet, a saw, enough water for 8 to 10 litres of irrigation, drugs for anaesthesia and for pain, splints and plaster, and a workshop that can make a peg or a simple socket. It needs records: name, date, injury, time of injury, time of operation, level, what was found, what was done, what happened. Without records nobody learns. The first failure to expect is the wound infection rate, because trained non-doctors run about 60 per cent more infections and 90 per cent more dehiscences, with no antibiotics to rescue them. The second is the day the infirmary has to tell a family it will not do a hip disarticulation, and why.

11. Protocols

These are decision and care checklists. They are deliberately not operative instructions. The cutting is taught by a trained person over years, in a room, on a patient, with a teacher's hands over yours.

Protocol 1: Deciding whether a limb must come off

1. **Resuscitate first.** Airway, breathing, circulation. Control bleeding by pressure, then by a wide tourniquet if pressure fails. A decision about a limb made on a patient in shock is a bad decision.
2. **Exclude what is not an indication.** An insensate sole (more than 50 per cent recover over 2 years). A fracture above the injury. Swelling alone.
3. **Look for what is.** Already traumatically amputated. Irretrievable damage. Ischaemia from unrelieved vascular injury, crush or compartment syndrome where fasciotomy will not be enough. Bleeding other efforts cannot stop. Overwhelming or chronic sepsis.
4. **Ask the three questions.** Is saving the limb possible? Is it reasonable? Will saving it give a better final result than amputation plus a prosthesis?
5. **Ask what you have.** Blood, anaesthetic, post-operative nursing, physiotherapy, a prosthesis. If the answer to the last is no, say so to the patient.
6. **Lean towards salvage in the arm**, and towards amputation in severe soft tissue injury around the ankle and foot.
7. **Get consent, including for a higher level**, because the soft tissue injury is usually worse than it looks.
8. **Do not use a severity score to decide**, and in polytrauma do damage control only, re-deciding within 48 hours.
9. **Write it down before you start.**

Protocol 2: The tourniquet

1. Wide, not narrow. Cord and wire do not work and cause injury.
2. Apply above the injury, tighten until bleeding stops, and write the time on the skin.
3. Treat 2 hours as the working limit. Risk of muscle death and limb loss rises after 3 to 4 hours and irreversible damage is common after 6.
4. Do not loosen it to "let blood in".

5. Before any planned release after more than 2 hours, have fluids running and expect a sudden fall in blood pressure and a dangerous heart rhythm.
6. In the operating room, release before the end of the operation so bleeding points can be found.

Protocol 3: The stump in the first week

1. **Never close a contaminated or war-wound stump at the first operation.** No skin sutures.
2. Irrigate with 8 to 10 litres of clean potable water or saline.
3. Dress with dry fluffed gauze reinforced with absorbent cotton wool, held by a loose crepe bandage or non-circumferential tape. Do not pack tightly: a tight circumferential bandage soaked with drying exudate acts as a tourniquet and causes extreme pain.
4. If that happens, loosen or replace the outer layers only.
5. **Do not take the dressing down on the ward.** If it soaks through, overdress or replace only the outer cotton and bandage.
6. Judge the wound by the patient. Smiling, eating and sitting comfortably means it is doing well.
7. A sour ammoniacal smell is normal. A foul smell with the last compress sliding off pus is infection.
8. Elevate the limb and use a plaster back-slab at night to prevent contracture.
9. Give enough pain relief that physiotherapy can start the same week, before closure.

Protocol 4: Delayed primary closure

1. Timing: about 4 to 5 days after the first operation.
2. Take the dressing down in the operating room, under anaesthesia, not on the ward.
3. A good wound has a bleeding muscle surface that contracts as the last compress is removed.
4. If infected soft tissue or bone remains, amputate higher, leave open, and try again in another 5 days.
5. Close without tension. Flaps that met easily at the first operation may not meet now, because cut muscle swells.
6. Place a suction drain deep to the muscle if there is dead space, and remove it at 24 hours.
7. Do not put a skin graft directly onto bone. It needs viable soft tissue or at least periosteum.

Protocol 5: The guillotine stump

1. Guillotine amputation is damage control only: extrication from rubble or a wreck, or a patient dying of gas gangrene or gross sepsis.
2. Expect to revise it. The stump is an inverted cone and will not take a prosthesis.
3. **Clean, on leg or upper arm, less than 48 hours old:** re-amputate at the correct level now, leave open, close at 5 days.
4. **Clean, on leg or upper arm, more than 48 hours old:** dress every 2 to 3 days, elevate, re-amputate at 2 weeks when swelling has settled, leave open, close 5 days later.
5. **On forearm, finger or toe:** dress every 2 to 3 days and let it granulate. Do not attempt local flaps.
6. **Infected:** debride in the operating room, repeatedly if necessary, shaping flaps for later closure as you go.

Protocol 6: Levels, for the person planning the operation

1. The worst soft tissue injury, not the fracture, sets the level.
2. Below knee: minimum tibial stump 5 cm, ideal about 15 cm, bone section 2 to 14 cm below the tibial tuberosity, up to 18 cm in a very tall person.
3. Never amputate in the distal third of the tibia.
4. Cut the fibula about 2 cm shorter than the tibia.
5. Prefer a disarticulation to a bone section close to a joint, and a knee disarticulation to an above-knee amputation, especially in children.

6. In a very short below-knee stump the fibula is removed, because it swings out and causes pain.
7. In the arm, save every centimetre.
8. In the old, frail or critically ill, choose a safer higher level rather than risk a second operation.

Protocol 7: The room, before any major operation

1. Instruments cleaned, then steam-sterilised at 121 °C for 20 minutes unwrapped or 30 minutes wrapped, with the clock restarted if pressure is lost (THRIVING library, WO-12).
2. Hands and arms scrubbed for 5 minutes the first time and 3 minutes thereafter.
3. One needle and one syringe per person per injection.
4. Run a spoken checklist before the knife: name, what operation, which side, written consent including a higher level, blood available, tourniquet time started, who is watching the airway, who is counting swabs. The nineteen-item version cut deaths from 1.5 to 0.8 per cent.
5. A second trained person holds the airway and does nothing else (THRIVING library, WO-10).
6. Count the swabs out and in.
7. Write the operation note before you leave the room.

Protocol 8: The first year afterwards

1. Firm bandaging of the stump to reduce oedema and shape it. Teach the patient to do their own.
2. An interim prosthesis as soon as sutures are out, worn for short periods at first. Expect it to last about 2 months.
3. Delayed healing should not delay getting the patient up.
4. Examine the stump at intervals: length and shape, joint movement and contracture, skin for blistering and ulceration, scar for adherence, soft tissue for neuroma, bone for spurs and infection.
5. A neuroma gives sharp electric-shock pain on pressure and feels like a hard lump up to 2 cm. It can be cut out.
6. Exclude all of the above before calling pain "phantom limb pain".
7. A child's prosthesis lasts about 6 months with growth. An adult's lasts up to about 3 years. A well-made traditional peg or pylon lasts longer than any modern limb and is better in wet ground.
8. Pair every new amputee with an established one. Mentoring by another amputee is described as extremely therapeutic.
9. Expect unemployment, social withdrawal and in some places family breakdown, and plan for them as part of the treatment.

12. Numbers to carry

1. **Civil War amputation mortality: 24.3 per cent overall.** Finger 2.5 per cent, thigh 53.6 per cent, hip 83.3 per cent. The closer to the body, the more likely they die.
2. **Primary against secondary, Confederate thigh: 38 per cent against 73 per cent.** Delay roughly doubles it.
3. **Lister: 45 per cent to 15 per cent**, on 35 and 40 cases. Real, small, and contested.
4. **Trueta: 6 deaths in 1,073 open fractures.** Debride well, leave it open, plaster it, wait.
5. **Delayed primary closure at 4 to 5 days.** Never close a contaminated stump on day one.
6. **Tibial stump: 5 cm minimum, 15 cm ideal.** Never the distal third of the tibia.
7. **Tourniquet: 2 hours is the working limit.** Write the time on the skin. After 6 hours the limb is usually lost.
8. **Irrigate with 8 to 10 litres.**
9. **Abscess drainage cures about 76 per cent without any antibiotic.**
10. **Trained non-doctors: no excess deaths, but about 1.6 times the wound infections and 1.9 times the dehiscences.** Their training took three to five years.

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