Medical Lessons learnt from the US and Canadian experience of treating Combat Casualties from Afghanistan and Iraq

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2009 Churchill Fellow in the category Medical and Health: “Treatment & Rehabilitation of Traumatic Injuries”
Learning from US/Canadian experience treating combat casualties

US Army poster at the Warrior Transition Unit at Walter Reed Army Medical Center

MISSION OF A WARRIOR IN TRANSITION

I am a Warrior in Transition.
My job is to heal as I transition back to duty or continue serving the nation as a Veteran in my community.
This is not a status, but a mission.
I will succeed in this mission because I AM A WARRIOR AND I AM ARMY STRONG.
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I would like to sincerely thank the Winston Churchill Memorial Trust for enabling me to travel so extensively across the globe to see first-hand how our main NATO Allies care for their combat casualties at these World-renowned hospitals.

I would also wish to express my gratitude to my kind hosts:

Captain Eric Pagenkopf and Lieutenant Colonel Raymond Fang at Landstuhl Regional Medical Center;

Lieutenant Colonel Robert Stiegelmar at University of Alberta Hospital and Dr Jacqueline Hebert at Glenrose Rehabilitation Hospital;

Lieutenant Colonel Romney Andersen at Walter Reed Army Medical Center and National Naval Medical Center;

Major Joseph Hsu at Brooke Army Medical Center.

Finally and most importantly, I must thank my wife, Sangita for allowing me to disappear for two months, the day after returning from our honeymoon!
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**Introduction**

The wars in Afghanistan and Iraq are the first conflicts in recent memory in which substantial numbers of combat casualties are returning to the UK. In contrast, the conflicts of the previous decade in the Balkans and First Gulf War, resulted in fewer casualties. Prior to this the Falklands War of 1982, which lasted two and a half months, was probably the last time our military sustained such a large number of injured Service personnel.

The conflict has also changed from conventional battlefield warfare where bullets, fragmentary projectiles and landmines are the main source of injury and death, to one of counter insurgency with asymmetric warfare and an increased use of improvised explosive devices (IEDs), resulting in new and different patterns of injury. Body armour has improved substantially with greater protection to the torso, head and neck. Prior to body armour a bullet or blast that struck the torso or head would have been fatal. Now with protection of the core and thus the major organs, it is the unarmoured extremities (arms and legs) that take the brunt of the force resulting in soft tissue injury, fractured bones and on occasion, traumatic amputation. If however the force of the blast is sufficient to defeat the body armour, the internal injuries are overwhelming and may prove fatal irrespective of the severity of the extremity injuries. With recent advances in Field Medicine including combat tourniquets, haemostatic wound dressings, modern medical resuscitative strategies and shorter casualty evacuation timelines by helicopter, more of these critically injured casualties are surviving to reach Field Hospitals. Thus with increased survival, the surgical workload has increased significantly for the “extremity” surgeons (Orthopaedics, Vascular and Plastics). Arriving in the Field Hospital starts a long chain of events that will result in the return of the Serviceman or woman to their home country for treatment, rehabilitation and return to duty or discharge as a Veteran.

Great advances in medicine have always occurred during times of war, often in response to injuries resulting from newly-developed weaponry. From World War I with the humble Thomas splint to treat femoral fractures and early facial reconstruction, World War II with burns and plastic surgery and mass antibiotic production, to the Korean and Vietnam wars with the development of management of severe abdominal and vascular trauma, lessons have been learnt to permit not only the treatment of injured soldiers at the time but also improvement of treatments for all mankind.
My Winston Churchill Memorial Trust Fellowship allowed me the opportunity to travel to hospitals where these vital lessons are being learnt and to bring these back to the UK and disseminate these ideas and strategies amongst my military medical colleagues.

My Background

I read medicine at the University of Edinburgh, graduating in 2000 with MB ChB. After my pre-registration year, I chose to pursue a Masters degree in Sports Medicine from Queen Mary University of London. Subsequently I joined the Royal Air Force Medical Services and worked through Basic Surgical Training in Portsmouth and attained Membership of the Royal College of Surgeons of England. Before applying for higher surgical training in Trauma & Orthopaedics, I spent one year in research at the Defence Medical Rehabilitation Centre (DMRC) at Headley Court. It was here that I first came across the polytrauma patients arriving back from Afghanistan and Iraq, who later inspired my application to the Winston Churchill Memorial Trust.

After taking up my training post in Orthopaedics, I continued my research with military patients investigating amputations, examining outcomes for amputees and the complications of their surgery. Some of this data was shared with the military doctors in the US to co-author scientific papers. This collaboration and shared interest has facilitated my visit to these hospitals.

I am currently on the civilian phase of the eight-year surgical training pathway of Trauma & Orthopaedics as a ST4. I would like to eventually specialise in limb reconstruction surgery as a Consultant.

Combat Casualty Care for UK Service personnel

When a UK Serviceman or woman is injured in combat, they receive immediate first aid from other members of their team. All military personnel have basic first aid training and one in four is trained to a higher level. They will be evacuated by land or air to the Role 2+/3 British Military Field Hospitals in
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Camp Bastion, Afghanistan or Basra, Iraq. At the Field Hospitals, patients who have had severe injuries such as those from blast-type mechanisms or gunshot wounds will require resuscitation, surgical stabilisation, with control of bleeding, and immediate treatment of significant head, chest or abdominal injury. The individual undergoes a thorough examination from head to toe and has appropriate radiological imaging such as X-rays and computed tomography (CT) scans to diagnose all injuries. Extremities which have soft tissue damage require debridement (cleaning or washout and removal of dead or heavily contaminated tissue) of the wounds. If a bone is broken and the soft tissue overlying it is not injured, this is termed a closed fracture. If however a bone is broken and there is a wound over this, this is termed an open fracture and initial management is with debridement, and mechanical stabilisation of the fracture, using external fixators, plaster casts or traction devices. An external fixator (ex fix) is a temporary stabilisation device that places a threaded bolt into the bone either side of the fracture and spans it from the outside with a strut of aluminium or carbon fibre. Wounds are left open at this stage as they are contaminated with bacteria and will become infected if closed too early. Open fractures are difficult to treat due to the risk of infection of the soft tissues or bone, injury to blood vessels or nerves close by and delayed healing of any of the above damaged structures.

Once stabilised and the immediate threat to life has abated, all casualties have aeromedical transfer to the Role 4 Royal Centre of Defence Medicine (RCDM) Birmingham for definitive surgical treatment. RCDM is established at the civilian University Hospitals Birmingham (UHB) NHS Trust, which comprises Selly Oak and Queen Elizabeth Hospitals, and as a teaching hospital has all specialities available. UHB has over its two sites, 75 critical care beds, 1213 inpatient beds and a Burns Unit. Neurosurgical, Maxillofacial, Otolaryngological, General Surgical, Urological input is available, but the majority of patients have extremity injuries requiring Orthopaedic and Plastic surgery care.

In terms of definitive management, fractured bones are treated with either internal fixation techniques such as plates and screws or intramedullary nails that pass along the hollow axis of the bone so that the metal is buried under soft tissue, or definitive external devices using Ilizarov techniques such as the circular frame. Open wounds will require several repeat inspections and debridements as necessary, followed by delayed closure at a later date, with Plastic surgical reconstruction if necessary. Reconstruction techniques include covering the soft tissue defects with skin grafts, or tissue transfer using pedicle flaps or free flaps. A skin graft is transfer of skin from one
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“donor” area to the wound “graft site”. Muscle along with its covering skin can be transferred as a flap, either attached to its blood supply on a pedicle, or in the case of a free flap, detached and reconnected using microvascular surgical techniques.

The Defence Medical Rehabilitation Centre (DMRC) at Headley Court provides the single point of referral as the Role 4 Tri-Service Unit for rehabilitation and prosthetic limb fitting. It has 66 inpatient beds for Complex Trauma and Neurological injury patients, and a further 100 residential places for patients on rehabilitation courses. On discharge from RCDM Birmingham, all patients are referred to DMRC for rehabilitation and the more severely injured or amputee patients will often be admitted directly as inpatients. All amputees admitted to DMRC for inpatient rehabilitation are subsequently referred to the Prosthetic Limb Fitting Service. As of September 2008, there are 53 UK combat amputees, of which 85% have lower limb amputations, 23% have upper limb amputations, and 21% have multiple amputations. 33 have returned to duty of whom four have deployed back to combat zones. Nine have left the Services.

US Combat Casualty Care

All US combat casualties are first admitted to the US Role 3 (also termed Echelon 3) Field Hospitals in Afghanistan or Iraq. Due to geographical distance no transport aircraft is able to fly directly from these locations to the Continental US (CONUS). They must stop for refuelling in Europe and hence all aircraft stop at Ramstein Air base, in Rhineland-Palatinate, Germany. Patients are therefore transferred to the nearby Landstuhl Regional Medical Center (LRMC), in US military terminology an Echelon 4 facility (there is no equivalent in the UK system as aeromedical flights fly direct to RAF Brize Norton or Birmingham Airport without the need to refuel). These patients are medically stabilised at the hospital in Landstuhl, and intermediate care such as further wound washouts and debridements are performed. They are then transferred when stable and able to tolerate the long flight to CONUS to one of the three main Echelon 5 centres of military trauma care, depending on patient need and where they are normally stationed. East Coast Service personnel are transferred to Walter Reed Army Medical Center (WRAMC) if Army, or National Naval Medical Center (NNMC) if Navy or Marine. Army casualties stationed further south or requiring Burns Unit care will be transferred to Brooke Army Medical Center (BAMC), San Antonio, Texas. West coast Navy or Marine casualties will go to Naval Medical Center San Diego (NMCSD), in San Diego, California. These three
CONUS hospitals have been designated as Comprehensive Combat and Complex Casualty Care (C5) facilities and as such have appropriate acute surgical, medical and rehabilitation services.

Following acute care, Service personnel requiring more than six months rehabilitation are removed from their original unit (e.g. infantry or combat unit) and posted to Warrior Transition Units for supervised rehabilitation, case management and administrative purposes. These Warrior Transition Units are present at the military hospitals and Bases. Patients deemed to have massive brain or spinal cord injuries who are unlikely to be retained in the US military are rapidly discharged into the Veterans Affairs (VA) healthcare system, with four designated VA Polytrauma Rehabilitation Centres based at: Palo Alto, California; Minneapolis, Minnesota; Richmond, Virginia and Tampa, Florida.

Canadian Combat Casualty Care

The Canadians have provided personnel for a Role 3 Field Hospital at Kandahar Air Field (KAF) in Afghanistan since February 2006 when they assumed responsibility from the US. They have no military Echelon 4 or 5 facilities of their own in Europe or Canada and therefore use US military transport assets to evacuate their casualties from the battlefield to KAF Hospital and from here to LRMC in Germany. They are then transferred to Canada by US/Canadian military or civilian charter aeromedical flight to a civilian hospital deemed closest to either where the casualty is stationed, or where their family is based (as the two may not coincide), such as the University of Alberta Hospital (UAH) in Edmonton. Unlike the UK, there is no dedicated military rehabilitation system so military patients who have completed acute care are admitted to civilian rehabilitation hospitals, an example of which is Glenrose Rehabilitation Hospital (GRH) in Edmonton.
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Aims of my Fellowship

By visiting the hospitals at Landstuhl Regional Medical Center (LRMC) in Germany, University of Alberta Hospital (UAH) and Glenrose Rehabilitation Hospital (GRH) in Canada, Walter Reed Army Medical Center (WRAMC), National Naval Medical Center (NNMC), Brooke Army Medical Center (BAMC) and Naval Medical Center San Diego (NMCSD) in the USA with expertise in the early care, reconstructive surgery and rehabilitation of combat casualties, I aimed to learn lessons from the experience of our NATO Allies from which we too might benefit.

To facilitate the exchange of ideas, midway through each of my visits I would give a PowerPoint presentation on UK Combat Casualty Care so that my hosts could learn of our treatment strategies, successes and problems. On discussion, I found that these were often common issues and problems and this forum gave us the opportunity to raise points and discuss treatment strategies.

It has also been my aim from the outset to disseminate this knowledge learnt to the wider UK military medical community to improve the care and outcomes of our injured UK Service personnel.

Itinerary

I have deployed to the British Military Field Hospital at Basra Iraq, for two months in 2006, but not yet to the Field Hospital in Camp Bastion, Afghanistan. In order to follow the casualty pathway, I planned to start the Travelling Fellowship at Landstuhl, and then visit Edmonton in Canada to observe the Canadian experience, and then the US pathways with visits to Washington DC to WRAMC and NNMC, San Diego, California to NMCSD, and finally San Antonio, Texas to BAMC.

Inevitably, there were some changes of plans as LRMC was only able to accommodate me in late December 2009, so this was my final destination. Furthermore the trauma surgeon who was to be my hosting officer at San Diego, Commander Michael Mazurek, was tragically killed whilst cycling by a motor vehicle in November 2009. This had major repercussions for combat casualty care at NMCSD.
and my visit was understandably cancelled. The week I had originally intended to spend at NMCSD was therefore spent in Washington DC instead.

**Duration of visits - LRMC: 1 week; UAH and GRH: 2 weeks; WRAMC and NNMC: 2 weeks; BAMC: 2 weeks.**

**Landstuhl Regional Medical Center, Landstuhl, Rhineland-Palatinate, Germany**

LRMC is the largest overseas US military hospital with 140-bed capacity, although rarely more than 100 are in use at any one time, and is operated by the US Army and Air Force. All personnel medically evacuated from Afghanistan and Iraq have passed through LRMC and this was approximately some 46,000 since October 2001. It is designated as a Level 2 Trauma centre by the American College of Surgeons. It provides transiting care for Continental US-based troops but definitive care for European-based US troops (i.e. Echelon 5 or Role 4 equivalence). My host at LRMC was Captain Eric Pagenkopf, Consultant Orthopaedic trauma surgeon, of the US Navy.

No CONUS patient can stay longer than two weeks, as there must be sufficient beds for incoming casualties from the Field Hospitals. As a result, Dr Pagenkopf and his team will definitively treat uncomplicated closed fractures at LRMC. Complicated closed fractures that will require more than two weeks to treat (e.g. calcaneal or ankle pilon fractures) are sent back to the designated CONUS
hospitals to avoid bed-blocking issues. All patients with open fractures have wound inspections and debridements at LRMC with definitive treatment in CONUS hospitals.

Unlike WRAMC, NNMC or BAMC, this hospital does not have a training programme for junior doctors, so all medical staff are Consultant equivalents with the routine ward work done by Physician Assistants (PAs); there is no equivalent of the PA in the UK system. Priority 3 (P3) “walking wounded” returning from abroad are reviewed in clinic where they are first seen by the Orthopaedic PAs. If the case is complex, then an Orthopaedic surgeon reviews the patient. Priority 1 and 2 (P1 and P2) patients are much more severely injured and are therefore brought either to the ward or to the 24-bed Intensive Care Unit from where further stabilisation procedures are planned prior to transfer to CONUS.

LRMC will typically have at least 12 hours notice of a seriously injured patient expected from the Field Hospitals. A C17 Globemaster aircraft is tasked with the aeromedical transfer and will fly with its Air Force Medical team for collection and transfer to LRMC. These 12 hours gives the hospital time to establish how many beds it has, how many it needs and where to transfer existing patients if space needs to be made. The relevant specialities are notified and procedures planned. During my visit here, one of the combat casualties I saw was injured in an IED blast against his armoured jeep. The injuries to his legs were so severe that the Field Hospital had performed a below knee amputation on one side as the open fracture of his tibia made the leg unsalvageable; the other leg had an ex fix applied. He also had burns to his face and hands. This case serves to highlight the early management of polytrauma patients at LRMC. In this case, the patient was too unwell to go to the operating theatre for assessment and washout of his wounds on arrival. A CT scan was performed to allow assessment of injuries rapidly without disturbing the patient and his surgical procedures were planned for the following day. Dr Pagenkopf told me that LRMC policy is for debridement and washout of wounds every 48 hours in the early stages, if the patient is staying and too unstable for transfer. After the third or fourth washout, they may reduce the frequency to every 72 hours.

At this time, the patient had re-exploration and washout of all his wounds, debridement of dead muscle that had become apparent since his previous procedure in the Field Hospital. Washout is performed with motorised pulse lavage to increase the force of the jet and speed up the flow of sterile water, which is not used in the UK. On the amputated side, it was noted that the bone was too
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Long for the soft tissue to cover it, but this was left alone for definitive revision and fashioning of the stump at BAMC where he would be transferred due to his burns. Almost all open wounds have Vacuum Assisted Closure or VAC® dressings (Kinetic Concepts Inc), which is a topical negative pressure dressing. These are used during transfer to help keep the wounds clean and control wound exudate. This had been removed to inspect the wound and was reapplied at the end of the procedure. A plaster cast was applied to the below knee amputation to prevent joint contractures which would result in a fixed flexion deformity at the knee and exacerbate any future disability.

Combat casualty with right below knee amputation and ex fix on left leg

Same patient following debridement of right residual leg and application of VAC dressing

There is a weekly Morbidity and Mortality meeting at LRMC with feedback from the C5 hospitals to let the doctors at LRMC know of the outcomes of their management. There are also several videoconferencing sessions between the Field Hospitals, LRMC, WRAMC, NNMC, BAMC and NMCSD. This allows discussion and feedback from the various hospitals who have been involved in the care of a patient as they have transited through the system and the ability to find out what has happened, if
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A procedure that was performed was the correct thing to do, and to potentially stop performing procedures that turn out to be dangerous with follow up.

On my last day I attended the ITU ward round where the patient above was discussed in great detail, led by Lieutenant Colonel Raymond Fang, Consultant General surgeon and Intensivist. Due to the seriousness of his injuries and the fact that he had developed a ventilator-associated pneumonia, he would not be transferred to CONUS the following day. Instead it was planned that he would have a further wound washout and consider transfer the following week when he might be more stable. The use of the iLA Membrane Ventilator® (Novalung GmbH) which is an artificial lung surface that can oxygenate the blood and remove carbon dioxide outside the body was discussed, thus allowing severe blast lung injury patients to recover without the stress of mechanical ventilation.

I also took the opportunity to visit Ramstein Air Base to see the aircraft in action. The Boeing C17 Globemaster is the workhorse aeroplane, equally adept at carrying cargo, a tank or helicopter or forming a flying Intensive Care Unit. The Critical Care Air Transport (CCAT) team are comprised of Intensive Care doctors and nurses who will supervise the transfer of patients from the field hospitals via LRMC to the C5 CONUS hospital all the way to its Intensive Care Unit. The C17 I boarded was adapted to carry 30 stretchers and 30 seated patients.

Inside of C17 aircraft and ambulance buses loading patients into aircraft
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more C17s than can be counted on the ground at Ramstein Air Base!

University of Alberta Hospital and Glenrose Rehabilitation Hospital, Edmonton, Alberta, Canada

I was hosted by Lieutenant Colonel Robert Stiegelmar, of Canada’s Air Force and Consultant Orthopaedic trauma surgeon at UAH in Edmonton and Dr Jackie Hebert, Consultant Rehabilitation physician and Clinical Director of the Adult Amputee Programme at GRH. I spent my first day with Dr Stiegelmar being shown round the various departments of the 650-bed UAH and understanding the setup of the Canadian military and its medical services. As the Canadians do not maintain their own military hospitals (they were closed in the 1990s as a cost-saving measure), they have placed their military medical and nursing staff in civilian Level 1 Trauma centre hospitals. The Canadian military medical cadre comprises 34 Secondary care doctors (or Specialists), including 13 Anaesthesiologists, 10 General surgeons and five Orthopaedic surgeons. Interestingly there is no uniformed Rehabilitation doctor, although they have employed a civilian in this position in an advisory role to the military medical services.

The following day I visited Canadian Forces Base (CFB) Edmonton, home of 1 Canadian Mechanized Brigade Group, who deployed as the Canadian military contribution to the NATO mission in Afghanistan. There is a former hospital building here that is now used as an outpatient clinic facility for soldiers on the base, where Dr Stiegelmar does a monthly orthopaedic clinic that combines his
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interests in sports medicine and trauma. Indeed we saw a spectrum of patients from those with exercise induced leg pain and anterior cruciate ligament ruptures, to a double above knee amputee injured in an IED incident in Afghanistan several months before. He had ongoing shrapnel and infection issues in his residual limbs. There were also several patients who had sustained traumatic injuries from civilian mechanisms whilst in Canada e.g. motor vehicle collisions.

Later that week, I visited Dr Hebert at GRH to observe her practice with amputees. GRH is a 244-bed hospital and is the largest comprehensive tertiary rehabilitation centre in North America. It offers paediatric, adult and geriatric services on an inpatient, outpatient, and daycase basis. Within the adult division, they cover all the requirements for inpatient rehabilitation (e.g. brain injury, stroke, spinal cord injury and Neurological, Psychiatric, post-acute Orthopaedics, amputee care and post-acute burns). There are eight dedicated beds for amputees. Glenrose has signed a memorandum of understanding with the Canadian military to fast-track patients from acute care so that they are admitted quickly and no further delay is introduced to their rehabilitation. There is a dedicated Brain Injury Unit at Glenrose and military patients deemed suitable for neurological rehabilitation are admitted for a four to six week period for intensive treatment. Further rehabilitation is performed on an outpatient basis. The team has a liaison representative at CFB Edmonton for issues such as return to duty and suitable re-employment in the Services. For amputee care, the military also will pay for up to three prostheses per injured limb with no limit on the cost of these. In contrast for a civilian amputee, the publicly-funded health care (equivalent to our NHS) will only fund one prosthesis per injured limb and this amount is capped. The C-leg™ (Otto Bock) which is a standard prosthetic knee for above knee amputees, costs Canadian $20,000 and will be funded by the military for their patients but exceeds what the social health service will provide for civilians, unless topped up by the patient, insurance policy or Workers Compensation Board.
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I was able to meet Research staff at GRH and hear about major ongoing projects. Jonathan Halton, a senior occupational therapist, demonstrated to me how the Nintendo Wii™, a home entertainment gaming system, was being used in the rehabilitation of amputee patients. The Wii Remote with the additional Wii MotionPlus and a suitable game such as Wii Sports Resort was being used as an off-the-shelf solution for retraining muscle co-ordination, timing and strength. The Wii Balance Board with the Wii Fit game was used for balance retraining. The 3D graphics with instant visual feedback coupled with a game gave the rehabilitation exercises an objective on which to focus, which can be lacking when training in isolation from a target. The off-the-shelf solution is considerably cheaper than a custom designed device such as the CAREN, which will be discussed later¹.

Dr Hebert runs a combined clinic with Dr Stiegelmar for amputee patients requiring surgical input. Dr Stiegelmar is the main surgeon in Edmonton performing revision surgery to residual limbs (stumps) of both civilian and military amputees. GRH has admitted and rehabilitated five military patients so far, which represents one-third of the Canadian military amputees treated at this single centre. With upper limb amputees, Dr Hebert aims to fit a prosthesis within six weeks. After this, it has been found that the patients adapt to the missing limb and are consequently less motivated with the steep learning curve associated with using the upper limb prosthesis.

¹ As of 18 April 2010, the Canadian Forces Health Services are purchasing and installing a CAREN at GRH
I was fortunate during my visit to meet Master Corporal Paul Franklin, a paramedic with 1st Field Ambulance in CFB Edmonton. In January 2006, he was driving an armoured Mercedes Jeep in convoy in Afghanistan when a suicide bomber rammed the vehicle and detonated his vehicle-borne IED. MCpl Franklin was severely injured along with three others, one of whom died in the incident. His injuries resulted in him having bilateral above-knee amputations as well as significant burns. He was treated at KAF Hospital, then transferred via LRMC to UAH under Dr Stiegelmar’s care. He was admitted to GRH under Dr Hebert between March and May 2006. By March, he had already started touring to give motivational speeches. He continued outpatient rehabilitation until November that year. Such was his success that he had already returned to work, albeit on a daily half-day basis by September, only nine months following his horrific injuries. He has recounted his story in his book “The Long Walk Home”\(^2\). Paul explained to me that his experience of exemplary care at UAH and GRH is unfortunately not a common experience for all those that have returned. With no designated single centre of repatriation in Canada, the care patients receive is dependent on the local hospitals where they are transferred. GRH stands out very much as a beacon of excellence in Canada, as indeed the Parliamentary Committee concluded in 2008 in their report: “Bringing Our Wounded Home Safely”\(^3\). He has worked exceptionally hard to smooth the passage for future military amputees, in a system not used to dealing with seriously wounded personnel since the Korean War.

MCpl Franklin also spoke about the Northern Alberta Amputee Program or Franklin Fund\(^4\), a charitable foundation which he established with Dr Hebert. Its aim is to improve quality of life for people with limb loss, both civilian and military (the military already have their own charity Soldier On). This is done through a mixture of peer support for amputees and their families, education about limb loss, and funding research into amputee care and technology. The “Freedom Through Sport” initiative run by the charity is a series of sporting clinics that amputees can attend to determine what sports they can do, and implement adaptations as necessary. This promotes physical fitness and active living as an essential part of rehabilitation and recovery, and accentuates this ability rather than disability.


\(^3\) http://www.parl.gc.ca/39/2/parlbus/commbus/senate/Com-e/defe-e/rep-e/rep12aug08-e.pdf

\(^4\) http://www.franklinfoundation.ca
As of November 2009, there were 15 Canadian military amputees. Of these, nine have remained in Service, three are Reservists, and two have left the military. Tragically, one has committed suicide.

Photograph of MCpl Paul Franklin and myself at UAH

Walter Reed Army Medical Center and National Naval Medical Center, Washington DC, USA

The next stop was Washington DC to visit the 250-bed WRAMC in DC itself, and 208-bed NNMC, in nearby Bethesda, Maryland (about six miles apart). Due to the single service nature of secondary health care in the US military, WRAMC solely treats Army active-duty and retired personnel whilst NNMC treats Naval and Marine active duty and retired personnel (i.e. retired in Service healthy) plus dependents. Veterans Affairs Hospitals treat medically discharged veterans with Service-related injuries. Both facilities are staffed by doctors from all three services (Army, Air Force and Navy). Due to the Base Realignment and Closure programme, WRAMC will be closing in 2011 and all services present at this site will be moving to a combined hospital, Walter Reed National Military Medical Center (WRNMMC), at the current Bethesda site. My host was Lieutenant Colonel Romney Andersen, who is Clinical Director of the combined Orthopaedic Departments at WRAMC and NNMC.
With almost daily transfers of patients back from LRMC, the throughput was exceptional. The first case I observed was a young soldier involved in an IED blast who had sustained massive injuries to his extremities. He already had a below-knee amputation on one side performed in the Field Hospital; the other lower leg had severe injuries with an open fracture but was nonetheless deemed viable and therefore stabilised with an ex fix. As I discovered, the US does not use plaster casts or traction at all (unlike the UK) – it is their doctrine to use ex fixes on fractured bones. This patient was having exchange of the ex fix for an Ilizarov-type circular frame. The US military doctors use the Taylor Spatial Frame™ (TSF) by Smith & Nephew as the standard circular frame for open tibial fractures. This uses a Stewart-Gough platform with six struts (hexapod) to allow correction of deformity in three planes (forwards/backwards, sideways, rotationally and shortening/lengthening).
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Right leg open fracture (wounds now closed), stabilised with ex fix

Leg X-ray of tibia and fibula fractures with ex fix

Exchange of ex fix for TSF

Leg X-ray with TSF
Of note, like the UK, the US doctors did not use bone graft in the initial treatment of acute open fractures due to the risk of infection, performing delayed grafting if required. In contrast they used bone morphogenic protein rhBMP-2 (INFUSE®, Medtronic) liberally compared to current UK practice. BMP causes stem cells to differentiate into bone cells and encourages their deposition of bone matrix to heal fractures. Its expense means that it is used in the UK after other treatments have failed whereas the US doctors used it early on in treatment. Wound closure was always performed using the modified Allgöwer-Donati suturing technique as it offers the advantage of grasping a relatively broad amount of tissue and spreading the tension force over a large area while not disrupting as much of the vertical blood flow in the skin as other suture techniques; it is useful to close skin where the blood flow is compromised. Often a topical negative pressure dressing was applied as an "incisional VAC dressing" over a successfully closed wound to give an outflow for any wound exudate. Neither of these are done in Birmingham.

A trend I noted from the patients admitted was a specific pattern of injuries inflicted by the use of IEDs against mine resistant armoured vehicles (MRAPs) where the hull was not breached. The occupants usually survived the blast itself but due to the differential acceleration from the blast forces on the vehicle floor or seat compared to its occupants’ feet or bottoms, they would sustain vertical compression fractures of their calcanea (heel), ankle pilon and lower lumbar vertebrae. Such an injury pattern is rare and in civilian trauma, usually seen in patients who have fallen from a

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substantial height. The calcaneal fractures could be open, and I observed the reconstruction of comminuted (multiply fractured) calcanea using a variety of orthopaedic techniques. Throughout my time observing extremity trauma surgery at WRAMC and NNMC, I noted that we are performing similar procedures at RCDM Birmingham. A significant difference however was that free flap reconstruction of limb soft tissue defects were performed by microvascular-trained hand Orthopaedic surgeons. In the UK, such procedures are more commonly performed by Plastic surgeons.

Further example of TSF placed for a tibia open fracture with X-ray to show how the bone is stabilised

I met Major Kyle Potter, a Consultant Orthopaedic tumour surgeon who specialises in revising residual limbs following amputation. Dr Potter introduced me to the Ertl procedure. Normally in a below-knee amputee, the tibia and fibula are not joined at their lower end in the residual limb and in weight bearing the load is taken by the prosthetic leg from the proximal tibia. The Ertl procedure
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brings a flap of fibula over into a recess cut into the tibia, which fuses with time and gives a residual leg that can bear weight at the end. I also noted their management of heterotopic ossification (HO), abnormal bony tissue that is deposited in the soft tissues. This has been noted in the residual limbs of trauma amputees and can occasionally cause problems such as pain, difficulty with prosthesis fit, pressure ulcers and erosion of the ectopic bone through the skin. If it is necessary to excise HO due to the above symptoms that cannot be resolved by changing the prosthesis or rest and analgesia, they perform the surgery when it is mature, as judged by “cortication” on CT scan. If immature and excised too early, HO can recur, but waiting unnecessarily can delay rehabilitation. If the HO lies close to any vital structures such as blood vessels and nerves, CT scan data is used to construct a 3D model in plastic by CAD/CAM process to help plan the excision. In contrast, the UK uses technetium-99 isotope bone scan to determine the maturity of the heterotopic bone, with late excision.
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I was also able to spend some time with the Rehabilitation physicians both in clinic, their ward round review of orthopaedic patients and in the weekly multi-disciplinary meetings to discuss patient progress. Interestingly opioid painkillers are used differently compared to our practice at DMRC; in particular methadone dosed three times per day was used as a long acting painkiller. I visited over several days the amputee rehabilitation centre at WRAMC, the Military Advanced Training Center (MATC), headed by Colonel (retired) Chuck Scoville. This 31,000 sq ft facility is shared between patients at WRAMC and NNMC and has the capacity for 135 outpatient amputees at any one time. Notably, unlike DMRC, there are no inpatient beds for rehabilitation. These patients either have to be admitted under Orthopaedics in the hospital, or as outpatients use the hotel-like facilities at Mologne House or Barracks accommodation, if posted to the Warrior Transition Units. In addition there are Fisher Houses™ on site, large (20+ room) houses intended for the families to stay at whilst the combat casualty is an inpatient in the hospital. Sometimes the casualty who does not require medical or nursing care but is undergoing rehabilitation can stay there along with their families to help them readjust to family life. The Fisher House™ Foundation[^6] is a charitable body that funds the construction of these houses and gifts them to the US Government, who becomes responsible for their maintenance.

Within the MATC, there are numerous facilities including (some of the photographs here are taken from the MATC brochure):

![The MATC at WRAMC](http://www.fisherhouse.org)

[^6]: http://www.fisherhouse.org
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1) A peer support programme that has been established for amputees in which those more advanced in their rehabilitation visit to help and encourage newer patients adjust to their changed circumstances. There are also numerous celebrity visits and adaptive sports opportunities, such as rock climbing, basketball, kayaking etc.

![Wheelchair basketball, an example of adaptive sports](image)

2) A computer driving simulator with a Chevy SUV cab with disability adaptive equipment to relearn driving.

![Driving simulator](image)
3) The Gait Lab in the Center for Performance and Clinical Research (CPCR) uses sophisticated motion analysis equipment with 23 infrared cameras and two visual spectrum cameras (for overlay), reflective markers and six force plates. This provides three dimensional images of the patients’ movement. The information gained through motion analysis helps modify prosthetic devices and individualise physical therapy treatment approaches for each patient to improve movement skills such as walking, running and jumping. A similar facility exists at the Syncrude Center for Motion and Balance at GRH and at the CFI at BAMC but not at DMRC.

4) Computer Assisted Rehabilitation Environments or CAREN® (MOTEK Medical BV). This impressive US $1.2million simulator allows subjects to stand while supported in a harness in a virtual reality 3D world with moving and tilting terrain. It is being used for retraining the processing of proprioception and developing balance, as well as walking and running without the fear of falling.
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5) There is a firearms training simulator (FATS) and instructor to help soldiers regain this essential military skill.

6) There is a highly specialised gym to promote rehabilitation and retraining with specific equipment, a climbing wall, and highly regarded 225ft oval track with harness. This harness allows an amputee to walk or run without fear of falling and give a stronger sense of accomplishment. This frees up the therapist from steadying the patient, permitting them to stand further off and analyse and correct their gait more easily. Without the harness some have used it as a hurdle track!
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7) There is a family lounge and kitchen for the occupational therapists to assess the patients in various activities of daily living (ADLs) and see how they manage, with adaptations as required.

8) The MATC has prosthetic services and workshops on-site to allow custom manufacture and issue of prostheses, with quick turnaround times. I was able to see the new Power Knee™ v2 (Ossur) in use, which is a microprocessor-controlled motorised active knee for above-knee amputees. This bionic knee does the work for the patient to allow a concentric knee extension i.e. straightening of
the knee enabling the patient to stand up from seated or climb up stairs with less effort. Ossur only recommends it for use in unilateral above knee amputees, but I saw it trialled in a bilateral patient. The once high-tech C-leg was almost plain and uninteresting in comparison, as every above knee amputee at MATC seemed to have one!

Bilateral bionic Power Knees in action

With regards to US amputee outcomes, I was informed by Mr Scoville’s team that as of November 2009, there are 938 amputees, of whom 20% have upper limb amputations and 25% have multiple limb amputations. 133 have returned to service and 40 have deployed into the operation theatres of Afghanistan or Iraq.

"Lieutenant" Laura Lee, Therapy Dog, Orthopaedic Outpatient Department, NNMC
Churchill visited WRAMC in 1959 and met with President Eisenhower in the Presidential Suite, which is in the old hospital. He was presented with a portrait painted by Eisenhower himself, who had taken up painting to relieve stress on the advice of his doctor. This previously hung in the room but a copy has now taken its place. A photograph commemorates the presentation of this painting.
I travelled to San Antonio, Texas to visit the 224-bed (expandable to 450) BAMC. This hospital holds Level 1 Trauma certification and houses the only military Burns centre, with a 40-bed unit. It retains this Level 1 status by accepting care of civilian patients injured in trauma. Combined with the nearby US Air Force Hospital at Wilford Hall Medical Center, it accepts 50% of the trauma in the region, with the remaining 50% going to the University Hospital in San Antonio. Combat casualties however are solely treated at BAMC. I was hosted by Major Joseph Hsu, Consultant Orthopaedic trauma surgeon.

Dr Hsu specialises in lower limb reconstruction and it was a great opportunity to see his work in the operating theatre, pre- and post-operatively on ward rounds and in his follow-up clinics. Most of the surgery I observed involved the application of Taylor Spatial Frames (TSFs) to heavily contaminated open fractures of the tibia in the lower leg. The experience at BAMC of free flaps to cover leg soft tissue defects in the presence of infection has been poor. He therefore demonstrated his technique of angulating the fractured bone in the frame to shorten the distance so that a pedicled soleus flap suffices to cover the bone. The TSF then allows progressive correction of the angulation over several months. Dr Hsu used the topical pulsed ultrasound device Exogen™ (Smith & Nephew) to encourage bone healing.

I was very interested to see that Dr Hsu and his lead reconstruction physiotherapist Johnny Owens allowed patients in TSFs to do almost all physical activities, short of swimming. This includes single leg squats, free weights, and even flipping tractor tyres! Closed chain weight bearing exercises (where the foot is planted on the ground) are the preferred exercise type. By observing the patients throughout the treatment spectrum from initial operation to rehabilitation, I could see the challenges patients encountered with these large external frames. The psychology of the patient has to be right to accept a large elaborate “meccano” frame around their leg for many months, with the discomfort and problems this can entail. Pin site infection is common although usually minor. Patients have to be willing to comply, as corrections to the TSF hexapod are made daily by adjusting new lengths on each strut. I noted the problem of toe clawing (possibly due to missed foot
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compartment syndrome) and its treatment, which could involve rubber tubes tied between the toes or fine wires placed axially along the length of the toes.

Once the frame was off, the patient had healed bone but there may have been substantial loss of muscle with resulting leg and foot weakness. I was introduced to the Dynamic Bracing Solutions™ energy-storing ankle foot orthosis (AFO). Originally designed for patients who had weakness or even foot drop following polio, this was being introduced for use in military patients with reconstructed legs with extensive loss of muscle, or ankle fusions following complicated fractures. Patients with salvaged legs or ankle fusions can walk but cannot run or jump due to stiffness and pain. The energy-storing AFO allows them to gain this function whilst keeping their leg, instead of electing to have it amputated and using a conventional below knee prosthetic leg. It does this by storing energy during the “heel strike” phase of the gait cycle and returning it as they “toe-off” (lifting the foot off the ground). When I saw the device on trial, these patients had not been long issued it and were still adjusting to using the device. In particular, the energy return meant their leg “kicked” off the ground and they had difficulty stopping. However, feedback from the patients was positive, giving them sufficient function when walking, loaded marching and running, that they had stopped considering elective amputation of their painstakingly-reconstructed but sadly still painful leg. The cost of US $10,000 per orthotic was substantial, but still less than the cost of providing an elective below knee amputee patient with a lifetime of amputee care. There is also a version that is under development

7 http://dynamicbracingsolutions.net
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by the BAMC prosthetists from their own design and costs approximately US $2,000. This also has had initial favourable feedback from the patients trialling this AFO.
For amputee care, the Center for the Intrepid (CFI) is adjacent and as everything is bigger in Texas, is 65,000 sq ft in its own dedicated building. In contrast the MATC at WRAMC is 31,000 sq ft and the amputee care centre at NMCSD is 15,000 sq ft. The CFI opened in 2007 and was built with donations from the American public, and is staffed and run by the military. The occupational therapists (OTs) do all upper limb rehabilitation, leaving neck, trunk and back, and leg rehabilitation to the physiotherapists, whereas in the UK the OTs do only hand rehabilitation. The particular aim of the OTs based in the CFI is to train selected patients with upper limb amputations to use myoelectric limbs, which is a robotic hand with or without an elbow joint controlled by electrical signals generated when muscles further up the arm or chest contract. Hence the patient requires a period of re-education where they learn to contract their biceps or triceps to open and close their i-LIMB™ robotic hand or ProDigits™ (Touch Bionics) for partial hand amputees with missing fingers. When fully trained in this novel technology, I saw patients performing complex dextrous acts such as opening combination padlocks on lockers, or tying shoelaces.
The facilities available at the CFI are similar to those at the MATC at WRAMC. There is therefore an ADL apartment (rather than mere lounge), firearms training simulator, physiotherapy, occupational therapy and on-site prosthetists with workshops, psychiatric services and peer group mentoring and adaptive sports clinics to let patients try sports with adaptive equipment if necessary. Furthermore the CAREN and Gait Lab at the CFI form part of the Military Performance Lab (MPL). The MPL has the dual aim of performing the research from which funding is based, as well as treating amputee patients. This CAREN has a 21ft 300° wraparound screen and the Gait Lab here has up to 26 infra-red cameras to track the position of reflective markers placed on a patient’s body. Joint angles are calculated and analysed as before. This can be combined with data from the eight force plates in the floor, parallel bars, and treadmill to calculate the torque that muscles or prosthetic components are producing. This can be correlated with electromyography (EMG) which can detect both the timing and intensity of muscular contractions. This information can be linked so that gait motion capture, force vectors and muscle contraction power can all be integrated simultaneously to assess efficiency and quality of motion. There is little in the way of good research evidence of the effectiveness of CAREN and Gait Labs, and the MPL intends to correct this. The CFI can manage 110 patients at any one time, but all on an outpatient basis. If they require nursing care, they remain as inpatients in BAMC, or as outpatients live in the Barracks accommodation (if posted to the Warrior Transition Unit), or in the Fisher Houses on-site with family.
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CAREN at CFI

Climbing wall at CFI

Gait Lab at CFI
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**Lessons Learnt**

The Travelling Fellowship was an extremely valuable experience and I feel that I learnt much from it, both in terms of practices that are worth exploring as well as reaffirming how similar much of the practice in the UK is with our NATO Allies.

**Patient Care Infrastructure**

Geography determines some aspects of US and Canadian care provision that is not an issue for the UK. The Echelon 4 facility at LRMC is required due to the need to further stabilise and treat patients prior to the long transatlantic journey. There is a weekly video conference between the Field Hospitals, LRMC and the CONUS Echelon 5 institutions for valuable feedback and discussion of treatment pathways. The UK also uses a conference call between treatment facilities to discuss patients. The Canadians use publicly-funded civilian hospitals for the complete care of their Service personnel following repatriation. This is analogous to our use of NHS facilities at Birmingham.

**Wound Care and Fracture Fixation**

Open wounds are irrigated and debrided every 48 hours; the frequency is reduced only after several washouts have been performed and the wound is clean. To aid washout, pulsed lavage is only used in relatively clean wounds as its use in heavily contaminated wounds would drive the debris further into the wound. When the wound is clean and suitable for closure, the modified Allgöwer-Donati suture technique is used. Of note, VAC dressings are used in virtually all open wounds. Even after successful closure, an incisional VAC dressing is applied.

Unlike UK military practice, external fixators are used on all fractures, whether open or closed. As a result, for open tibial fractures US military surgeons prefer definitive external circular frames rather than internal fixation. With an open fracture there is a high risk of infection and failure if bone graft is used early; to avoid this problem bone morphogenic protein-2 is used liberally in place of bone graft in early management. In the presence of infected wounds free flaps have had a high failure rate; pedicle flaps are therefore increasingly being used as an alternative.
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The Ertl procedure of tibio-fibular synostosis is also being reintroduced to enable end-loading of the residual limb in the below knee amputee.

Rehabilitation

Upper limb amputees are fitted with their prosthesis within six weeks of their injury to prevent them adapting to the missing limb and becoming less motivated in learning to use their prosthesis. The i-Limb may potentially revolutionise return to function in selected patients of the 20% of military amputees who have upper limb amputations. In the UK, use of the pneumatic post-amputation mobility (PPAM) aid allows early upright walking of lower limb amputees even before their residual leg wound has healed. US and Canadian medical services do not use this adaptable prosthesis and their patients are consequently mobilised relatively late, as a standard prosthesis can only be fitted when the wound has healed. For those who have undergone limb reconstruction with significant muscle loss or ankle fusion, the energy-storing AFO has shown early promise to help regain a higher level of function.

Heterotopic ossification is managed early in symptomatic amputees with conservative and/or surgical measures. The maturity of this abnormal ossification is gauged by CT scanning to guide timing of surgical management. Recurrence is then prevented by the use of radiotherapy and/or a six week course of non-steroidal anti-inflammatory drugs to inhibit bone formation.

Patients’ engagement in their rehabilitation is key. Numerous strategies are available, these include peer support for destigmatising injury and demonstrating what can be achieved later on with hard work. Participation in sport has a role in de-emphasising the disability associated with amputation and also promotes physical and mental well-being. Patients in circular frames are permitted to do almost all physical load-bearing activities to aid bone healing and prevent disuse atrophy. The Nintendo Wii, which is a games console, is an entertaining and low cost method of retraining balance and co-ordination. Gait labs have been used successfully elsewhere in developing and relearning normal gait patterns.
Conclusions

My travelling fellowship allowed me to trace the pathway that combat casualties from our main NATO Allies take when they are repatriated. I was able to see how each hospital works and interacts with the others up and downstream from them. It also enlightened me to the logistics required by the medical branches of their militaries to support and staff the Field Hospitals, retrieve, resuscitate, stabilise and evacuate injured soldiers, and then perform definitive treatments and finally rehabilitate them.

We are doing similar things with respect to treatments and rehabilitation, albeit with “different accents”. The Canadians have a social health care model similar to our NHS and use civilian hospital facilities for treatment and rehabilitation of their military personnel. From what I have seen their treatment and outcomes are very good and comparable to ours. The high-tech and high-expense approach in the US with almost limitless funding for treatment and rehabilitation, as evident from the liberal use of expensive drugs, orthopaedic implants and frames, and futuristic rehabilitation equipment, still leads to similar outcomes to our own in the UK. All of us are treating these complex fractures in a similar manner in the orthopaedic setting. Rehabilitation differs only in terms of budget, as the opportunities military patients get for physiotherapist supervision, adaptive sports, and final outcome appear similar too. This in itself is a valuable lesson, as the UK will never have the military medical budget that the US has per soldier.

I was glad to be able to share our common experience in treating these brave individuals who have been injured in the line of duty. I still have several years left in training as a Specialist Registrar but I will put into practice what I have seen and learnt during the Fellowship for the benefit of my future civilian and military patients.