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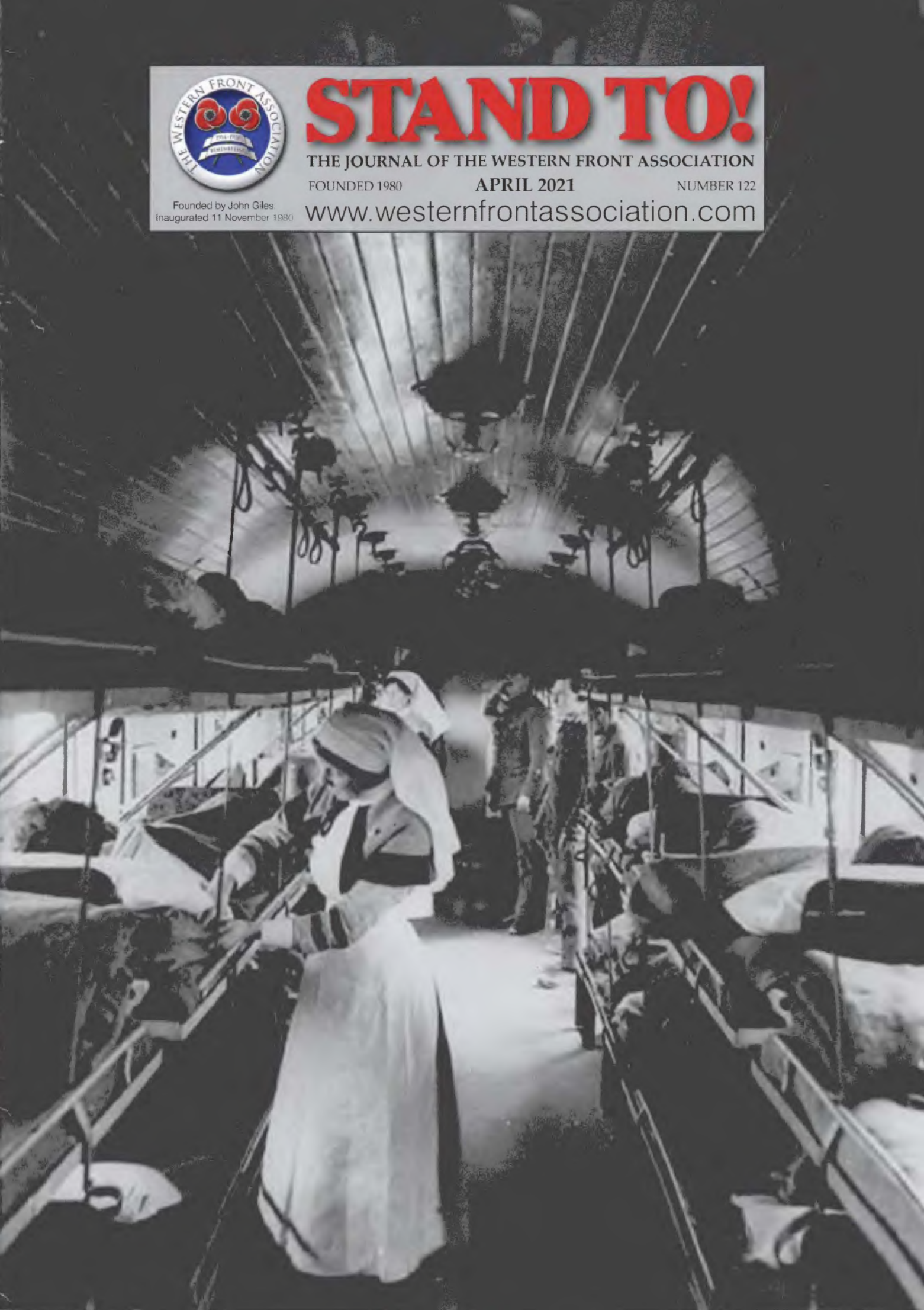


# Disaster to Triumph

## Saving life and limb on the Western Front 1914–18

### by Tom Scotland

*This article sets out to show how tremendous progress was made in the treatment of wounded soldiers of the British Armies on the Western Front during the Great War. It describes groundbreaking advances in resuscitation, anaesthesia and surgery which established the foundations of modern war surgery and stresses the importance of blood transfusion.*

In 1914, medical officers were in possession of knowledge and expertise gained by their predecessors of the late 19th and early 20th centuries and an evacuation pathway for the wounded had been established (Image 1).

Most British military surgeons in 1914 were disciples of Joseph Lister and schooled in surgical practices of the Second Boer War (1899–1902). Lister was Professor of Surgery at the University of Glasgow, when in 1867 he applied dressings soaked in carbolic acid to surgical wounds, with a view to killing harmful bacteria, thereby preventing them from gaining access to and colonising sterile operation sites.[1]

During the Boer War, antiseptic dressings were applied to wounds in the belief that they prevented bacterial contamination, but this conflict was fought on dry grasslands of the Transvaal and Orange Free State and most wounds were caused by conical rifle bullets fired by Boer marksmen from long range and of relatively low energy. Only a minority of wounds were caused by shellfire. The Great War on the Western Front was often fought on richly manured fields teeming with lethal bacteria and wounds were caused by high energy shell fragments and sharp-nosed streamlined bullets of enormous muzzle velocity, which drove contaminated clothing and debris into the depths of wounds. Nevertheless, Listerian principles were adopted and wounds were frequently sutured without exploration in the dressing stations or field ambulances before antiseptic dressings were applied: 'The experience of the South African War and with surprisingly moderate variation of the Russo–Japanese, led to the belief that, in a large proportion of wounds, superficial or very casual chemical antisepsis with immediate suture was not only permissible but desirable'.[2]

FIG. 151.—RIFLE-SPLINT APPLIED.
(Short rifle (Lee-Enfield) applied.)

*2 Rifle Splint (Royal Army Medical Corps Handbook, 1911).*

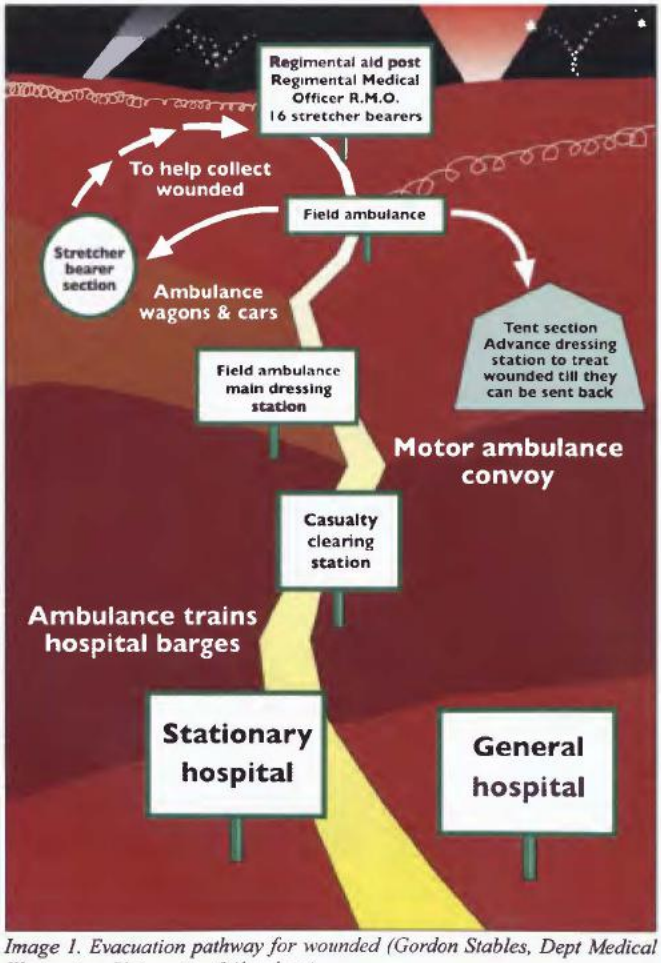



*Image 1. Evacuation pathway for wounded (Gordon Stables, Dept Medical Illustration, University of Aberdeen).*

Casualties were evacuated via field ambulances to clearing hospitals (renamed casualty clearing stations (CCS) in 1915) several miles behind the front line. Senior Consulting Surgeon to the BEF, Sir Anthony Bowlby, outlined recommended treatment for different wounds at clearing hospitals during the opening months of the war.[3] Simple flesh wounds required antiseptic dressings, while fractured forearm bones needed antiseptic dressings and splintage. Compound fractures of the femur required antiseptic dressings and Rifle Splints. These splints failed to immobilise the fracture, resulting in excessive bleeding around the fracture site, and many died from blood loss en route to, or at, the clearing hospitals.[4]

Those wounded considered suitable for surgery were evacuated by hospital train to base hospitals on or near the French coast, a journey that sometimes took several days. In the field ambulances during the first five or six months of the war, and later in the first clearing hospitals, wounds were superficially disinfected and sutured. The time between first aid at the front and effective operation at the base was commonly several days.[5]

Soldiers with penetrating wounds of the chest and abdomen were not generally considered for surgery and most died. It was mistakenly believed that catastrophic haemorrhage would ensue if a surgeon touched a lung and that thoracotomy (opening a chest cavity) would require a pressure chamber.[6] Furthermore, it was thought that patients with abdominal wounds were more likely to survive if surgery was withheld.[7] These were dreadful errors of judgment.

Evacuees to base hospitals often arrived moribund and medical personnel were confronted by overwhelming sepsis caused by pyogenic (pus forming) staphylococci, streptococci and faecal organisms. It was pointless covering wounds with antiseptic dressings, and it was dangerous to suture them at dressing stations. Many who underwent wound closure in this way were handed a death sentence, because organisms were locked inside where they produced vast amounts of pus under great pressure. Such infections were out of the experience of even the most senior surgeons: The results were appalling. During the first six months of the conflict the mortality and morbidity from 'septic' infection dealt to the surgical profession in every nation concerned a staggering blow, from which it recovered only through tedious and painful apprenticeship.[8]

Other wounded soldiers reached base hospitals suffering from gas gangrene caused by the deadly organism *Clostridium perfringens*, which occurs naturally in manured soil and only thrives in the absence of oxygen. Gas gangrene was common in contaminated and neglected wounds, especially if they had been sutured in dressing stations or field ambulances, or if

the circulation to the limb was compromised, or if the wound contained much dead muscle. Wounds of the thigh and buttock were particularly susceptible. Fragments of clothing and debris carrying *Clostridium perfringens* and driven into the depths of wounds, predisposed to deadly infection established long before victims reached base hospitals. Haemorrhage, circulatory collapse and prolonged fatigue were potent contributory factors. The incidence of gas gangrene varied from 5–6 per cent of all wounds in 1915 to a little over 1 per cent in 1918 after effective measures had been introduced to combat it. The percentage mortality from gas gangrene in the BEF was 22 per cent.[9]

Affected individuals were usually in a collapsed state, with a barely perceptible pulse and unrecordable blood pressure. Palpation of affected limbs revealed a crackling sensation beneath the examiners' fingers indicative of gas formation within the tissues. Gangrene spread rapidly along muscle fibres causing further muscle destruction, while the release of toxins soon resulted in multiple organ failure and death.

Enterprising surgeons realised that existing methods of treatment were hopelessly inadequate. A radical new procedure called 'wound excision' was introduced to deal with contaminated wounds. This involved early complete removal of all devitalised and contaminated tissue, converting a filthy wound into a macroscopically clean one, thereby reducing the incidence of overwhelming septic infections and gas gangrene and increasing the probability of survival. Henry Gray from Aberdeen was Consulting Surgeon to a group of base hospitals in Rouen, and Edward Milligan was a young Australian surgeon working in the forward area. Gray and Milligan were the first to publish work on wound excision in 1915.[10, 11] They endured opposition and hostility from clinicians who lacked vision to see beyond existing methods of treatment. Fortunately, Sir Anthony Bowlby recognised the importance of wound excision and adapted casualty clearing stations to carry out this vital surgery before patients were sent by train to the base.

Just as surgical techniques were woefully inadequate in 1914, so too were resuscitative measures, since there was very little understanding of the impact of major bleeding. In 1917, surgical (wound) shock was defined by a Special Investigative Committee set up by the Medical Research Committee (MRC) in August of that year, as a condition of circulatory failure due to deficient entry of blood into the heart.[12,13] In 1914 and 1915, wounded soldiers with a rapid thready pulse and low or unrecordable blood pressure were given intra–rectal saline in an attempt to improve their clinical condition. Saline solution was administered using a rubber tube inserted through the anus. Saline was rapidly absorbed through the rectal lining into the circulation, resulting in a transient improvement.

Unfortunately, hydrostatic pressure within tiny blood vessels soon forced the saline into the interstitial space between the body's cells and any improvements were lost. For reasons which are unclear, intra–rectal coffee was often administered to patients with penetrating chest wounds.[14] Subcutaneous saline, delivered through a wide–bore needle into the tissues around the axilla (armpit) was employed, in the hope that it would be absorbed and have a beneficial effect. It was useless, as Geoffrey Marshall showed in 1915.[15]

Marshall was a respiratory physician working as an anaesthetist in CCS 17 at Remy Siding, several miles west of Ypres, where he had been sent by Sir Anthony Bowlby to investigate alarming numbers of anaesthetic deaths of badly wounded men. He concluded that resuscitation was required first and that nitrous oxide/oxygen anaesthesia was the safest anaesthetic to use. Although this would be insufficient for a healthy person, it was good enough for an individual with a compromised conscious level due to massive acute blood loss.[16,17] Chloroform and ether had their places, as had spinal anaesthesia, employing a local anaesthetic agent to anaesthetise the nerves to the legs, but all were too dangerous to use in the most severely wounded patients.[18]

During the Battle of the Somme in 1916, intravenous saline was employed to improve the condition of the wounded, but again there was only transient improvement due to the hydrostatic effect described above.[19] That same year, William Bayliss, Professor of Physiology at University College, London, experimented with Gum Arabica (Acacia), derived from the acacia tree. Gum Arabica is a complex polymer of glycoprotein and polysaccharides. Bayliss found that unlike saline it stayed in the plasma of shocked experimental animals.[20] It wasn't until 1918, however, that Gum Arabica became generally available for treating wounded soldiers suffering from shock and it was a poor substitute for blood transfusion, which was first used at Number 14 Canadian General Hospital in 1915[21] and then at Canadian CCS 2 in 1917 during the Third battle of Ypres by Canadian Lawrence Bruce Robertson, who transfused fresh blood from lightly wounded donors.[22]

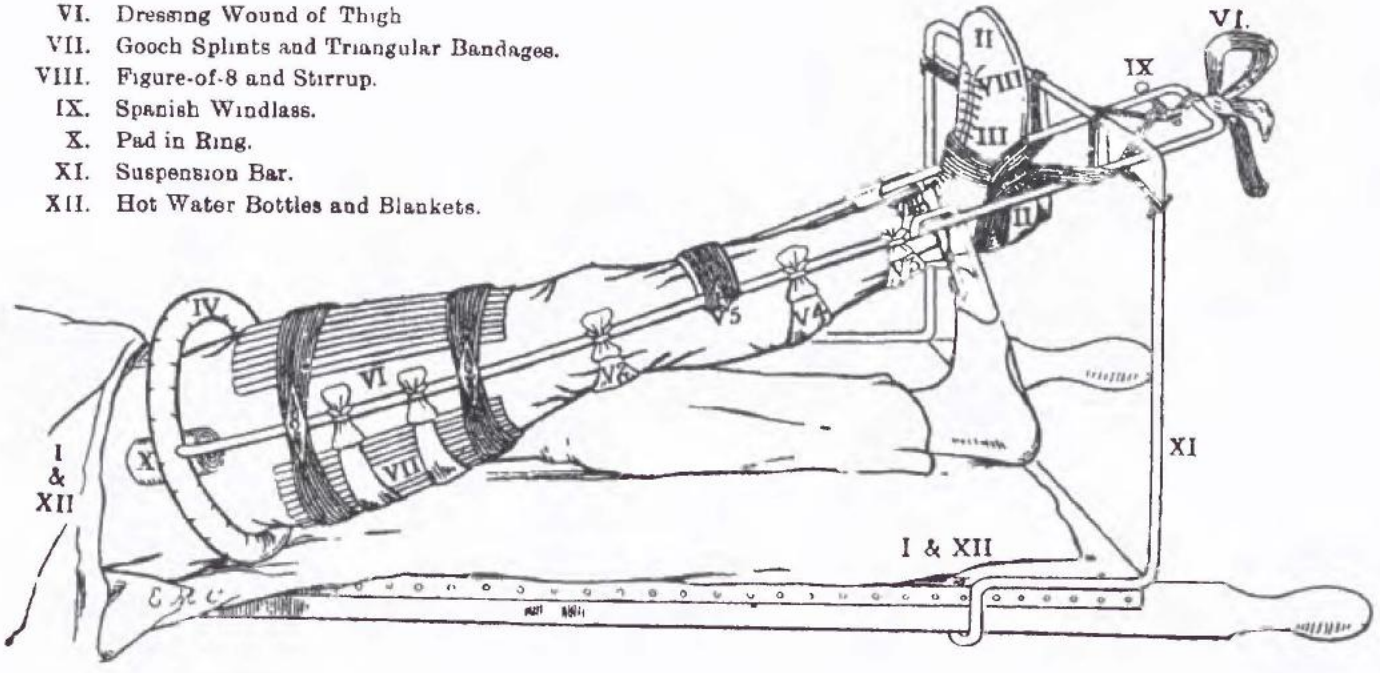
*Lawrence Bruce Robertson (Courtesy Archives of Ontario).*

The image below shows surgeon George Gask from St Bartholomew's Hospital operating on a soldier with a penetrating wound of his chest at Canadian CCS 2 during the Third Battle of Ypres, where blood transfusion administered by Robertson contributed to the survival of many cases. For example:

> 2nd Lieut A J D. Admitted July 29th, 1917, under care of Major G E Gask in a collapsed condition; severe penetrating wound of chest, from which there had been a large amount of bleeding; condition inoperable. Blood transfusion (740 c.cm.) carried out. After 100cc had been injected operation was begun; thoracotomy, removal of shell

*George Gask operating on a patient at Canadian Casualty Clearing Station Number 2 in 1917; he is performing a thoracotomy (Courtesy Archives of Ontario).*

I. Warming (Réchauffment).
II. Extension.
III. Modified Clove-Hitch over Boot.
IV. Splint.
V. Fixation of Leg.
VI. Dressing Wound of Thigh
VII. Gooch Splints and Triangular Bandages.
VIII. Figure-of-8 and Stirrup.
IX. Spanish Windlass.
X. Pad in Ring.
XI. Suspension Bar.
XII. Hot Water Bottles and Blankets.




A Front Line Application of the Thomas Splint

*Thomas Splint; Wallace, C S; Fraser, J.* Surgery at a casualty clearing station *(London: A&C Black, Ltd., 1918, p 105).*

> fragments, irrigation of pleural cavity, closure of chest wall; further progress good; evacuated to base nine days later in good condition.[23]

Blood transfusion also improved the condition of many badly wounded soldiers with penetrating abdominal wounds. By 1915, it was accepted that abdominal wounds needed surgery as soon as possible to reduce early deaths (within an hour or two of wounding) from haemorrhage and later deaths (any time after 6 hours) from sepsis. The first recorded successful bowel resection was performed by Owen Richards at CCS 6 on 18 March 1915.[24] Early intervention reduced the mortality from 80 per cent to 60 per cent.[25] Designated CCSs with personnel experienced in dealing with these wounds were soon located as close to the front as possible. Surgeon Gordon Gordon–Taylor from the Middlesex Hospital working at CCS 5 had particular expertise in the management of abdominal wounds. He declared:

> The results of surgical treatment of abdominal wounds did not improve in spectacular fashion when operation became orthodox until blood transfusion came to aid the victim, but some men are, from the very first, mortally wounded.[26]

By 1917, Henry Gray had become an acknowledged authority in the treatment of musculoskeletal wounds.[27] Gray documented a mortality of approximately 80 per cent for compound fractures of the femur caused by bullet or shell in the opening months of the war.[28] In 1917, he became Consulting Surgeon to the British Third Army and insisted that all fractures of the femur be immobilised using a Thomas Splint (see above image), introduced by his friend and colleague Robert Jones from Liverpool, who was Director of Military Orthopaedics.

Every regimental aid post had a supply of approximately ten Thomas Splints.[29] The device could be applied in No Man's Land by stretcher bearers before the victim was evacuated to a designated CCS. The fracture was immobilised effectively with less resultant blood loss. The majority of patients reached the CCS in good clinical condition and fit to undergo wound excision to save limb and life. There were 1,009 fractures of the femur during the Battle of Arras in April/May 1917, with a mortality of 15.6 per cent and an amputation rate of 17.2 per cent.[30] The significant reduction in mortality was attributable to prevention of surgical shock by effective splintage.

*Oswald Hope Robertson (Rockefeller Archives Centre).*

After the Battle of Arras, Gray established a shock centre at CCS 3 to encourage clinical research into the problems of acute blood loss. Day to day running of the centre was in the hands of Captain Kenneth Walker, a great enthusiast and inspirational figure. Oswald Hope Robertson of the 5th American Base Hospital (Harvard Unit) visited CCS 3. He had expertise in transfusion using preserved blood which could be stored for up to 26 days provided it was kept cold.[31] Robertson preferred employing Group O blood, known as the Universal Donor, because it can be transfused into recipients of any blood group without causing transfusion reactions. He established a small blood bank at CCS 3.

Alan Worsely Holmes à Court of the 4th Australian Field Ambulance visited Walker at CCS 3 in May 1918 after mobile warfare had been re–established on the Western Front. He set up a Field Ambulance Resuscitation Team after returning to his unit. This consisted of one medical officer proficient in surgery and a second expert in the administration of nitrous oxide/oxygen anaesthesia and resuscitation, including blood transfusion. There was one NCO and three orderlies, specially trained for the work. Surgery was restricted to urgent procedures, such as ligation of bleeding major vessels and amputations of mangled and unsalvageable limbs.[32]

The Field Ambulance Resuscitation Team was first employed at the Battle of Hamel on 4 July 1918, a limited engagement by Australian and American soldiers under the command


*Australian Standardised Dressing Station (Australian War Memorial, Canberra, Ref EO 3904).*

*Operating theatre within Standardised Dressing Station (Courtesy Australian War Memorial, Canberra, Ref EO 2771).*

of Lieutenant General Sir John Monash. The attack was launched over a front of 6,000 yards and penetrated to a maximum depth of 4,000 yards. Sixty tanks advanced immediately behind an artillery barrage alongside leading waves of infantry while the recently formed Royal Air Force provided air support. The battle began at 03.10 and by 05.00 the attacking soldiers achieved their objective when they captured positions to the east of le Hamel.[33] The Field Ambulance Resuscitation Team was based at the main dressing station (MDS). This was of a standard design (see images on p.21), within which there was a well–equipped operating theatre.

Blood transfusion could be administered using preserved Group O blood, but the required cold storage and rather complicated mechanism involved in reconstitution for transfusion were disadvantages. Stored citrated blood was preferable. This was prepared an hour or two before by removing blood from a typed donor and transferring it directly into a bottle containing an isotonic sodium citrate solution to prevent it clotting. No reconstitution was required to make it ready for use, and provided the blood was used within 2 hours, it worked very well.[34] Fresh blood from a lightly wounded donor was a further option. Potential donors and recipient were tested for compatibility to avoid transfusion reactions. A Kimpton Brown Flask (see below) was inserted into a donor vein to withdraw blood before placing the flask in such a position that blood could not escape. When inserted into the recipient's vein and held upright, blood entered the circulation.

*Kimpton Brown Flask (Dr Rod Westhorpe, formerly Honorary Curator, Geoffrey Kaye Museum of Anaesthetic History, Melbourne, Australia).*

Flasks were autoclaved for sterility, and liquid paraffin was used to lubricate the inside and prevent blood from clotting. Holmes à Court devised a simpler method to prevent clotting. He dissolved flakes of wax in ether, which was poured into the flask. When the ether evaporated, there was a thin coating of wax on all the surfaces.[35]

Casualties began to arrive at 06.00, and 410 stretcher cases passed through between 06.00 and 21.00, of which 30 (7.3 per cent) demanded immediate surgical intervention.[36] The most commonly performed operation was amputation of a shattered limb. Patients were frequently cold and clammy with a rapid, barely perceptible pulse and low blood pressure. The slightest movement of mangled extremities would have been excruciatingly painful, worsening the patient's general condition. Similar cases were encountered at Remy Siding in 1915 by Geoffrey Marshall, whose patients presented late and were suffering from systemic effects of severe blood loss with superimposed sepsis.

Marshall documented a percentage mortality of 90 per cent for amputations above mid–thigh.[37] On 4 July 1918, Australians dealt with their cases very quickly, before infection had gained the upper hand, and this greatly improved the outcome. Amputation stumps were apposed with a couple of loose stitches and patients evacuated to base hospital for further management. CCSs could be bypassed, leaving them to deal with compound fractures of the femur and penetrating wounds of the chest and abdomen. Gray stressed the importance of early amputation, noting it was performed much less frequently than indicated. It is to the credit of the Australian Field Ambulance Resuscitation Team that it tackled this problem most effectively. Gray declared:

> When the limb has been so badly damaged that its subsequent amputation is a matter of certainty, the earlier it is removed the better it is for the patient. The splinting of these badly damaged limbs is a difficult and painful process, and, as they are frequently associated with haemorrhage, conservative treatment becomes still more difficult.
>
> Early amputation is called upon far more frequently than it is performed. Not only is it the safest treatment from the point of view of shock, it is also the easiest treatment from the point of view of the medical officer.[38]

The second type of case dealt with by the Field Ambulance Resuscitation Team at the Battle of Hamel was severe bleeding from a major vessel. The surgeon had the expertise to perform a life–saving procedure by exposing the bleeding vessel and tying it off. In the case of an extremity, prolonged limb–threatening use of a tourniquet was avoided. Gray wrote:

> When an important artery or vein has been divided in the depths of a wound, the operation required in order that it may be tied may present great difficulties. If, however, the casualty clearing station is some distance away and there is no alternative but that of dispatching the patient with a tourniquet that must of necessity remain in position many hours, these difficulties must be faced. In arriving at a decision as to whether to operate or to trust to a tourniquet, it is worth remembering that about 80 per cent of limbs whose blood supply has been cut off by a tourniquet for a period of three hours or thereby eventually come to amputation.[39]

Many lives and limbs were saved by early resuscitation and effective surgery, in contrast to the situation in 1914, when inadequate resuscitation, outdated surgical methods and appalling delays resulted in many avoidable deaths.

The Field Ambulance Resuscitation Team on 4 July was so successful that soon all five Australian Divisions had similar teams. Motor ambulance wagons were supplied for their use and gave teams mobility. Equipment could be loaded onto them and since the design of dressing stations was standardised, there was no difficulty transferring work to a new location. As the army advanced, the MDS was dismantled and loaded onto four lorries before leapfrogging over the ADS to become the new ADS, the former becoming the MDS. The ADS remained in close touch with the advance at all times. As well as undertaking clinical work, Field Ambulance Resuscitation Teams became responsible for teaching inexperienced medical officers how to resuscitate shocked patients. Clinical activity of the Field Ambulance Resuscitation Teams during the months of August and September 1918 is summarised below. It excludes cases requiring general resuscitative measures.

- Operations (948)
- Blood transfusions (52)
- Gum and other infusions (62)[40]

Many limbs were salvaged by the removal of tourniquets, and many lives were saved by the early amputation of mangled limbs and control of major haemorrhage. Severely shocked patients were resuscitated and arrived at CCSs in much better condition than they otherwise would. Major Gordon–Taylor became acting Consulting Surgeon to the British Fourth Army on 27 September 1918 and wrote:

> Several months' experience in the Casualty Clearing Zone behind the Australian Corps has enabled me to form an estimate of the excellent work of the resuscitation teams of that Corps. There can be no room for doubt that very many lives have been saved by the work of Major Holmes à Court and the members of the other resuscitation teams. Their experience in the Dressing Stations coincides with that of the Casualty Clearing Hospitals that in blood transfusion we have the most remarkable and valuable means of treating cases of severe shock and haemorrhage. Their results conclusively prove the value of these methods of resuscitation in the Field Ambulances.[41]

After the war, Holmes à Court returned to Australia where he submitted an MD thesis

on his wartime experience with the Field Ambulance Resuscitation Team. He published detailed results of a closely studied series of 60 shocked patients treated by his unit. Of the 60 patients, 11, or 18 per cent, died. The remaining 49 were passed on from the unit in good condition. Given the number of severely wounded casualties dealt with, Holmes à Court regarded the percentage mortality as low. Here are two examples from his series:

## Case XXXIV

Condition (a) General: extreme shock and severe haemorrhage; (b) Local: both legs shattered below knee; observed 4h after injury; very collapsed; radial pulse imperceptible. Treatment: réchauffement; blood transfusion, 700 c cm (citrated blood); condition improved; pulse now palpable, 136 per min, very thready; blood pressure, 80 mm Hg; Operation 1.5 hours later under $N_2O$ and $O_2$ anaesthesia, the left leg was amputated at the junction of the upper and the middle third. The right leg was placed on splint. Conditions now became very critical; blood transfusion, 600 c cm. Result: one hour later the condition showed improvement; the pulse rate was 114 and the blood pressure 98 mm Hg. Thirty–six hours later, progressing well.

## Case XLI

Condition (a) General: severe haemorrhage; collapse; (b) Local: shell wound of left side of the neck; left common carotid artery severed; observed 1.5 hours after injury. Patient had fainted from loss of blood; the wound was plugged with temporary clot. Treatment: left common carotid artery was ligatured above and below the injury. The foreign body was removed. Gum infusion, 750 c cm. Result: Pulse became stronger (previously imperceptible); rate, 96 per minute; blood pressure, 120 mm Hg; subsequent recovery.[42]

Holmes à Court concluded that life could be maintained after a loss of five–sixths of the total blood as long as the blood volume was rapidly restored by blood transfusion. Citrated blood appeared to be as effective as preserved blood and was more convenient to handle when working under adverse conditions. Preserved blood was used in cases where no blood donors were readily available provided adequate facilities existed for the preservation and storage of the blood cells.

Infusion of Gum Acacia (Arabica) was effective in restoring the circulation as long as the loss of blood had not been excessive. This method was suitable for patients suffering from haemorrhage of a moderate degree. Saline infusions, both isotonic and hypertonic, only resulted in a transient restoration of blood volume, a fall in blood pressure occurring within 20–30 min after intravenous injection. Salt solutions were therefore of little use in acute haemorrhage.[43]

The response of the Australian Medical Services to the restoration of mobile warfare in 1918 was a remarkable example of surgical achievement built upon lessons learned during 4 years of conflict. Soldiers were resuscitated by blood transfusion within an hour or two of being badly wounded and clinicians of experience used safe anaesthesia to undertake major limb and life–saving surgery. This was in marked contrast to the situation in 1914, when many soldiers died because no one understood what surgical shock was, resuscitation was practically non–existent and blood transfusion was not available. Anaesthesia carried many dangers, and surgery was performed so late that sepsis and gas gangrene killed thousands of soldiers. Surgeons today would do well to take note of the advances made in resuscitation and surgery during the Great War or run the risk of making the same mistakes that others have made before.

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