History

200 Years of ‘Legging It’ – A comparison of amputation surgery in 1805 to 2005

T Stevenson

“From the time that man first waged war upon, & begun to wound & kill his fellow-men, he has been ready to avail himself of all the knowledge & skill that could be obtained to save & cure…”

W. H. Flower - 1859(1)

As Introduction

Amputation is the oldest capital operation in existence, and has been practiced since Neolithic times for punitive, therapeutic and ritualistic reasons for many thousands of years(2). This paper reviews the indications, contra-indications, surgical procedure, morbidity and mortality, rehabilitation and prostheses associated with amputation, particularly in the Naval theatre of war around 1805, and compared with the modern world of medicine and surgery of today.

Amputations Of The Past: 1805 (Or Thereabouts!)

The first and foremost consideration of conducting amputation during this time was that the patient would be wide awake and fully aware of the procedure being done to them. This meant that all operations needed to be carried out as swiftly and as (relatively) painlessly as possible. After the discovery and subsequent implementation of general anaesthesia, time became a luxury of which the surgeon could take full advantage.

Amputation was extremely common-place two hundred years ago. Many sources discuss amputation as though it was the most routinely performed procedure by surgeons, for example surgeon John Haddy James wrote a book about the causes of mortality after amputations in 1850 and in it states, “More than thirty years experience... has enabled me to collect an extensive record of operations of all classes, and among them amputations, of course, form a considerable proportion.”(3) His use of the words “of course” implies that he expects the reader to know that amputations indeed made up a large proportion of operations at that time. With regard to the navy, a source charting the history of surgery at sea concludes, “…it was common practice to hack off broken or wounded limbs with merry abandon…”(4). This may be an exaggeration however, when faced with no hospital facilities, little room or time allowed for a patient to languish in bed to recover, perhaps it is understandable that the navy surgeon would just remove the limb and be done with it, enabling the man to be ready for duty or replacement as soon as possible.

Indications

The operations were performed on patients who were wide awake and carried a substantial risk of haemorrhage, infection, both resulting in death. It was also not unheard of for patients to die of shock during the procedure(5). However, with these risks well known, the operation would still be carried out.

The main indications were trauma and disease. In cases of trauma where fractures occurred, the standard management, particularly in open fractures, was amputation at the joint above where the injury had occurred. The thinking behind this practice was to prevent infection of the open bone and subsequent generalised sepsis leading to almost certain death. Crush injuries, and in the case of military casualties, gun-shot wounds, lacerations from
swords and bayonets, and cannon ball injuries all required amputation. Whilst it may seem that no attempt was made to save the limb, this was not the case. John Woodall, the “Father of Sea Surgery” (1569-1643) published a book called “The Surgeons Mate” in 1617 and actively discouraged amputation where possible, stating “over forwardness doth often as much hurt as good.” (6) His idea of management, whilst argued against at the time, makes more sense by today’s standard, “Nothing cureth fractured boane so much as rest.” (7) Indeed amputations were considered by many surgeons the last possible option and done in order to preserve life.

The trauma expected in civilian life comprised crush injuries and lacerations from wagons and mills and fractures from falls. John James’ book on the mortality of amputation, mentioned earlier, neatly sums up the traumatic reasons for amputations according to each limb:

- Fore-arm → gun-shot wound, laceration by mills
- Arm → laceration and crush
- Thigh → wagon crush, mines exploding, jumping (falls)
- Leg → wagon crush, mines exploding, jumping

At sea, reasons for amputation would be battle trauma, although in bad weather, accidents were common. The following table contains information from surviving certificates contained in the “Chatham” and “Greenwich” chests – Navy Pension boards, responsible for

<table>
<thead>
<tr>
<th>Date</th>
<th>Sailor/Age/Rank</th>
<th>Ship</th>
<th>Injury</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/11/1801</td>
<td>Judonie Blight – 24 – Able Seaman</td>
<td>HMS Thistle</td>
<td>Lost right eye off coast of Egypt</td>
<td>Nil</td>
</tr>
<tr>
<td>01/06/1806</td>
<td>Michael Martin – 26 – Able Seaman</td>
<td>HMS Jason</td>
<td>Received lacerations of the face, neck, arms, hands, legs, &amp; feet by explosion of a magazine whilst taking &amp; spiking 6 guns in an enemy battery.</td>
<td>No amputation recorded Developed ulcer at the wrist</td>
</tr>
<tr>
<td>19/02/1807</td>
<td>Charles Kellott – 31 – Landsman</td>
<td>HMS Royal George</td>
<td>Injury of 2nd finger of right hand due to a splinter, in action of Sir Thomas Duckworth in passing the Dardanelles</td>
<td>Ulceration of wound led to amputation above the 1st finger joint</td>
</tr>
<tr>
<td>13/08/1807</td>
<td>Owen Hughes – 25 – Ordinary Seaman</td>
<td>HMS Belligerent</td>
<td>Crush of the big toe of the right foot</td>
<td>Toenail fell off, so amputated at the 1st joint</td>
</tr>
<tr>
<td>30/07/1810</td>
<td>Robert Daniels – 34 – Sergeant, Royal Marines</td>
<td>HMS Euryalus</td>
<td>Gun-shot wound in right fore-arm after cutting out a French vessel near Toulon</td>
<td>Amputated above the elbow</td>
</tr>
<tr>
<td>10/10/1810</td>
<td>Henry Hoskin – 26 – Quarter Gunner</td>
<td>HMS Victory</td>
<td>Fell from booms into the waist, causing violent concussion of the brain whilst getting foresail ready to be sent aft</td>
<td>Nil</td>
</tr>
<tr>
<td>24/11/1810</td>
<td>William Thompson – 35 – Able Seaman</td>
<td>HMS Blake</td>
<td>Hurt left foot by capstan bar falling on it, fracturing metatarsal bones, at Copenhagen whilst conveying along main deck to wash seamen’s clothes</td>
<td>No action taken, although wound has caused seaman great distress</td>
</tr>
<tr>
<td>10/06/1811</td>
<td>John Tuffnell – 33 – Able Seaman</td>
<td>HMS Ibis</td>
<td>Chime of cask damaged tendons of the 1st &amp; 2nd fingers of right hand whilst doing as Captain of the Hold employed &amp; was fully sober.</td>
<td>Fingers went to sleep &amp; afterwards sailor endured amputation</td>
</tr>
</tbody>
</table>

Table 1 Pension Certificates from the Chatham Chest & Greenwich Chest (9)
issuing pension certificates to injured sailors:

The amputations performed are highlighted in bold just to draw attention to the fact that of this random sample of sick certificates, four (possibly five) out of eight cases underwent minor amputation for their injuries.

The other major indication for amputation, both at sea and at home, was disease. Unfortunately, diseases were not always well described two hundred years ago, and where sources have described amputations in these cases, they refer to “Disease Process” or “Infection.” The assumption that by “Disease Process” they are referring to what we now call peripheral vascular disease, ulceration, the consequences of Diabetes Mellitus, Tuberculosis infection or untreated malignancy. By infection, the books tended to refer to “Mortification” or dry gangrene due to disruption of the blood flow (ie not from sepsis) which was common both in injury, disease and following surgery. Sepsis was almost always inevitable in civilian trauma injuries, especially in cities, as the streets were often lined with horse dung, and thus home to many forms of bacteria, all able to enter a wound site following, say, a wagon wheel crush injury or compound fracture(10).

Contra-Indications

There were very few contra-indications to amputate two hundred years ago and the only debate was when to amputate. Many surgeons would argue that primary amputation, conducted immediately at the time of injury led to the greater success. Others argued that delaying for as long as possible, and thus performing secondary amputation, was advantageous.

Many believed in amputating without hesitation because of the detriment to the body a traumatic injury could cause. For example, a famous surgeon in his day, John Atkins, published a book “The Navy Surgeon” and spoke of amputation during battle, “…the heat and surprise in action makes it the properest time for amputation, men meeting their misfortune with greater strength and resolution than when they have spent a night under thought and reflection”(11) suggesting that a man steeled for battle would be able to use his own red mist to withstand the horror of losing a limb to the surgeon's blade. Other surgeons, such as John Hunter, liked to wait for several hours “until the first inflammation had passed,”(12) as did surgeon John James “Secondary amputations in civil practice and performed under favourable circumstances, were and are, on the whole, attended with less mortality than primary”(13). Finally, there were surgeons who would remain undecided, and hence found themselves in a dilemma, such a military surgeon John Bell, “When there is a question about amputating, in a very bad compound fracture, the question is, whether the patient will consent to lose the leg at once, or risk the dangers of immediate gangrene and death?”(14) There is difficulty in finding reliable statistics to see which argument may be correct, however a senior naval surgeon by the name of Alexander Hutchinson decided to settle the argument once and for all following the battle of Algiers 1816. He circulated questionnaires to the surgeons of the fleet regarding the number and nature of wounds requiring amputation, duration of delay before amputation, mortality rate and period of survival. His results showed surgeons who practiced immediate amputation dealt successfully with more serious injuries and conducted more amputations per patient with a mortality rate of 33.3% - significantly lower than where amputation was delayed (45.8%). Whilst today's epidemiologists may criticise his study, it won many of his contemporaries over, and Hutchinson went on to make important recommendations for further reduction of mortality following amputation(15).

A converse view was given by surgeon Stephen Hammick in 1830 who wrote of an occasion where he had a patient whose limb was prepared for amputation, however the patient’s physician would not allow it, fearing for the patient’s life, which over-rulled both the surgeon and the patient’s desire for the operation to go ahead. The patient survived and the limb eventually healed, but the patient “spent five years in bed recovering and was utterly miserable” and never regained full mobility(16).

The only other contra-indication I could discover was where the patient was beyond saving, so palliative measures were taken to
ensure as much comfort was given as possible, rather than putting them through the agony of an amputation that would only hasten their demise, as recounted by John James: “He [the patient] dies with the system being conscious of some irreparable injury.” (17). In these instances, although never official, a minority of surgeons were rumoured to have been liberal with the administration of opiates, particularly opium (laudanum), to ease the passing of the stricken patient.

Surgical Procedure
Notes taken by an anonymous student on May 6th 1814 on a lecture about amputation delivered by a Mr Cooper (probably Samuel Cooper) give guidance on the procedure:

“Make your incision... below the patella... 8 inches from patella... the posterior & anterior Tibial artery require tying... Keep the limb cool after amputation.” (18)

To take a step back, let us look review the conditions in which operations would take place. The surgeon of old would typically perform amputations at the patient’s home, in their own home, or in the case of the navy surgeons, on ships at sea. As a consequence, they would carry their own instruments wherever they went.

Surgeons in the cities might have access to large hospitals with teaching theatres or

Fig 1 Surgeon William Beatty’s Amputation Set (Royal College of Physicians and Surgeons of Glasgow)
The situation for the surgeons at sea was far less luxurious. The conditions were well described by navy surgeon Tobias Smollett in his assumed autobiography “Roderick Random” where he writes of after being press-ganged into the HMS Thunder what awaited him in the sick bay – “about fifty miserable distempered wretches… huddled one upon another… and deprived of the light of day as well as of fresh air; breathing nothing but a noisome atmosphere of the morbid streams exhalings from their own excrements and diseased bodies, devoured with vermin hatched in the filth that surrounded them.” (19)

William Turnbull, famous surgeon and former navy surgeon, wrote a handbook for navy surgeons in 1806 and in it definitively covered everything the young surgeon would need to know about amputation. He began with the instruments:

With regard to the procedure, Turnbull wrote of 4 main steps to bear in mind:

“The first [step] is the prevention of haemorrhage… by a full command of the tourniquet… and a minute application of the tenaculum afterwards… The second important step… is the separation of the nerves… in order to prevent the symptoms of pain & spasm… The third important step… is the proportion of the stump, which should be no more than completely to cover the denuded parts, and not so much as to lap over and endanger the formation of matter… The last circumstance regards the after treatment; and here the great object is to obviate inflammation… and afterwards to check any excess of discharge, which might reduce the constitution of the patient.” (21)

The following paragraph describes amputation of a hand, written by surgeon William Northcote.

“For amputation of the hand, three assistants placed thus. One… should stand behind him [the patient] to hold the body; another on the side of the affected arm, which he is to hold fast; a third assistant must hold the hand about to be amputated. Then proceed to fix the tourniquet with a compress on the brachial artery… [The skin is pulled taught and surgery begins] Having divided the skin, order the same [second] assistant to draw it up as much as possible; then cut through the flesh to the bones circularly, close to the edge of the retracted skin, & divide the intermediate skin and ligament between the bones by the catlin, with which we also separate the periostuem a little, both from the radius & ulnar to prevent its being lacerated by the teeth of the saw, which we must next apply on the outer side of the arm; ordering the assistant to draw up the flesh as much as possible to open a passage to the bones, that they may be cut off a little higher than the incision, and that the flesh may afterwards wrap over them… and thus the flesh and skin being longer than the bone, and folding over the stump, with greatly hasten the cure. Work the saw upon the both bones after they have been partly entered by the teeth and cut through them as speedily as possible, but be
careful to have both bones divided at the same time without splintering them. The limb being thus amputated, order the assistant to relax a little the tourniquet, that by starting forth of the blood the ends of the arteries may be discovered, which must be secured by ligature with a crooked needle and waxed thread, made pretty broad to prevent it from cutting through the coats of the artery, which is thus intercepted by passing the needle twice round and securing the ligature by the surgeon’s knot.”(22)

”(22) This detailed account seems to hold true the same principles used today and to demonstrate similar procedure for another limb, the following is a generalised method with which to conduct an amputation at any level, from John Atkins’ The Navy Surgeon:

“In this operation, the first thing we ought to have in intention is the stopping of the blood... There are 3 methods in practice: the 1st by medicines astringent or styptick; the 2nd by cauteries, actual or potential; & the 3rd by a deligation of the artery... The turniket is put in, & twisted to a degree sufficient to check or interrupt the course & motion of the blood... Guide it [the knife] for a smooth circumcision... bringing it at once as near the bone as you can, & as far round... also, you are to separate the flesh... and clear it for the saw... The saw is to be set on both bones at once (if two) & divided at as few strokes as possible... the nearer you come through, the easier to move, lest the bones should splinter.”(23)

From these two accounts, one can see a big similarity in how to conduct the operation. And from both accounts we can also draw the conclusion that the surgeon’s biggest worry was haemorrhage. This was assisted considerably by the introduction of Petit’s screw tourniquet.

Morbidity & Mortality
Amputation as we have already seen was a dangerous business. And the mortality was indeed high. The chances of developing infection were significant. Much depended on luck and some of the surgeons were able to publish figures of low mortality, such as Hammick: “During my service, I have performed 287 amputations, of which 16 have died.”(24) That works out at about a 5% mortality rate.

The causes of mortality after amputation went as follows – shock & exhaustion, and pyaemia (secondary infection) with the shock & exhaustion being twice as frequent as pyaemia(25). Other causes were sepsis, gangrene, and tetanus, often found in horse manure on the streets, and so able to freely enter traumatic wounds. Unfortunately it was
difficult to find many statistics for the different causes of death, although below are a series of tables documenting the mortality rates following amputation in hospitals:

So here, out of 300 cases performed by one surgeon over 33 years, 43 died (approx 14%) with amputations at the thigh providing the larger death rate and amputation at the fore-arm the lowest.

A far more severe death rate occurred in Paris at 65%. Presumably the conditions of the hospital had an effect on whether or not the patient would develop sepsis or gangrene.

Or perhaps the varying death rates came from surgeons’ idiosyncrasies, for example an American Surgeon, Samuel Gross, would touch his knife on the sole of his boot and then use it for the whole operation. Sponges would be reused between operations, merely dipped in water if soaked in blood or dropped on the floor, surgeons would happily wear their aprons which were stiff with blood without ever washing them (a stiff apron was the sign of a good surgeon) and in one case attributed to Robert Liston, where in his haste to remove a leg, he also removed the patients testicles, two fingers from an assistant and the coat tails of an observer. The observer promptly dropped dead of shock fearing he had been cut. The patient and assistant both went on to develop gangrene and both died, so it became the only operation on record with a 300% mortality rate(28)

Figures at sea for mortality were just as variable. Strangely, the death rate due to infection at the Battle of Trafalgar was only 10%. Either the conditions were inhospitable for the growth of bacteria, or perhaps the surgeons were being a little more conscientious about their cleanliness: “[John]

Table 3 – Devon & Exeter Hospital 1816-1849 Mortality rates of 300 amputations(26)

<table>
<thead>
<tr>
<th>Primary</th>
<th>Cases</th>
<th>Deaths</th>
<th>Secondary</th>
<th>Cases</th>
<th>Deaths</th>
<th>Disease</th>
<th>Cases</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thigh</td>
<td>13</td>
<td>8</td>
<td>Leg</td>
<td>18</td>
<td>7</td>
<td></td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Leg</td>
<td>18</td>
<td>7</td>
<td>Arm</td>
<td>19</td>
<td>3</td>
<td>118</td>
<td>118</td>
<td>11</td>
</tr>
<tr>
<td>Arm</td>
<td>19</td>
<td>3</td>
<td>Fore-arm</td>
<td>18</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Fore-arm</td>
<td>18</td>
<td>0</td>
<td>Total</td>
<td>68</td>
<td>18</td>
<td>26</td>
<td>26</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 4 – Extract of all Primary Amputations in Paris for Traumatic Lesion 1836-1846
(From Malgaigne) (27)
Atkins practiced scrupulous cleanliness, anti-sepsis and thorough debridement of wounds… [which] included methodical planning, with clean, polished instruments laid out in order on a linen cloth, threaded needles, ample clean water and an antiseptic solution, two sea chests as operating tables covered with clean clothes and a receptacle for dismembered limbs.”(29) Atkins’ mentor, James Yonge, senior surgeon at Plymouth, also practiced extreme cleanliness which was said to be the key factor of his success.

The varying mortality rates would continue to remain pretty high until the discovery of Joseph Lister’s carbolic acid spray. When that was implemented, the morbidity and mortality rates of all operations, not just amputation, began to drop.

Rehabilitation & Prostheses
The sailors of the Chatham Chest received a generous annual pension for their injuries. But what was the future in store for an amputee? The stereotypical image of the peg-legged pirate was probably quite accurate. Prostheses were simple wooden ‘pegs’ or, for the slightly wealthier, a crafted wooden leg,

The prostheses would depend on where the amputation had occurred. With regard to post-operative pain, it was considered much easier to fit a below-knee amputee with a comfortable prosthesis, as recounted by Hammick, ”Let me urge you very strongly, whenever you possibly can… take off the limb below instead of above the joint; its advantages are very great!”(30)

With regard to rehabilitation, there is almost nothing in the literature. It obviously had to happen somehow, as so many people underwent amputations and there are plenty of accounts of how surgeons saw patients several years later when they were back to normal and pain free.

Modern Day Amputations: 2005
(Or Thereabouts!)
The first thing to say about amputation is how much less common it is than it used to be. Approximately 5,500 amputations are performed annually across the entire UK, with 75% of the patients being over 65 years old, and 65% of the patients being men (2003)(31). Most limbs can be saved following trauma, so why are amputations carried out now?

The main indications for amputation now are shown below in table 5:

<table>
<thead>
<tr>
<th>Indication</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral vascular disease</td>
<td>85%</td>
</tr>
<tr>
<td>Trauma</td>
<td>10%</td>
</tr>
<tr>
<td>Tumours</td>
<td>3%</td>
</tr>
<tr>
<td>Infection</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Table 5 – Main indications for amputation in the UK(32)

Amputation through the lower limb accounts for 85% of all amputations(33). One of the main causes for all these amputations is diabetes. Diabetics are 15 times more likely to suffer amputation than someone without.

The indications for a below-knee amputation are gangrene, ischaemic ulcer, advanced unreconstructible ischaemia, acute or chronic infections (including osteomyelitis) severe enough to preclude healing at a distal level(34). These indications are perhaps not all that different to those in 1805, but we understand them a little better, and are able to do more to prevent these conditions reaching the need for amputations.

From a trauma perspective, the standard managements of compound fractures is now reduction and fixation, with every attempt made to restore 100% functionality to the limb. Amputations still have their place, for example, severe crush injuries, war injuries such as bomb blasts and mines, and also severe burn injuries. Most of the disease processes bring about the need for amputation surgery by affecting the circulation at whatever level, as the figures suggested in table 5.

Contra-Indications
The universal contra-indications for modern day amputation are gangrene, ischaemia, or infection of such severity as to preclude healing at the level of desired amputation(35).
This is perhaps countered by a ‘watch-and-wait’ policy with appropriate patients, or by short-term and aggressive treatment with antibiotics, or if delay is impossible, then to amputate at a more proximal level.

In some cases, particularly now that the average age of an amputee being much older, it may be a simple case of the patient being unfit for surgery, and where it is just not appropriate to either patient or family to start removing limbs. These contra-indications show a stark similarity to those two hundred years ago.

**Surgical Procedure**
The procedure has changed very little from that used two hundred years ago. The main differences now lie with the conditions under which operations are conducted. For a start, the discovery of anaesthesia and sterile techniques have offered an entirely different environment in which to operate and so have allowed the surgeon the opulence of as much time as he needs to operate. The typical amputation of, say, above the knee lasts about 20 minutes, although is subject to lengthening if any complications arise during surgery.

Scrupulous cleanliness is now a must, with surgeons and staff changing into clean clothes specific to the theatres, and applying sterile gowns and gloves in which to conduct the operation, to maximise the reduction in risk of infection.

With regard to anaesthetic, amputation can be performed under general anaesthetic, or in the cases of patients unfit for that, spinal anaesthetic or epidural. So some patients are still awake, just like two hundred years ago, only now they cannot feel a thing!

**Morbidity and Mortality**
For all the advancements made over the last two hundred years, amputation still carries a substantial risk of morbidity and mortality following operation. Infection is still a relative problem, with a recent study showing that limb amputation shows the highest rate of surgical site infection at 14.3% of cases compared to eight other categories of surgery(36).

A Norwegian study looked at morbidity and mortality of lower limb amputation and found that in 97 patients, 122 amputations were performed including 45 above (AKA) and 77 below (BKA) knee amputations, with a conversion rate from below to above knee amputation of 14%; in 65 of those patients 107 complications occurred (67%); the incidence of wound infection was 10% in the BKA group and 2% in the AKA group; and finally the hospital mortality for BKA was 9% and for AKA 18%. Long-term survival was 62% at 1 year, 50% at 2 years and 29% at 5 years(37), showing a still-high mortality figure.

Another major problem leading to high post-operative mortality is age. An American study looking at survival following lower limb amputation in an elderly population found that mortality risk increased with advanced age, more proximal amputation level, and renal and cardiovascular disease particularly after the first year(38).

Recommendations are now to provide specialist care to patients with predictors of long-term mortality and try and reduce figures in this way.

**Rehabilitation and Prostheses**
Aftercare of a modern western world: this has been revolutionised over the last 200 years, with patients able to expect a full multi-disciplinary approach geared towards helping them adjust and adapt to ‘life without limb’. With dedicated orthotics and prostheses departments in hospitals, at least 90% of patients with a transtibial amputation will successfully use prosthesis in contrast to a success rate of 25% of geriatric transfemoral dysvascular amputees(39). The main factor to account for this difference is that there is a hugely increased energy requirement to walk on an above-knee prosthesis.

While they face the problems of stigma and embarrassment in public, people without limbs today are well cared for and have a vast amount of opportunities open to them. So long as they are well provided for, rehabilitation and prostheses for amputees will only improve in the future, especially with the advancement of myoelectrics, the computerised limbs that move on command.
Conclusion
Amputations were carried out far more frequently in Napoleonic times for much broader indications and although the procedure has changed remarkably little, it used to be carried out far more swiftly. Both periods afforded good operational success, the principal difference being mortality from infection in the post operative phase.

As we are now into the 21st century, we can only expect further advancement in surgery, medicine and technology.

The asymmetric nature of the recent conflict in Afghanistan has shown that amputations still have a major place in a military environment and there is still the potential for it to face the Naval Surgeon at sea, be it in a conflict scenario or a trapped limb. However although the techniques are very similar, fortunately surgical conditions, facilities and the long term outcome have improved markedly.

Nonetheless when one considers the conditions at sea in Napoleonic times with no anaesthetics and the inevitability of post operative infection, the successes achieved in amputation were remarkable.

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Picture References
Fig.1 Courtesy of Mick Crumplin
Fig.2 Courtesy of Mick Crumplin
Fig.3 Courtesy of James Beaton, Royal College of Physicians & Surgeons of Glasgow
Fig.4 Courtesy of Lt Cdr J Scivier, Commanding Officer HMS Victory

Special thanks to:
• Mick Crumplin, Honorary Curator, Museum of the Royal College of Surgeons, Lincoln-Inn Fields, London
• Tina Craig, Library of the Royal College of Surgeons, London
• Jane Wickenden, Institute of Naval Medicine, Alverstoke, Gosport
• Staff & Crew, HMS Victory, HM Historic Dockyards, Portsmouth
• Royal Naval Museum Library, HM Historic Dockyards, Portsmouth
• Archives & Manuscripts, Wellcome Institute for Medicine, London
• Mr Aaron Sweeney & Vascular Team, Lewisham Hospital, London

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General Duties Medical Officer