THE WINSTON CHURCHILL MEMORIAL
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Report by - BECK HEFFERON - 2016 Churchill Fellow

To study physiotherapy and rehabilitation after amputation to improve patient care and quality of life

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Signed Beck Hefferon

Dated 15th September 2017
Executive Summary

Keywords: Physiotherapy, Rehabilitation, Amputation

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Project Description

The objectives of this fellowship were to gain exposure to and knowledge from, international centres of excellence in the rehabilitation of amputees. Primarily, it sought to collect information from different models of amputee specific multidisciplinary and physiotherapy care. Core aims were to secure best practice guidelines and protocols for contemporary prosthetic rehabilitation, the osseointegrated prosthesis for the rehabilitation of amputees (OPRA) programme and the ‘Neuromotus’ treatment for chronic phantom limb pain. Importantly, the lessons learned from my fellowship will seek to inform and improve patient care and quality of life for amputees in Western Australia.

Highlights

The highlights of the fellowship were many and included:

- The opportunity to meet Dr Max Ortiz-Catalan and his brilliant team driving the future of neurally controlled prosthetics and phantom limb pain research. Learning and trialling the Neuromotus treatment and the unique opportunity to bring the programme back to Australia;
- The astounding generosity of Dr Max Ortiz-Catalan which has seen the BioTec software for the Neuromotus treatment made open access;
- This enables the Neuromotus programme to be universally available with information from collected data promoting a world-wide registry to capture the experiences of phantom limb pain in amputees;
- Meeting Dr Rickard Brånemark, the founder of Osseintegration Prosthesis for the Rehabilitation of Amputees (OPRA). His expert patient care, perspectives and advice regarding the future developments of this programme was greatly appreciated;
- Witnessing the future of prosthetic and therapeutic robotic capability and observing the ingenious team of researchers forging this reality at the University of Texas, Cockrell School of Engineering;
- Experiencing the seamless proactive teamwork, the state of the art facilities and the exceptional rehabilitation provided through the Center for the Intrepid (CFI);
- Spending time with Kirsten Hagberg whose inspiring dedication provided me with exceptional insight into the fundamental responsibilities of rehabilitation following the OPRA programme;
- Visiting the team of C.A.R.E. and the geniality of Dr Berlin and Dr Stromberg, their readiness to share with me their knowledge and medical perspective, as well as all the clinicians who selflessly shared time, expertise and resources;
- Witnessing advances in clinical prosthetic innovation in the US and the opportunity to learn the physiotherapy skills required to teach patients in their use, which will directly benefit clinical practice in WA;
• Meeting Carolyn Hirons and observing the positivity, professionalism and seamless multidisciplinary collaboration at PACE Rehabilitation;
• Spending time with Louise Tisdale at The Maltings, observing the role of extended scope of physiotherapy practice in pain management, and learning from her exceptional professional experience with a similar cohort of patient to those in my care in Australia; and
• Meeting the dedicated and proactive team at Roehampton and observing the finesse with which they deliver early mobilisation, their attention to detail and their motivating approach.

**Major Learning Outcomes**

Major learning outcomes included the following:

• United multidisciplinary collaboration stands out as the most influential promotor of excellence in patient care of the amputee;
• Smart technology has transformed clinical practice across the rehabilitation spectrum. Visual and multimedia documentation of assessment, treatment and evaluation can be instantaneously communicated with the multidisciplinary team (MDT) and wider rehabilitation network optimising management and preventing problems from escalating;
• A skilled and well-resourced administrative and clerical support service is essential to proficient core team communication and was cited by clinicians as a key enabler of clinical efficiency and optimal patient outcomes;
• OPRA surgery is now strongly associated with significant improvements in quality of life reflected in almost 2 decades of robust evidence to support its enduring success. Technological advances, reduced complication risks and shorter rehabilitation protocols are making this an increasingly popular option for amputees from nonvascular causes. This fellowship has created a unique opportunity for WA Health to collaborate with these leading teams and introduce the first service of this kind within WA Health at SCGH;
• The ability to transition research evaluations into immediate clinical practice holds promising direction for future care models;
• Early mobility aids empower patients psychologically, by reducing time spent immobilised and sedentary in the pre-prosthetic phase. Early ambulation promotes multiple systemic health, allows for assessment of prosthetic potential and would provide a cost-effective method of reducing unnecessary prosthetic costs;
• Singular MDT extended care pathway documents, such as those standardised throughout the NHS, can provide comprehensive long-term records. These capture lifelong patient experiences, facilitate accurate and appropriate MDT intervention and improve the capacity to review patient progression across lifespan through all facets of rehabilitation;
• Technology is enabling unprecedented symptom relief for a significant percentage of amputees disabled by chronic phantom limb pain and will become available in WA as a direct result of this fellowship; and
• Sophisticated prosthetic designs that are proven to improve everyday functionality, reduce risk and fear of falling, are now readily available and should be advocated for within the WA Health service.
Conclusions

The conclusions of this fellowship have already:

- Informed new protocols for the Amputee Clinic at Sir Charles Gairdner Hospital (SCGH) in WA;
- Contributed to the planning of a proposed Multidisciplinary Centre of Excellence for Amputee Rehabilitation within the West Australian North Metropolitan Health Service;
- In collaboration with the SCGH Orthopaedic Department formulated the Multidisciplinary Team (MDT) and physiotherapy protocols required to establish an ‘Osseointegrated prosthesis for the rehabilitation of amputees’ (OPRA) programme for public funded patients in WA;
- Generated amendments to the WA Department of Health Model of Care for the Rehabilitation of Amputees;
- Secured the loan of the ‘Neuromotus’ equipment and BioPatRec software programme in preparation of a clinical trial of this conservative treatment for phantom limb pain. With ongoing support from Dr Ortiz Catalan, his team in Sweden and the SCGH Amputee Clinic, my fellowship will directly result in this treatment becoming available to patients within SCGH. Should this trial be successful future collaboration with both the SCGH pain team and other WA hospitals will be explored;
- Generated international professional connections for ongoing collaboration and guidance in the developing these projects in WA;
- Generated plans to introduce early mobility aids in the rehabilitation pathway at Sir Charles Gairdner Hospital. Early standing promotes multiple systemic physical and psychological health benefits, allows for assessment of prosthetic potential and would provide a cost-effective method of reducing unnecessary prosthetic costs; and
- Contributed to plans for a mobile programme of interdisciplinary training and education and a web based clinical resources hub. Supported by Training Centre in Sub Acute Care, Western Australia (TRACS WA);

Furthermore, I look forward to sharing the gains of this fellowship at the 2017 Australian Orthotic Prosthetic Association (AOPA) National Congress, through the World Confederation for Physiotherapists amputee special focus forum and beyond.
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Introduction

Currently in Australia the devastating consequence of diabetes claims one limb every three hours. Diabetes WA 2016 [1] predicts this will increase in coming years with 1 in 3 adults set to have the disease in Australia by 2025. The global picture is similar where the number of lower limb amputations is set to exceed 3.6 million by the year 2050 [2].

The loss of a limb is a life shattering experience for both the individual and their family. The realisation of permanent disability and sudden loss of independence leaves many marginalised with a plethora of profound physical, psychological and social challenges. Distortions to body image and associated lower self-esteem can be demoralising and affect employability and societal identity. Quality of life (QOL) is undermined as a result and as many as 30% of amputees globally are reported to be suffering from mental health issues such as depression [3][4].

Rehabilitation is multifaceted and amputees face a number of unique milestones on their road to successful recovery. Skilled multidisciplinary management that includes but is not limited to, medical, physical, psychological, prosthetic and occupational care is the model of choice [5] and must be available across all phases of reintegration back into normal life. Lifelong support is crucial to minimise medical and physical sequelae and provide ongoing prosthetic management. Historically in Western Australia the relatively small amputee population coupled with the geographical size of the state and restraints of the healthcare system have created logistical barriers to technological, medical, prosthetic and therapeutic advances seen overseas.

Recent military conflicts in the Middle East and global terrorism have created a surge in traumatic lower limb injuries and amputations. This has provoked both the US and UK governments to significantly invest in the research and advancement of trauma medicine with both now committed to developing state of the art military rehabilitation centres. Modern treatments go beyond the aim of basic survival with surgical and prosthetic innovation and rehabilitation technology promoting levels of recovery and functionality sufficient for returning to active duty. Predictably, the knowledge and research this is generating may pave the way for improved care of all amputees in the future.

My Churchill Fellowship facilitated visits to principal centres that are setting international gold standards for multidisciplinary and interdisciplinary care. It enabled me to meet clinicians at leading facilities providing the ‘osseointegration prosthesis programme for the rehabilitation of amputees’ (OPRA) and the auspicious new Neuromotus treatment for phantom limb pain. I visited providers at the forefront of prosthetic innovation and exceptional research programmes leading the world in neural interface technology and amputee gait analysis. Throughout my travel in the USA, Sweden and the UK I was openly welcomed by these exceptional teams. I was included in their daily routines and was fascinated to experience firsthand the integral role that physiotherapy continues to forge, the fundamental necessity for interdisciplinary collaboration and how this continues to advance rehabilitation outcomes.

This fellowship has been a most wonderful experience. It has taught me a number of lessons as both a health professional and a person. I have been fortunate to connect with some brilliant and experienced clinicians, who, with generosity and vision work tirelessly to improve the quality of life of those living with amputation. In addition, I have gained invaluable insights into the different limb loss experiences of amputees from the decorated US military to the disadvantaged in the UK.
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<td>University of San Francisco: Center for Osseointegration Research, Education and Surgery (iCORES)</td>
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<td>Physical Therapist Assistant Clinical Professor, without salary, Physical Therapist, Director of Orthotics and Prosthetics, Certified Prosthetist Orthotist Prosthetic Resident</td>
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<td>University of Miami Miami, Florida</td>
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<td>ABC Prosthetics and Orthotics Orlando, Florida</td>
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<td>Chelsea Dornfeld, Scott L. Saunders, CPO, LPO,</td>
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<td>The University of Texas at Austin: Cockrell School of Engineering</td>
<td>May 30th -31st 2017</td>
<td>Richard R Neptune, Hannah Frame, Shelby Walford, Nick Womac</td>
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<td>Reneu Robotics Laboratory-Rehabilitation and Neuromuscular Robotics Graduate Programme</td>
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<td>Research Project Harmony Robot Project Harmony Robot Project Brain machine interface Maestro hand exoskeleton Maestro hand exoskeleton Maestro simulations</td>
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<td>Sahlgrenska University, Dept. Prosthetics and Orthotics and Centre for Advanced Reconstruction of Extremities (C.A.R.E) Gothenburg, Sweden</td>
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<td>Chalmers University of Technology- the Biomechatronics and Neurorhabilitation Laboratory and Neuromotus programme Gothenburg, Sweden</td>
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Background: The History, Impact and Causes of Amputation

Lower limb amputation is one of the oldest surgical procedures known to human civilisation. First documented by Plato in 385BCE, Hippocrates later described it in detail as treatment for vascular gangrene. Prosthetic limb remnants have since been discovered in Egyptian tombs and traditionally amputation has, and still is used, as both ritual and punishment in some cultures today [6].

World War 1 left over 41,000 major lower limb amputees in the UK alone. The Queen Mary Convalescent Auxiliary Hospital in Roehampton London founded by Mrs. Mary Eleanor Gwynne Holford in 1915 is believed to have been the first specialised rehabilitation centre for those with limb loss in the world. In 1925 its name was changed to Queen Mary’s (Roehampton) Hospital and in 1961 it joined the NHS. In 2006, it moved to state of the art facilities in its current location where it continues its service to both military and civilian amputees today.

The Diabesity Epidemic

The concurrent escalation of obesity and diabetes in the context of disease has been termed the diabesity epidemic [7]. In recent years, a notable shift has arisen in developed countries which have grown from two distinct changes in modern times - conflict and lifestyle. In the year 2000, the International Diabetes Federation (IDF) predicted that by 2030, there would be 324 million people in the world with diabetes, however, by 2015 there were 415 million, already exceeding that prediction [8] [9]. In Australia, diabetes has traditionally afflicted the older adult but diagnosis at increasingly earlier ages, means we now see individuals in their 40s and 50s with limb loss. Indigenous populations are at a disproportionate risk due to early onset metabolic disorders, renal and cardiac disease fuelled by increasingly inactive lifestyles, cultural disharmony and burgeoning levels of obesity. Those living in remote areas face the added challenge of accessing metro based services and the likelihood of diminished quality of life. Superimposed on an ageing population, these issues threaten to create one of the biggest challenges confronting Australia’s health system today.

Rehabilitation

My thanks to Dr. Kerstin Hagberg from Sahlgrenska University Hospital for sharing this quote that beautifully summarises the true essence of amputee rehabilitation:

“While the primary objective of amputation surgery is to remove an extremity which is useless or which endangers the life or health of the individual, the ultimate goal is the successful rehabilitation of the patient back into the normal life of his community. This goal can only be realised when a satisfactory durable stump has been formed; a comfortable well-constructed prosthesis has been selected and properly fitted; and the amputee has been diligently trained in its effective use and has been carefully guided toward a healthy mental attitude. These four factors - the good stump; the functional well fitted prosthesis; proper training in the use of the artificial limb; and sound psychological adjustment - are mutually interdependent and it cannot be over be overemphasised that each is of profound importance” [10].
Recovery is complex and challenging both physically and psychologically. Early phase goals include the resolution of stump oedema and surgical wounds and the treatment of acute post-operative phantom limb pain. Education to prevent joint contractures and falls begins immediately, and adjustment to loss of sensation, muscular imbalance and restricted mobility is addressed. Once adequate muscle strength has been regained, prosthetic rehabilitation is considered. Learning to walk with a prosthesis is extremely challenging with increased energy expenditure estimated at between 50 to 150% that of normal depending on amputation level. Secondary medical problems and musculoskeletal pain may develop from unchecked gait deviations, ill-fitting prosthetics or overloading the contralateral limb, and all threaten mobility and function. The primary goals of achieving the highest degrees of independence and quality of life come at the price of vigilance, and commitment to lifelong self-care.

**Multidisciplinary Care**

Multidisciplinary care occurs when professionals from a range of disciplines with different yet complementary skills, knowledge and experience, work together to deliver comprehensive healthcare aimed at providing the best possible outcomes. In doing so, they accommodate the physical and psychosocial needs of patients and their carers [11]. When this care is combined with a patient-centred biopsychosocial approach, treatment planning can collaborate evidence based knowledge and clinical expertise from each discipline, addressing the core values and goals of the patient. This serves to maximise patient and family education and minimise potential complications along the rehabilitation pathway.

In Western Australia, the Sir Charles Gairdner Hospital Amputee Rehabilitation Service treats approximately 300 amputees annually. It provides education and specialised care from the pre-operative stage through the acute inpatient stay and onto either rehabilitation at Osborne Park Hospital or discharge home. Once strong enough to begin prosthetic training, patients return to the amputee outpatient clinic for MDT planning. Patients with prosthetic potential are scripted for an interim prosthesis and then start gait retraining and are discharged once they have safely achieved their rehabilitation goals. However, patients also receive lifelong support provided by the SCGH MDT. The rehabilitation clinic is open in structure, meets once a week and consists of:

**International Healthcare Differences and Roles within the MDT**

Despite international differences in health service provision, globally the MDT approach prevails as the gold standard. It featured prominently throughout the major centres I visited, reflecting its
standing as the internationally recognised amputee rehabilitation model of choice with a proven ability to improve patient outcomes for those with chronic illnesses \cite{5,12}.

The roles I encountered were as follows:

- **Rehabilitation Consultant, Specialist Surgeon or Specialist in Physical Medicine (Physiatrist)**
  - Co-ordinates all aspects of amputee related inpatient and outpatient care;
  - In Australia, the USA and Sweden they are responsible for pharmaceutical pain management whereas this responsibility is shared with extended scope physiotherapy practitioners in the UK;
  - Management of comorbidities.

- **Physiotherapy**
  Physiotherapy is integral to all stages of care and plays a crucial role within the MDT. The key responsibilities include but are not limited to:
  - Pre-operative - Education for patient and families on preparation, perioperative and acute phase care including pre-operative exercise, contracture prevention, oedema control and early mobilisation;
  - Post-operative - Oedema education and management, residual limb care and exercises, falls prevention, pre-prosthetic conditioning;
  - Assessment of prosthetic potential;
  - Prosthetic retraining if applicable - Physical reconditioning to address inevitable deficits in balance, proprioception, strength and flexibility, gait training and lifelong prevention of secondary musculoskeletal problems;
  - Pain management - Physiotherapists in the UK as extended scope practitioners, have prescriptive rights to assess, manage and prescribe pain medications commonly used by amputees such as lyrica and gabapentin. This is not the case in Australia where allied health professionals (AHP) do not have prescriptive rights; and
  - Lifelong care and the application of regular and appropriate outcome measures to evaluate progress in physical, functional and quality of life domains.

- **Prosthetists**
  In all centres that I visited the prosthetists were required to be certified by their national professional board, as is the case in Australia. Their key responsibilities include:
  - Assessment of potential prosthetic users;
  - Prescription, casting, fabrication and modification of appropriate prostheses;
  - Lifelong follow up in collaboration with MDT; and
  - Liaise directly with public funding providers, private insurers, and legal teams.

- **Occupational therapists (OTs)**
  - Facilitate the return to activities of daily living (ADLs) including;
  - Transfer training and functional mobility needed for daily tasks;
  - Assistive equipment and home modifications;
  - Play a leading role in the rehabilitation of the upper extremity; and
  - With advances in myoelectric and bionic upper limb prosthetics, OTs lead in retraining patients in their use and integration back into vocational and community activities.

- **Psychologists and Counsellors**
  - Support patients and their families through acceptance and adjustment;
• Play a pivotal role in assessment of an individuals’ cognitive capacity to learn the use of a prosthetic limb;
• Promote self-management of comorbid conditions and adaption to living with limb loss; and
• Provide mandatory psychological evaluation for acceptance into the OI/OPRA programmes and firearms training within the US military.

• Podiatrists
In Australia where approximately 85% of lower limb amputations are preceded by a diabetic foot ulcer, podiatrists contribute considerable expertise in:
• The prevention of limb loss;
• The management of individuals with toe and partial foot amputations; and
• Provide the assessment and management of peripheral neuro-vasculopathy and care of the contralateral foot.
This was reflected in centres where vascular and diabetic patients were the main cohort, but not where trauma was the most common cause.

• Case Workers
• In contrast to Western Australia, internationally, case workers are becoming more common as an increasing number of amputees’ present with complex chronic co-morbidities. This was especially evident in the USA where the health system dictates that provision of care is not necessarily equitable or continuous.

Parallel to the MDT, many facilities that I visited also provided peer support, buddy programmes and advocacy groups. In the USA the Amputee Coalition and Department of Veteran Affairs, both provide excellent support and resources via organised events and online resources. In Sweden, buddy support is included in the pre-operative protocol for OPRA patients, and in the UK both PACE Rehabilitation and St. Mary’s Hospital run comprehensive programmes with additional psychological support.

International Variants of Multidisciplinary Healthcare

Throughout my fellowship, I observed significant variations driven by differences in healthcare models. The USA provided the most visible disparities where patient access to appropriate and timely therapeutic and prosthetic care is significantly limited by socioeconomic, ethnic, gender, occupational and geographic differences. This is not so dissimilar to current Australian disparities seen between private and public rehabilitation pathways, where the hospital at which the amputation was carried out may determine whether optimal or minimal specialist rehabilitation care is provided. This determination can lead to significant barriers impacting the provision of physiotherapy, prosthetic expertise, medical and psychological support. The average two-year cost per amputation in the USA is estimated to exceed $90,000 with lifetime prosthetic requirements predicted to range between $345,000 and $600,000 [3]. This sum is inconceivable for many, and fortunately in Australia all amputees are spared such costs. In Sweden and the UK, the national healthcare systems ensure a base level of equitable care through minimal patient fees in the Swedish system and free NHS provision in the UK, above which self-funding options exist.

Prosthetic use has repeatedly been identified as a positive promoter of quality of life that improves return to work and psychological wellbeing [3]. Differing insurance schemes in the USA however, guided largely by occupational and geographic differences, dictate the accessibility and lifelong entitlement to prosthetic componentry and physiotherapy intervention. Significant barriers then
present, resulting in significant numbers of amputees missing out on prosthetic rehabilitation and my discussions with US based prosthetists confirmed this. In stark contrast, the US Military and Veterans Health Departments go beyond the MDT approach and amputees receiving Military funded rehabilitation can expect exceptional interdisciplinary intervention and lifelong follow up as requested.

Interdisciplinary teams differ in that the participants share goals and overlap practice, rather than working on separate discipline specific goals [13] and indeed the CORE-1 action statement from the Department of Veterans Affairs and Department of Defence (VA/DoD) Clinical Practice Guideline for Rehabilitation of Lower Limb Amputation[14] states that "Interdisciplinary team assessment and management should be employed in the care of all patients with amputations throughout all phases of care" and I was privileged to observe this in reality during my visit to the Centre for the Intrepid(CFI). This experience is documented later in this report.

The Role of Physiotherapy

The Physiotherapy profession was first established in the UK in the late 19th century and its crucial role in amputee rehabilitation has been recognised widely since World War I. In the USA, the Walter Reed Army Hospital in Washington was the first to set up a designated school of physical therapy to train “reconstruction aides” to deliver rehabilitation to injured servicemen and it remains the most pivotal discipline in modern amputee rehabilitation today. Whilst fundamental treatment techniques to restore functional mobility have changed little, advances in prosthetic design, rehabilitation technology and the introduction of osseointegration surgery (OI) have extended the physiotherapy scope of practice. This fellowship has provided exceptional exposure to these advances.

The assumption a prosthesis can simply replace the original limb and it is easy to use is far from accurate. Limb loss results in profound motor and sensory deficits and the loss of proprioception means amputees no longer “feel” the ground accurately or can control the prosthesis naturally. As able-bodied people, we take for granted our ability to balance and coordinate walking patterns, to change speed or direction at will, negotiate different surfaces, steps or inclines and walk in different environments. This ability stems largely from a subconscious sensory feedback loop between our brain and musculoskeletal system relaying the direction and intensity of the ground forces we receive through our feet. The ability to adjust to this loss is often a major challenge of rehabilitation.

Amputation resulting from diabetes is considered a dire consequence of late stage disease and usually presents with multiple systemic conditions such as peripheral and cardiovascular disease, retinopathy, renal failure and contralateral limb peripheral neuro-vasculopathy. Amputees present as one of the highest populations at risk of injurious falls which is accentuated in the pre-prosthetic phase. Further complications relating to the physical difficulties of getting up on a single leg include heightened risk of injury and damage to the contralateral limb. Physiotherapists must be aware of these comorbidities and understand how they influence cardiovascular endurance, physical and cognitive learning capacity, injury risk and exercise prescription. Patient and family education for chronic disease management, care of the contralateral limb and increasing physical activity is routine. This highlights the enduring role of the physical therapy and the need to continue promoting lifelong multidisciplinary care. Once initial prosthetic mobility is achieved, the door opens to gaining more independence and progressing to community reintegration and advanced activities such as cycling, sports and running.

Early Prosthetic Considerations

In the pre-prosthetic rehabilitation phase, patients find themselves unable to mobilise without a wheelchair. Standing requires a frame, and due to excess forces placed on the contralateral side,
hopping is usually avoided. The loss of a limb directly changes the individual centre of gravity (COG) because a matter of necessity forces the amputee to shift their body weight over the contralateral side. With no sensory feedback from the amputated side, neural plasticity rapidly resets this position as the ‘new’ normal and compensatory balance mechanisms develop. This creates a cardinal challenge as optimal prosthetic gait demands the patient shift their COG equally left and right as they bear weight through each limb. This however, contradicts the patient's compensated internal representation of the ‘new’ normal, making equal weightbearing feel very abnormal initially. The loss of proprioception and floor contact sensation compounds this, and facilitating patients to trust and weight-shift fully into the prosthetic socket is arguably the most fundamental skill the physiotherapist must teach. New challenges however, arise once gait training begins. Gait deviations develop from either poorly loaded/fitting prosthetics, a patient’s physical impairments, pain, or all three. Causes can be difficult to identify as amputee gait analysis is complex and physical and prosthetic performance can be interlinked. Added to this, individual movement habits create very different patterns of pressure through the prosthesis during walking, leading to higher risks of stump injury and further gait deviations.

Prosthetists are skilled at adjusting the mechanical alignment of a prosthetic limb, whilst physiotherapists are well placed to recognise and treat the patients’ physical deficits. For the patient to attain optimal control and function of the prosthesis these skills must interlink and progressive rehabilitation centres now advocate for physiotherapy and prosthetic collaboration. The provision of a three-way problem solving approach where qualitative patient feedback is central to a joint treatment session is in its infancy in WA, but will become a major consideration on my return as a direct result of this fellowship.

Care of the residual limb in the context of safe prosthetic use is essential knowledge for all amputees and I was pleased to see the use of wheelchair stump supports for transtibial amputees (TTA) were standard for oedema management and contracture prevention. The use of early mobility aids (EMBs) was routinely taught by the treating physiotherapist at all centres visited. EMBs are not currently used in WA despite their recommendation in both the current VA and 2016 BACPAR guidelines. There are many benefits of these relatively low-cost devices (which include Immediate post-operative prostheses (IPOPs), Pneumatic post amputation mobility aids (PPAMs) and temporary transfemoral mobility aids (Femurett aids). These include effective limb volume reduction, desensitisation of residual tissues, possibly enhanced healing and the psychological and cardiovascular benefits of mobilising patients who are not yet suitable for casting, into standing and partial weightbearing. With increasing general knowledge of the risks posed to health from prolonged sitting, this opportunity to stand, especially in the already dysvascular population, is in itself reason to pursue this treatment method in WA.

Assessment to predict the level of meaningful mobility attainable in lower limb amputees has historically been the responsibility of amputee physiotherapist and numerous mobility outcome measures to quantify this now exist. Dr Robert Gailey, whom I met in Miami, developed the Amputee Mobility Predictor as a physiotherapy specific tool which is now regarded as gold standard around the world and correlates directly with the K levels used by funding bodies and prosthetic providers across the USA. The special interest group in amputee medicine (SIGAM) mobility predictor is popular in the UK and the Ottobock ‘MOBIS’ mobility scale has been developed specifically for Ottobock prosthetic componentry. Throughout my fellowship I was interested to learn whether particular outcome measures were universally favoured in order to compare and update our own. New measures that came to my attention included; the Prosthetic limb users survey of mobility (PLUS-M) which has only just this year been validated against established gold standard mobility measures; the
European standardised quality of life questionnaire (EQ 5D) which captures present day quality of life; and the previously mentioned SIGAM; all of which offer me new choices for quantifying the experiences of patients in my care.

**Prosthetic Innovation**

Optimal prosthetic gait retraining requires an in-depth understanding of mechanical and human biomechanics, such as how different ground forces interact with the human body and how they influence pressure distribution in the context of a prosthetic socket during the gait cycle. Historically, prosthetic casting, assessment and alignment are conducted with the patient sitting and standing. This static posture enables the prosthetist to accurately align componentry to the patient’s individual posture and balance this with the contralateral side. Sockets are designed to comfortably dissipate loading pressures across total skin surface areas and more tolerant bony parts of the limb, to avoid singular pressure points and direct weight-bearing on the cut end of the residual bone. In transfemoral amputees, safe placement of the prosthetic knee joint is achieved by aligning the vertical ground force line just in front of the knee axis so that it remains stable through stance phase. New transfemoral amputees with a traditional mechanical knee must be taught this skill in order to control and activate knee bend safely.

Historically, prosthetic knees have been ‘mechanical’, involving a basic hinge design that swings freely by default. The user controls the time at which the knee unlocks to bend whilst they are walking but once unlocked cannot control the amount of bend produced. The speed at which the knee bends and swings can be controlled by introducing resistance in the form of hydraulics, mechanical friction or a manual lock. The disadvantages of these knees are their inherent instability, especially when standing still and unfortunately are frequently the cause of falls. Injurious falls pose a major cost to healthcare and as mechanical knees are still standard prescription within WA, it was a key goal of my fellowship to observe the international shift towards more sophisticated computerised units. Microprocessor componentry is increasingly popular and in fact was the norm across the USA. These joints feature an internal computer known as the microprocessor which controls the joint’s resistance to bend either through a pneumatic or hydraulic fluid system. They are battery run and connected to sensors that read the angles and velocity of body segments above and/or below, with software that communicates this to an external computerised device in real-time.

The major benefits of microprocessor knee joints (MPK) are their ability to control the amount of knee bend delivered, and by repeatedly and accurately sensing the users gait pattern they constantly readjust the resistance for the appropriate support needed. This recreates a near normal gait pattern that can reduce falls by up to 80%, and improve walking speed and function by 15 to 30% providing significant benefits to everyday functionality and quality of life [16]. Consequentially, these units have become the recommended choice for OI prostheses and have recently been endorsed in the UK for prescription to public funded amputees under the NHS. These benefits, however, are not automatic and it is crucial that patients are professionally trained in their use. In contrast to a mechanical knee, patients must increase the load through their microprocessor knee (MPK) to gain the full benefit of the safety resistance. This is often counterintuitive in the early stages and requires diligent interdisciplinary training from both the treating physiotherapist and prosthetist. The opportunity to attain the specialised training and knowledge required to teach MPK skills was a valuable aspect of my fellowship.
Post Amputation Pain

In an 1871 study, surgeon Silas Mitchell first described his observation of phantom limb pain in American Civil War amputees as pain perceived by soldiers in a leg or arm that had been removed [17]. Today, the global prevalence of phantom limb pain is approximately 80% of all amputees, causing intense bouts of electrical, shooting or sharp pain, that bear little correlation to cause, level, or side of amputation [18]. Post amputation pain commonly occurs in three distinct forms. Firstly, stump pain originating within the residual limb itself can result from underlying bone and soft tissue problems, such as heterotrophic ossification or neuroma formation, which over time cause painful pressure points within a prosthetic socket. Secondly, phantom sensations are feelings of movement, pressure or touch that can be distracting, but not usually painful and thirdly, phantom limb pain (PLP) which is distinctly and intensely painful and debilitating. Whilst PLP is by nature intermittent it can inflict misery multiple times a day and is a major cause of sleep deprivation in those afflicted. PLP is still treated in numerous ways, through medical, psychological, physical and more recently technological approaches. As yet, no clear pathophysiology has been defined for PLP, and treatment options remain largely ineffective in the long-term [19].

Medical Pain Management

In Australia, neuropathic pain medications are still the most common approach for PLP and prescription is consultant controlled which differs to the approach used overseas. For instance, in the UK Senior physiotherapist Louise Tisdale from The Maltings at the Royal Wolverhampton Trust explained her rights as an extended scope practitioner enable her to adjust and prescribe directly to her regular patients and much of her programme involves educating patients and monitoring dose and compliance. Pain in chronic conditions such as amputation requires complex management and in Australia, patients often follow prescriptions from several different referral sources increasing the risks of misuse and unnecessary healthcare costs. The practice of extended scope prescription by specialised physiotherapists can identify these issues more readily and assist in optimising treatment whilst minimising the risks of long term medication use.

Patient feedback was extremely positive. The immediacy of this treatment without the need for additional medical appointments was cited as the most beneficial aspect. Louise also introduced me to the National Institute for Health and Care Excellence (NICE) pathway for pain management in amputees which she follows closely and I then observed the NICE pathway in practice at St. Mary’s in Roehampton. In the UK medications are chosen and monitored according to co-morbidities, potential interactions, patient choice, potential issues with medication abuse or adverse effects (desirable or not). As is the case in Australia, gabapentin and lyrica, are considered by most to be the “first-line” medications and usually administered as well as conservative methods. This was my experience throughout the UK, with all centres public or privately controlled adhering to NHS and BACPAR guidelines. To compliment this clinicians at St Mary’s Hospital in Roehampton also follow a clear pathway and algorithm to guide clinical reasoning for all types of post amputation pain (Appendix D) that could be adopted by our own MDT in the future.

Conservative Pain Management

The high incidence of chronic pain experienced by the amputee population can lead to the increasing use of over the counter analgesics such as ibuprofen and codeine in addition to prescription medications. Long-term use of such drugs promotes serious health and dependency risks and reinforces the push to develop more effective conservative treatments. Traditionally, desensitising
techniques such as, massage of the residual stump, relaxation techniques, compression therapy and the use of early walking aids have been the mainstay of physiotherapy treatment. Whilst evidence neither supports or refutes their use, both the Veterans Affairs/Department of Defence Guideline for Rehabilitation of Lower Limb Amputation (VA DoD) [14] and British Association of Chartered Physiotherapists in Amputee Rehabilitation (BACPAR) [5] recommend them. More recently, both mirror box therapy and Transcutaneous Electrical Nerve Stimulation (TENS) have proved effective in short term pain reduction with graded motor imagery demonstrating good outcomes for perceived disability in PLP [20][21]. Another treatment I was introduced to in the US was the silver lined shrinker (compression sock) designed to ameliorate PLP brought on by artificial lighting and other environmental triggers.

As technologies advance new therapies have emerged using virtual reality. Dr Max Ortiz Catalan from Chalmers University in Sweden has taken this one step further to develop a treatment that decodes conscious muscle activity detected from electrodes placed on the patient’s stump to create the illusion of a restored limb through augmented reality [22]. This is achieved by creating and then matching a representation of the missing limb to the unaffected side, enabling the user to see the recreated whole and is the foundation for the Neuromotus programme.

**Neuromotus**

The generosity of Dr Ortiz-Catalan was a highlight of the fellowship. The opportunity to learn and trial firsthand the new Neuromotus treatment, as well as observe its effects on both lower and upper limb patients, was inspiring. My thanks go out to Eva Lendaro and Catherine Widehammer for generously giving me their time to teach me how it is applied.

![Neuromotus User Guide](image)

*Courtesy of Integrum “Neuromotus User Manual”*

**Osseointegration**

Historically, the prosthetist’s challenge has been to find a secure and comfortable way of securing a prosthesis to a patient’s limb in a way that promotes mobility and function. The most common way has been to cast a replica of the residual limb and from it create an individualised socket that a prosthetic limb attaches to. The patient then slides the residual limb into it and secures it with suspension sleeves, cuffs or belts. The pressure created by weightbearing and the interface between
the patients’ skin and the socket have been a notorious area of poor fit, resulting in skin breakdowns and pain. Sockets are infamous for being uncomfortable to sit in, restricting hip movement and being awkward to don and doff. Transfemoral amputees with extremely short residual stumps, heavy scarring or frequent volume fluctuations, regularly struggle to get meaningful use from their limb and often give up the prosthesis altogether. The osseointegration procedure is now providing these patients the opportunity to still have a prosthesis but without the socket.

Essentially, it involves implanting a titanium rod into the core of the patient’s femur and allowing the natural process of osseointegration to become established. In a second surgery, approximately 3-6 months later, a permanent abutment is inserted through the soft tissues and into the implant. This is then left to protrude out through the patient’s skin for connection to the external prosthetic componentry. The external aspect of the prosthesis can easily be removed and attached by the patient at will.

Osseointegration for reconstructive surgery was the brainchild of Swedish Dental Surgeon Dr Per-Ingvar Brånemark, who first introduced it with dental implants in 1965. In 1990 his son, Rickard Brånemark, performed the first ever osseointegration surgery on a transfemoral amputee in Gothenburg, Sweden and the procedure has expanded dramatically around the world since then. The benefits of implanting the prosthesis directly to the residual bone include direct ground force perception, a phenomenon Brånemark coined ‘osseoperception’, which improves awareness of where the limb is in space thus improving walking confidence and reducing fear of falling. Unrestricted hip range of motion allows patients to sit in any position such as with their legs crossed or ride a bike comfortably and the energy efficiency of walking is greatly improved. It eliminates socket related pain and interface problems and has been repeatedly proven to improve quality of life [23]. Dr. Brånemark’s team in collaboration with Integrum and Sahlgrenska University founded the Centre for Advanced Reconstruction of Extremities (C.A.R.E.) in 2015 at the Mölndal site of Sahlgrenska University Hospital in Gothenburg. This modern unit provides inpatient, outpatient and rehabilitation care for OPRA patients from all over the world. The C.A.R.E team continue to refine the OPRA system including developing innovations incorporating neural interface technology directly through the implant. Such innovations promise to provide direct neural control of the prosthetic limb and have already been trialled on upper limb subjects.

The procedure mandates a regimented physiotherapy led protocol of specific graded partial weightbearing to ensure success. This begins on a short prosthesis, progresses to a full length prosthesis to be used with crutches for a 6-month period and aims for complete assimilation of the prosthesis into daily activity with 12 months (Appendix B).

The selection criteria for this procedure are strict. For example, it is only prescribed for those patients who have failed with conventional socket prosthesis rehabilitation (as opposed to new amputees). Given the large risk of infection and/or mechanical failure and the stringent rehabilitation commitment required, only adult amputees without vasculopathies, diabetes, a body weight of less than 100kg and who are deemed cognitively appropriate are eligible. Due to the permanent stoma created for the extrusion of the implant, the risk of infection is constant. A vigilant hygiene routine is essential and risky environments such as public swimming pools, spas and saunas must be avoided. High impact loading activities and running are also prohibited due to the risk of implant fracture.

A multitude of modified versions of this procedure now exist around the world and the rehabilitation protocols vary. A single stage protocol has however, emerged using a ‘press stud’ technique to insert the implant and abutment in a single surgery. The training prosthesis is then provided almost immediately and weightbearing begins within days. In this variant, transtibial amputees are now
common and diabetic and vascular patients with stable pathology are now eligible. These changes have been rapid and are challenging traditional boundaries within both the orthopaedic profession as well as the amputee rehabilitation community at large. Without doubt, these procedures will continue to gain popularity generating new directions in amputee physiotherapy and I was fascinated by the vigorous conversations the topic provoked throughout the fellowship.

Reviews of Hospitals and Rehabilitation Centres visited

The University of California in San Francisco: UCSF Medical Center, USA

Background: UCSF Medical Center is a leading teaching hospital in the US and home to the international Center for Osseointegration Research, Education, and Surgery (iCORES). It houses the first US based Osseointegration Prosthesis for the Rehabilitation of Amputees (OPRA) programme endorsed by the Food and Drug Administration (FDA). OPRA received approval from the FDA in July of
2015 and was launched at UCSF in January 2016. It has, to date, provided this pioneering option to 9 patients, both upper and lower limb amputees from varied backgrounds.

**Findings:** The iCORES clinic is a multidisciplinary collaboration aiming to translate next-generation projects for human use. The primary projects involve the advancement of the OPRA procedure to introduce pathways for ‘bidirectional communication between the central nervous system and external component of upper extremity implants’. The multidisciplinary team works seamlessly to support patients through all phases and facets of the programme, closely following the protocol devised by Dr Brånemark and his original team from Sweden. (Appendix B). Pre-operative assessment and admissions for either of the two separate surgeries involved, take place in the UCSF Medical Centre whilst the 12 month long rehabilitation programme is run through the adjacent Orthopaedic Institute. This interdisciplinary programme interlinks with medical, radiological and oncological specialties depending on patient needs. Full representations of allied health disciplines compliment this.

The iCORES team meets weekly to discuss ongoing management plans for prospective and current patients and the OPRA clinic runs in conjunction with the weekly sarcoma rounds, to review both inpatient and outpatient from all phases of treatment. All members of the team are present for these and the patients themselves are actively encouraged to ask questions. Physical therapists and Prosthetists from the UCSF Orthopaedic Institute work closely with the OPRA programme. Their role is to facilitate patient selection and provide education and physical preparation before, in between and post surgeries. Essentially, they provide specialist loading programmes, prosthetic rehabilitation and play a pivotal role in ongoing evaluation of progress together with the iCORES research scientists.

Dr Brånemark’s interaction with prospective patients is in-depth. His attention to detail in providing sincere explanations regarding the surgical process, anticipated benefits, possible complications and focal challenges was inspiring. Learning directly from Dr Brånemark about his vision for UCSF to lead the US for this kind of bionic technology was fascinating and I was intrigued to hear the significant interest it has drawn from the Department of Defence.

This opportunity to meet the clinic team and observe their interactions with the patients was informative. Meeting the patients themselves, and hearing their perspectives gave me valuable insight.
into patient expectations, concerns, and how this procedure is improving their quality of life.

A psychologist will join the team shortly to provide mandatory pre-selection evaluations. This is necessary to identify and exclude patients who would be unable to cognitively or behaviourally commit to appropriate care of the implant or the stringent rehabilitation protocol. I was interested to see the UCSF physical therapist plays a key role in guiding and facilitating this selection, as in my experience behavioural and cognitive issues can significantly undermine motivation and compliance with therapy. The programme has also assigned a research officer to coordinate data collection before and at regular intervals post-surgery. Questionnaires being used to collect information on quality of life, mobility and functionality are the QTFA, SF-36, EQ-5D, OPUS (Satisfaction with Device and Services) and OPUS (Quality of Life Index). These are collected at Baseline, 6, 12 and 24 months after Stage 2 surgery. (Appendix C). Gait analysis and range of motion examinations are performed at baseline and 24 months after the second stage surgery. The rehabilitation process after Stage 2 is run conjointly by the prosthetist and physical therapist and follows a strict protocol.

Recommendations and Resources

- To embrace the UCSF MDT protocol and use the professional connections and experience gained to inform and formulate a potential OPRA programme for publicly funded patients in WA.
- Transfer the applicable elements of the UCSF physiotherapy, prosthetic and research protocols as model components to inform a WA based OPRA programme.
- Support and evaluate WA developments through ongoing professional networks generated by this fellowship.
- Interview with Dr. Brånemark explaining history and future visions for OPRA https://www.youtube.com/watch?v=jjS-4v2bWY
- TED talk about the development of neurally connected prostheses being developed by the Brånemark Team https://www.youtube.com/watch?v=V4UQU4392wM

Sahlgrenska University Hospital, Gothenburg, Sweden

Background: Sahlgrenska University Hospital is Europe’s largest hospital providing 2700 emergency and standard healthcare beds for the region of greater Gothenburg (population 700,000). It also provides specialised ampute care for Western Sweden (population 170,000). The Department of Prosthetics and Orthotics is located independently from the hospital in a purpose-built facility which unites orthopaedic technicians, prosthetists and physiotherapists in one building with the ‘Gåskola’ or ‘Walking school” as the central forum for this shared working environment. The centre provides approximately 20,000 outpatient episodes of care annually for the management of upper and lower limb prosthetics, osseointegration rehabilitation and general amputee rehabilitation.

Centre for the Advanced Reconstruction of Extremities at Sahlgrenska University Hospital

Background: The Centre for the Advanced Reconstruction of Extremities (C.A.R.E) is located in the Mölndal Campus of Sahlgrenska Hospital. It has evolved from the Centre of Orthopaedic Osseointegration (COO) pioneered by Dr Rickard Brånemark and is the primary international service for lower and upper limb amputees from around the world. In the absence of Dr Brånemark who is currently seconded to UCSF, the team of surgeons is led by Associate Professor and Senior Consultant Dr Örjan Berlin and Senior Consultant Joakim Strömberg who invited me to attend and observe their specialist OI inpatient unit and weekly clinic.
**Findings:** The dedicated multidisciplinary team from Physiotherapy, Occupational Therapy, Prosthetics and Research have extensive experience in OI, meeting weekly to assess and progress prospective and current osseointegration patients. The specialised C.A.R.E unit has seven beds reserved exclusively for OI patients and has priority use of the operating theatres. This ensures that patients travelling from outside of the area can receive all elements of patient care in a single visit. These include pre-assessment imaging, surgical workups and post-operative care. All members of the C.A.R.E team are committed to collaborative research. The programme has collected nearly 20 years of data on implant characteristics, benefits and efficacy of prostheses, and impact on quality of life. The commitment to relentless appraisal is impressive and provides valuable lessons for the future of a similar programme in WA. Behind the clinical face of C.A.R.E lies equal commitment from:

- Integrum (the company that engineer the implant system design and a world leader in prosthetic and bionic technology based in Gothenburg);
- The Sahlgrenska Academy at Gothenburg University for its research; and
- Sahlgrenska International care unit that supports non-Swedish citizens.

It was exciting to learn from Dr Berlin and Dr Strömberg, the details of the implant system and their assessment protocols. Understanding what to look for and expect in x-rays and scans with regard to progression, or not, of the osseointegration process, is an essential skill that informs future management, appropriate intervention and how the subsequent physiotherapy/rehabilitation should be modified. In a similar fashion to Dr Brånemark’s team assessment at UCSF, every member of the C.A.R.E team outlined their role, intentions for treatment and gave special attention to education on possible complications. These include but are not limited to infections, superficial or deep to the bone, mechanical failure of the abutment screw, loosening of the implant itself and associated pain. Whilst superficial infections are the most common, occurring, on average every couple of years, treatment with oral antibiotics is usually successful and no infections have progressed deeper to the bone to date. Interestingly, implant failure is most common within the first two years - after which the risk reduces [23]. A real highlight of visiting C.A.R.E was observing the MDT clinic and the spectrum of cases reviewed including a:

- A transfemoral patient who had safely and successfully used his prosthesis for over a decade;
- A new multi amputee learning how to don and doff his prosthesis with his remaining hand;
- A transtibial amputee only recently included in the programme.

Learning about the mandatory physiotherapy programme and the specific skills to deliver this was such a valuable experience and spending time with Kerstin Hagberg so inspiring. Kirsten is highly respected as the primary international authority on OPRA physiotherapy, and has been involved with C.A.R.E since its inception, pioneering the physiotherapy loading and rehabilitation protocols. She has devoted her PhD studies to this subject and continues to develop focal evaluation tools to gauge its success. These include the Quality of Life questionnaire for transfemoral Amputees (Q-TFA) now respected as the gold standard assessment tool for this cohort and used extensively around the world [24].

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In Sweden, approximately 3,500 amputations on approximately 2,900 patients occur each year, and as in Australia the major causes are vascular disease and diabetes, with the average amputee aged around 75 years. Prosthetic limbs are taxpayer funded and prosthetists enjoy relative freedom of choice with regard to casting choices, fabrication and component prescription. Similarly, in Australia, hand casting remains the method of choice.

Recently however, the new ‘Modular Casting Method’ from Icelandic prosthetic company, Ossur has been introduced as a quicker alternative for appropriate transtibial amputees and it was fascinating to watch the process applied. This method shortens the traditional timeframe from initial casting to preliminary gait training from a matter of weeks, to a matter of hours. Meaning, for appropriate patients, a single visit can deliver their interim prosthesis, provide all the prosthetic and physiotherapy guidance and instruction required for them to take that limb home at the end of the day. As in Western Australia, many patients are from remote locations and must travel and stay in the city to accommodate their prosthetic rehabilitation. This puts financial strain on patients and families and deters some from continuing with a prosthesis altogether. Whilst the process involves specific equipment, the cost saving benefits to both clinicians and the patient in terms of time, travel and efficiency are clear. Its simplicity and speed of application would make it a practical solution for remote clinics and hospital settings and will generate future discussions with prosthetic providers in WA.
The ‘Gåskola’ or hospital walking school also provides general amputee rehabilitation in a purpose-built gym and multidisciplinary collaboration is integral to the model of care. Clinicians believe rehabilitation should be functional, facilitating transition to the patient's home environment, and rehabilitation methods should promote a strong emphasis on independence and self-management. Floor-based exercises classes and a strong alliance with treating prosthetists is standard practice. A force plate situated in the parallel bars quantifies dynamic partial weightbearing facilitating both the therapist and patient to ‘learn’ how this ‘feels’. All amputees and especially the OPRA patients can then progress safely through the graduated loading phase of rehabilitation ensuring safe reintegration to community living. This is an invaluable tool providing real-time feedback to the patient and therapist and worth considering at SCGH. Physiotherapy sessions are 1:1 and the prosthetists are always on hand to work jointly, hence all aspects of prosthetic gait retraining can be addressed efficiently and in a timely manner. There is a strong belief that peer support is beneficial at this stage, therefore meetings with previous patients are facilitated and encouraged and as buddy system is routine for potential OPRA candidates.

**Recommendation and Resources**

- Replicate the C.A.R.E interdisciplinary approach to inform a coordinated rehabilitation pathway for the care of osseointegration patients in WA.
- Consider implementing force plate technology for both OI and general gait retraining programmes to improve accuracy and safety of treatment and generate research data.
- Introduce discussions around the long-term patient benefits and cost analysis of modular casting systems in rural WA centres.
- Embrace the C.A.R.E physiotherapy and prosthetics collaborative approach toward functional rehabilitation to improve transition between healthcare and community settings.
- Continue the professional networks generated by this fellowship to progress on going physiotherapy skills specific to the OPRA procedure.
**Bräckediakoni Rehabcenter Sfären, Stockholm, Sweden**

*Background*: Sfären is the sister Rehabilitation Centre to Sahlgrenska in Gothenburg. It provides an outpatient service on weekdays and accepts patients on referral from local acute settings, independent prosthetists and GPs. It also provides follow-up for established patients over subsequent years. Whilst the main Hospital is adjacent to Sfären, there are no onsite nursing or medical services however, they can be paged if required.

**Findings**: Unlike at Sahlgrenska, Sfären doesn’t have a prosthetic department and instead enlists the services of four independent providers, Team Olmed, Aktiv Ortopedteknik, Linds Ortopediska and Ortopedia Ortopedteknik. This is similar to SCGH and it was valuable to learn how this was coordinated. Each prosthetic company is allocated specific days and times in the week to attend the centre and patients’ appointments are aligned with these. This scheduling minimised distraction inherent with multiple providers attending simultaneously, improved time efficiency clinically, and simplified appointment bookings and administration. Both the physiotherapists and prosthetists worked together to analyse, intervene and evaluate treatments. The level of mutual respect between the professions was exceptional and all interventions are patient centred, practical and functional.

Equipment and treatment methods employed here were similar to those in Gothenburg, with a strong emphasis on functional floor exercises, dynamic balance and independent mobility. The use of force plate gait analysis equipment is routine for patient feedback and research.

In contrast to Sahlgrenska, the average patient at Sfären is older, frail and with more co morbidities. Prosthetic provision is government funded and the modular socket system is popular with low activity transtibial amputees. Lead physiotherapist Lena Gudmundson, shared her experiences and perspectives concerning increasing amputation rates and the causes of such in the patients seen at
Sfären and in Sweden in general. Lena reported that this cohort have predominantly diabetic and vascular pathology with increasing trends towards more co-morbidities and a younger age. This resonated strongly with me as a similar trend has been emerging at Sir Charles Gairdner Hospital in Australia. Whilst I was in Gothenburg Kirsten Hagberg introduced me to the ‘Swedamp’ National Registry that started in 2010 [25]. This is a National Quality Registry for Amputation and Prostheses across Sweden and Lena generously shared her positive feedback for the scheme. Sfären also collects its own data which is maintained independently. This generated a valuable discussion on the importance, benefits and challenges of research and data collection in clinical practice. This kind of database is unmatched in Australia and the development of such could capture, not just state by state information, but create a clear picture of the true impact of amputation across the nation. This would secure valuable statistics for future advocacy, coordination and planning of advanced care initiatives that could benefit all amputees in Australia.

The National Registry for Amputation and Prostheses (Swedamp)

“The target is to capture information on all amputation procedures on the lower extremities and to monitored them throughout the continuum of care, from surgery and prosthetic fitting, to rehabilitation and follow-up. This has been achieved by collecting and documenting data on: Initial diagnoses, interventions, inpatient care, patient-reported health effects and PROM and other risk factors. Follow-up data has been collected at 3-5 months, 6-11 months and 12 months after initial registration in the Swedamp. Should a new amputation occur on a patient already registered the additional surgery and its’ data is entered as a new entity.” [25]

It was developed to provide a dataset for the evaluation of factors leading to amputation.

- evaluate the patients’ pre and post amputation situation
- capture the incidence, amputation level, position, complications, prosthetic fitting and rehabilitation provided
- Capture a comprehensive perspective of the amputation experience and its consequences, beyond the capacity of an inpatient data registry.

Additionally, it serves to highlight variances in patient care during surgery, prosthetic fitting and rehabilitation based on analysis of treatment frequency and strategy, amputation position, healing level and prosthesis accessibility.

Furthermore, the registry provides:

- data for cost analyses at regional and national levels;
- guidance in the planning and treatment for patients at risk for amputation;
- data for the evaluation of prosthetic fitting and componentry, and rehabilitation; and
- data for feedback and improvement measures throughout the continuum of care.

Recommendations:

- Adopt the theoretical model, aims and objectives of the Swedamp registry to develop a core dataset for amputees receiving care within major WA centres.
- Consider adopting Rehabcenter Sfären’s example of allocating prosthetic time to dovetail with physiotherapy appointments to promote more efficient methods of physiotherapy and prosthetic collaboration.
St David’s Rehabilitation Hospital, Austin, Texas, USA

Background: St. David’s Rehabilitation is a well-funded network of hospital based inpatient physical medicine and outpatient facilities in Central Texas. It provides traditional rehabilitation to amputees from various causes including trauma, vascular and oncology. I was grateful to meet Dr John Latorre himself a transtibial amputee who heads this programme in Austin. His personal experiences provide significant motivation to excel in patient care and this influence is obvious throughout the team. Staffing ratios are generous and a strong multidisciplinary model provides intensive 1:1 therapy inpatient therapy seven days a week.

Findings: Physiotherapy is highly regarded within the MDT and plays a central role in both inpatient and outpatient programmes from attending patient’s medical reviews with the surgeon to providing comprehensive education and treatment across all phases of rehabilitation. I was impressed by the intensity of rehabilitation and its comprehensive treatment modalities. Inpatient care is structured into two stages; acute medical (stage 1) and follow-up gait retraining (stage 2). In stage 1, education and post-operative oedema control are key responsibilities. In contrast to Australia immediate post-operative prostheses, or IPOPs, are standard practice at St David’s and across the US and the assessment and application of such is taught by the physical therapist approximately day 2 post surgery.

The US best practice guidelines recommend the use of IPOPs, citing improved healing, and reduced oedema as the key benefits [14]. Numerous versions exist, and St. David’s provide patients with the ‘Flow Tech’ device. This device can be easily converted to an early mobility aid by the addition of a pylon and foot, enabling limited indoor ambulation for appropriate patients from a week post-surgery. Education and exercises to prevent contractures, improve trunk strength and promote healing are standard, although no specific outcome measures are routinely collected. Occupational therapy and physical therapy collaborate to teach safe transfers and indoor mobility and once safe with the Flow Tech, patients discharge home with a six week follow up appointment. The time frame, from surgery to prosthetic casting is similar to in Australia, with the average being between 8 to 12 weeks for patients without diabetes or vascular compromise.

Once cleared by the surgeon and physical therapist for interim casting, the patient is seen by the prosthetist and admitted for a further two weeks of intensive prosthetic, physical and occupational rehabilitation. This consists of 3 to 5 hours daily of intense therapy with an additional independent gym exercise programme.

I was fortunate to observe seamless teamwork between the occupational, prosthetic and physical therapists who worked collaboratively on initial balance and transfer practice, socket management, residual limb care, and intense gait and functional progression. This interdisciplinary teamwork ensures patients progress quickly, and that potential problems are identified and rectified early. All patients deemed appropriate are also encouraged to use the gym independently to ensure maximum gains can be made within a relatively short admission. Those who do need to extend the length of stay are entitled to do this through most health insurance policies. The initial prosthesis is funded according to the patient’s insurance cover and future entitlements dictated by this. Additional or special activity limbs must be self-funded through fundraising or donation.

As was common in the US facilities visited, every patient’s insurance billing claims and appointments are managed by a case worker. Patient records are electronic, available to access by members of the
MDT at any time. Multimedia technology is standard for visually documenting and evaluating gait analysis and exercise prescription between the patients and the MDT.

Outpatients

The outpatient service is run by senior physical therapist, Dr Kerri Kallus. Patients are referred from the inpatient team or external clinics. Key responsibilities include, continued education for stump care, volume changes and socket fit and progression of gait retraining that will promote strength, balance and independent mobility with minimal aid.

Physical therapy is provided for 2 to 3 hours per week and collaboration with the prosthetists and occupational therapists ensures patients overcome functional deficits with optimal fit and gait patterns. Most insurance policies will allocate approximately 20 sessions however, additional sessions can be sought if warranted. Multidisciplinary team communication was excellent and clinicians share information via the same electronic system utilised by the inpatient team, greatly optimising clinical efficiency in transitioning patients between these phases of care.

The preferred physical therapy techniques and equipment in this outpatient setting have a strong focus on fostering independence with prosthetic donning, doffing and transfers. Gait belts are used for functional exercises to improve stability, balance and to foster an efficient and safe gait pattern. Stretching and flexibility are important, especially in the context of preventing contractures and gait deviations and there is a strong focus on falls prevention and long-term self-management. The well-equipped gym had parallel bars, balance, strength and cardiovascular equipment such as the ‘new step’ cycle with disability access for the less functionally mobile patients.

Images: Nustep disability access bike and Flow Tech IPOP system, St. David's rehabilitation Hospital, Austin, Texas

Weight assisted ambulation is an increasingly respected therapy for gait retraining in lower limb amputees [26] and was Dr Kallus’ most used piece of equipment. Dr Kallus maintains it encourages correct gait pattern with good posture and reduces dependence on upper limb support within parallel bars. It involves the use of a ceiling harness to support patients whilst they walk. This enables those otherwise unable to weight-bear independently or at high risk of falling, to build confidence with more normal walking patterns in a safe way. In amputee’ rehabilitation it is also a valuable tool for progressing patients to optimal loading of the prosthesis avoiding the secondary problems of soft tissue injury and pain elicited from, poor alignment or weight shifting.
Key limitations to successful rehabilitation are perceived to be patient motivation, comorbidity and insurance policy limitations. Standardised outcome measures are utilised in the inpatient phase and incorporate range of motion, strength and functional mobility. At stage 2 of the inpatient stay the Locomotive Capacity Index (LCI) is performed and relayed to the outpatient physiotherapist to be used as their baseline measure of mobility and inform the ongoing treatment plan. Outcome measures are rarely done in outpatients, unless an insurance claim requests clarification of the patient level of mobility.

Recommendations:

- Embrace the use of visual and gait assisted technology to facilitate multidisciplinary assessment, therapy and evaluation of rehab milestones.
- Educate vascular, orthopaedic and rehabilitation teams around the use of IPOPs and EMAs and further investigate cost effectiveness and viability of introducing advanced gait retraining methods as a standard rehabilitation option.

The Center for the Intrepid: The National Armed Forces Physical Rehabilitation Centre
San Antonio, Texas, USA

Background: The Center for the Intrepid (CFI) is a four storey, 65,000 square foot outpatient rehabilitation centre purpose built with donations from over 600,000 Americans and now under the control of the Department of Orthopaedic Rehabilitation at Brooke Army Medical Center. It opened in 2007 to provide state-of-the-art physical, psychological and occupational rehabilitation to US armed forces personnel suffering severe extremity injuries and amputations and to provide them the opportunity to maximize their ability to live and work productively [27]. Restoring optimal autonomous physical and mental function in this cohort is essential for return to active duty, and drives a dedicated interdisciplinary clinical team. Clinicians are mostly Army civilians or active-duty medical staff. Seamless collaboration enables 140-145 patients to receive comprehensive intensive care weekly. It was a privilege to be included in the MDT clinic, to observe the world class clinical expertise, facilities, and treatment methods employed.

Findings: The medical care carried out at CFI is under the direction of the chairman of the Department of Orthopaedics. Recently, the CFI has begun to accept civilian trauma patients from Brooke Army Medical Center where they receive the same entitlements as military patients. The exception to this is prosthetic provision, as the level of clinical expertise and componentry prescribed cannot be matched or maintained by non-military providers post discharge.

All amputees have a full-time case manager who works closely with the patient, their family and all staff at the CFI. They are the initial point of contact for multiple referrals employed to enhance care
and liaise directly with the treating clinicians. They often attend treatment sessions and help to coordinate multidisciplinary care plans, feeding back to the appropriate team members any subsequent issues or solutions to improve the patients’ outcomes.

**Research and Rehabilitation at the CFI**

**The Extremity Trauma and Amputation Centre of Excellence (EACE)**

The EACE vision is to serve as the nation’s premier centre for promoting excellence in the mitigation, treatment, rehabilitation and research that will assist service members and veterans with traumatic extremity injuries and amputations [28]. EACE which was set up at the CFI in 2015 and the Military Performance Laboratory (MPL) is the research facility central to its overarching philosophy. At EACE the four clinical focus areas for development are:

- Advanced Rehabilitation services;
- Medical/Surgical intervention;
- Advanced Prosthetic and Orthotics; and
- Epidemiologic Research.

EACE aims to promote multicentre studies and the development of multidisciplinary protocols to standardise data collection for longitudinal research of specific populations through the integration of both clinical and research teams across multiple rehabilitation centers [28].

The MPL incorporates state of the art equipment to provide motion analysis and collect information about amputee gait that informs the treatment modifications from the physicians, physical therapists and prosthetists that continually improve patient function. It includes a gait lab that tracks joint angles and movement through the use of infrared sensors from 24 different cameras. Force plates within parallel bars, stairs and treadmills can measure three directions of ground reaction force which provides real-time feedback on the rotational forces muscles or prosthetic components are producing. This can then be superimposed on electromyography (EMG) to clarify both intensity and timing and of muscular activity.

The Computer Assisted Rehabilitation Environment (CAREN) is another pivotal tool for the research mission of the CFI. The CAREN houses a 300° wrap around screen within a 21ft canopy that provides a multisensory virtual reality simulation environment. This recreates fully immersed military specific scenarios whilst tracking participants’ physical responses to their environment. Its unique ability to progress the challenge intensity and then advance gait training together with real-time evaluation makes it potentially a very effective treatment method for amputees [29] [30].

Occupational therapy (OT) aims to restore functional health and promote patients’ ability to manage activities of daily living and occupational tasks following injury or illness treatment. The CFI OTs and their technicians play a crucial role in treating and evaluating all upper limb conditions including amputation fracture, nerve injury, and soft tissue injuries. Patients at all stages of recovery attend the purpose-built therapy area and treatment modalities aim to decrease pain, improve joint range of motion, and muscle strength. In addition, OTs specialise in training for myoelectric, microprocessor and bionics technology. These technological advancements have significantly improved upper extremity prosthetic success enabling many upper limb amputees to regain both their independence and return to active duty. A multi-phase rehabilitation protocol is used starting as soon as patients are medically stable. This consists of:
Medical Stability; where considerations for the context of concurrent injury, preinjury, hand dominance, lifestyle interests and social support are crucial.

Pre-prosthetic Stage; where collaborative OT and physical therapy restores optimal upper limb mobility, posture and lower body strength and flexibility through group classes and individual programmes.

Prosthetic Training; where patients learn to use prosthetic devices in progressively functional settings such as the Activities of Daily Living Apartment, a functional training apartment that enables patients to trial everyday skills within a real-world environment. It is used for treatment and evaluation to ensure patients will be able to safely manage specific daily tasks in both a physical and mental capacity.

Community Reintegration; The Community Reintegration Programme co-ordinated by the OTs enables amputee patients to experience a wide variety of activities outside their clinical rehab programme including horse riding, paintball archery, kayaking, and golf. Return to driving of civilian and military vehicles is provided via simulation and real environments.

The Firearms Training simulator (FATS) is a state-of-the-art simulation firing range. It can be adapted to provide numerous virtual realities where patients can regain the physical balance, strength and psychological ability to handle different weapons in a host of combat settings. The opportunity to experience this first hand gave me a unique insight into the physical demands this would present for an amputee! Increasingly complex situations are devised and all but the actual bullets are real with advanced gaming technology able to capture movement control, preparation, execution and recoil. Adaptive strategies and assistive equipment can be incorporated enabling requalification with military weapons systems required to return to service. Retraining can progress onto the use of real firearms in supervised situations, such as hunting trips, as patients’ progress closer to discharge.

Physical Therapy for amputees at the CFI focuses on ability not disability. It provides diagnosis,
treatment and evaluation of physical impairments sustained through trauma and/or illness. Physiotherapy utilises multiple interventions to promote maximum rehabilitation through; amputation awareness and care of the residual limb, wheelchair mobility, strengthening activities and pre-prosthetic rehabilitation focusing on dynamic balance, proprioceptive and endurance training. Gait training using different componentry, and on a variety of surfaces, transitions patient to higher levels of mobility. This training is supported by the adaptive sports programme which provides a multiphase rowing programme, swimming, snow skiing, water skiing, track and field, basketball, volleyball, fencing, archery, shooting, golf, kayaking, and scuba diving. The third floor of the CFI provides access to the specialised climbing tower used by patients wishing to improve agility, strength and aerobic conditioning and a 400m running track. The Natatorium houses the ‘flow rider’; a unique indoor wave pool that promotes balance, confidence, coordination, strength and a six-lane pool for general swimming, pre-running activities, kayaking, water basketball and volleyball.

Behavioural medicine is central to the mission of the CFI. Its goal is to help patients maximise their physical, psychological, emotional and spiritual recovery. Patients identified by family or other staff with coping or behavioural difficulties are referred to the Psychologist Dr Benjamin Kaiser for 1:1 behavioural therapy and comprehensive psychiatric evaluation and support is available to amputees and their families at all stages of recovery and rehabilitation.

Meeting Dr Kaiser was inspiring and informative providing me the unique opportunity to trial some of the approaches and methods of support he provides to patients in his care. In conjunction with the now standardised behavioural and cognitive techniques effective in addressing destructive thought patterns and maladaptive behaviours, Dr Kaiser utilises emerging therapies such as Neuro modulation, with The Alpha-Stim® AID Cranial Electrotherapy Stimulation (CES) system for the treatment of anxiety, insomnia and depression [31]. Biofeedback devices that monitor heart rate variability and breathing rate, believed to be a key variability of physiological resilience and behavioural flexibility are also utilised [30]. Phantom limb pain treatments at the CFI include Graded Motor Imagery, Non-Invasive Electrical Stimulation and Blood Flow Restriction Therapy, that has been shown to enhance muscle size and strength in comparison to normal rehabilitation programmes. [32] The outcome measures he employs include:

- World Health Organization Quality of Life Instruments (WHOQOL-BREF) which is an abbreviated generic Quality of Life Scale developed through the World Health Organization to measure environmental, physical, psychological, and social well-being;
- Insomnia Severity Index (ISI) for sleep related issues;
- Tampa Scale of Kinesiophobia to evaluate the fear of movement; and
- Pain Catastrophizing Scale to gauge pain coping strategies (rumination, magnification, helplessness).

Dr Kaiser has been instrumental in setting up the Performance-Optimization Warrior Enhanced Rehabilitation or POWER programme, developed to identify and support patients with behavioural issues likely to impede their recovery. The POWER programme seeks to empower patients through individual therapy, nutritional, cognitive and fitness evaluation, group support, medication management and family inclusion groups to meet all behavioural health needs. It provides a collaborative and creative solution that recognises the complexity of limb loss and trauma that optimises multidisciplinary care for successful rehabilitation [27].
Under the exceptional lead of John Ferguson, the Prosthetic Department at the CFI utilises a team approach with certified Prosthetists and Orthotists working closely with their technicians. With an entire floor given to state of the art fabrication equipment all artificial limbs are made on site. The science of socket design has always been a major challenge for the prosthetic industry. Despite numerous faster machine assisted methods now available, standard hand casting is still the preferred method, augmented by computer assisted technology for all stages of prosthetic production. Wireless technology needed to adjust upper and lower limb extremity prosthesis remotely are designed onsite, as are unique specialty limbs for sport and other activities that can be fabricated from high-tech materials in combinations of acrylic resin to carbon fibre composite and titanium.

The team here are responsible for the invention of IDEO brace or the ‘Intrepid Dynamic Exoskeleton Orthosis’ which has revolutionised the functional outcomes for those who, due to advances in trauma surgery have avoided amputation but still suffer significant deficits in lower limb function. It is a carbon fibre orthosis that improves planter flexion ‘push off’, ankle stability and agility through its unique energy storage and return capacity that enables the wearer to return to running activities. The IDEO brace return to run programme is fundamental to the POWER programme and one of the CFI’s signature success stories [27]. Rehabilitation outcomes now surpass all that have been previously thought possible. With a large trial participant cohort assured and the MPL gait analysis equipment available to collect data in real time, specialist clinicians can assess and evaluate all prosthetic devices onsite to inform and optimise patient outcomes immediately.

Furthermore, in the case of the IDEO, this has led to similar designs being developed around the world that are providing exciting new opportunities to patients with other lower extremity dysfunctions including partial-foot amputations that are increasingly common in WA.

**MDT**

The amputee multidisciplinary team meets twice a week, prior to a patient clinic and I was fortunate to be invited to witness how this exceptionally resourced team evaluates, plans and delivers treatment and care. As in Australia, each patient due to be seen in the subsequent clinic was discussed by the MDT with medical concerns, therapy progress, goals, and treatment planning covered. Clinicians then transferred to six cubicles in the physical therapy area where patients were seen in tandem. Clinicians deftly rotated to patients individually, collaboratively executing the MDT’s plans. At every stage, the patients’ case worker was on hand to clarify, coordinate and document instructions. This enabled the team to effectively see approximately 15 patients. In contrast, in Australia we would see half that number in the same timeframe. Immediate follow up by orthopaedic and prosthetic teams ensured patients could have prosthetic/limb interface or alignment issues rectified immediately with no delay.
to subsequent physical therapy. An array of complex conditions presented from both military and civilian trauma. Prevailing medical concerns included multiple trauma/amputations, stump revision, neuroma and phantom limb pain all providing valuable learning perspectives.

Neuromas are growths that develop in the residual nerve tissues causing significant pain and disability. In Australia cortisone injection would be the initial treatment of choice but in the US targeted nerve innervation surgery is now common. A 2014 retrospective study undertaken in part at the CFI, found that all but one trial subjects experienced full relief in the transferred area and only one reported developing new neuroma pain post operatively as a result of targeted nerve innervation [33]. Senior Orthopaedic Consultant, Dr Jose Alderete, and Senior Physiatrist Dr Brandon Goff, both specialists in pain medicine, continue to recruit suitable patients to this treatment and were keen to share how successful this method has been.

**Recommendations and Resources:**

- Advocate multidisciplinary collaboration to minimise treatment delays and maintain optimal patient care between all facets of rehabilitation.
- Consider using the CFI MDT clinic format as a template for improving the time and clinical efficiency of the SCGH service and subsequent patient experience.
- Identify ways to involve research in local rehabilitation services and employ strategies to transition international evidence more immediately to clinical practice.
- Short video showcasing the CFI [https://www.youtube.com/watch?v=wJ2QNzioODI](https://www.youtube.com/watch?v=wJ2QNzioODI)

**PACE Rehabilitation Ltd. Manchester UK**

**Background:** PACE was the first independent prosthetic and rehabilitation clinic in the UK to offer patients a single point of access to comprehensive multidisciplinary care. The passionate and dedicated patient centred approach at PACE is outstanding. All clinical fields are represented including prosthetics and orthotics, physiotherapy, podiatry, occupational therapy, psychology and therapeutic services. Close connections are maintained with medical and surgical consultants and contacted as required. The enthusiastic commitment to clinical excellence and collaboration echoed throughout, and I was privileged to experience this highly professional and experienced team in action.

**Findings:** Carolyn Hirons is the lead physiotherapist and an extremely experienced and highly respected amputee specialist clinician. She regularly presents internationally and has been instrumental in developing and contributing to professional development and resources for physiotherapists across the UK. A highlight was learning her advice for gait deviation analysis and her assessment protocol for patients with osseointegrated prostheses. Gait observation is a finite skill requiring attention to several different physical elements simultaneously. It is often beneficial to have two points of observation that can then be compared. Interdisciplinary sessions between physiotherapists and prosthetists are standard at PACE, promoting joint analysis of active gait patterns and their physical and prosthetic properties. Every amputee displays a unique gait pattern in terms of muscle recruitment, timing, force and control which needs to be harnessed to optimise the capabilities of a prosthetic limb. With the focus and expertise on muscle and joint function from a physiotherapist perspective in combination with knowledge of biomechanics and prosthetic alignment from the prosthetists’ view subtle nuances can be picked up and fed back to the patient. I observed this in action with a bilateral above knee amputee using short training prostheses called ‘stubbies’ in order
to build the essential trunk control and thigh strength needed to control and drive full length above
knee prosthetics. Joint assessment identified and rectified both alignment and physical impediments
and collaborative problem solving enabled the patient to master the task at hand. This is an elemental
prerequisite for safe control of microprocessor knee units and these skills from both perspectives will
ensure I can competently implement them with future patients of my own.

MDT collaboration goes beyond the clinic and PACE enjoys working relationships with nearby first-
class sporting and recreation facilities. Patients wishing to trial high end componentry or learn
advanced mobility skills in the community are taken offsite with both the treating physiotherapist and
prosthetist to accompany them. Learning to negotiate different terrains, stairs slopes and
environments is essential to gain optimum control of a prosthesis and requires the patient to actively
drive these skills. Furthermore, a growing body of evidence now supports microprocessor units for
improved safety and quality of life [26]. The use of such units is becoming increasingly popular and has
prompted the NHS to develop prescription protocols. These protocols involve the patient trialling the
componentry before funding is agreed and doubles as a key opportunity for intense physiotherapy
and prosthetic rehabilitation. This approach is not available in WA unless privately funded so the
opportunity to bring these protocols for MPK prescription to Australia was a really satisfying and
productive aspect of my visit to PACE.

A major cohort seen at PACE are individuals who have suffered severe trauma. Counselling plays an
important role within the MDT providing private sessions to help individuals anxious about facing and
recovering from amputation surgery, the stress generated by traumatic events, lowered self-esteem
and emotional perceptions surrounding altered roles and body images. Evidenced based psychological
treatments applied through a behaviour therapy model that involves goal setting and future planning
are Counsellor, Sue Turner’s approach of choice. Additional treatment strategies include
hypnotherapy, eye movement desensitisation (EMD), Cognitive Behavioural Therapy (CBT) and
Neurolinguistic Programming (NLP) to treat a number of secondary problems including panic attack,
depression, anger, mood swings, sleep problems and post-traumatic stress disorders through a patient
centred approach.

The buddy scheme is also unique to PACE rehabilitation and facilitated by Sue. It provides the
opportunity for patients to meet others who have experienced similar trauma. Typically, volunteers
with a similar experience or traumatic event and compatible interests are matched and the buddy’s
role is to be supportive, encouraging and motivating during the journey to recovery.

The prosthetics Department at Pace is autonomous and exceptionally provisioned for full manufacture
of prosthetics on site. All clinicians are afforded full control over their designs, fabrication and patient
interactions through all stages of care. They are an extremely experienced team and liaise directly
with medical consultants and insurance companies for appropriate prescription. A highlight was their
generosity and motivation to share their knowledge in a truly interdisciplinary fashion which has
directly enriched my knowledge and understanding of prosthetic rehabilitation.

**PACE Advanced Programme**

PACE clinicians are particularly skilled in high level amputee rehabilitation and facilitate individuals to
achieve sporting and activity feats that are beyond many in the able-bodied population. The day after
I left, the whole team were heading to Mount Snowdon for the Snowdon challenge where 5 amputees
(one a bilateral) climbed Mt Snowdon in a day. Other trips have seen amputees take on Antarctic
trekking, skiing and kayaking and multiple Paralympians use their services. For those just starting out, one excellent initiative immediately translatable to Australia is a “couch to 5k run/walk programme” which can be joined online by amputees from anywhere in the world. Weekly training programmes and expert advice from the PACE physiotherapy team are provided and regular interaction with other teammates is strongly encouraged. A number of WA based amputees are now registered as a direct result of this fellowship.

**Recommendations**

- Adopt the PACE ethos for collaborative clinical excellence to improve rehabilitation outcomes
- Educate MDT colleagues in the scope of practice and treatment methods being provided by PACE and maintain contacts to augment this.
- Increase focus on rehabilitation outside of the clinic by utilising community based rehabilitation professionals and facilities to generate advanced activity options in the future.
- Consider the PACE buddy programme as a model to inform future WA based programmes.

**Images:** Trialling bionic ankle trial in park at PACE, Manchester, UK

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**The Maltings Mobility Centre, Wolverhampton UK**

**Background:** The Maltings NHS rehabilitation facility for amputees is controlled by The Royal Wolverhampton Trust. The facility is an autonomous outpatient centre providing comprehensive multidisciplinary therapy for amputees referred from within the National Health Service (NHS). Clinical services include specialist physiotherapy, occupational therapy, counselling, prosthetics, orthotics, podiatry, mobility equipment and full-time administrative and clerical services. The physiotherapy gym is equipped with parallel bars, two exercise bikes, a treatment plinth, therapy stairs, and a host of balance, mobility and gait retraining equipment. The patients seen here are lower limb amputees predominantly from vascular and diabetic causes, and are provided with pre-prosthetic assessment and initial prosthetic gait training. Patients are seen 1:1 or in small groups depending on the need. Onsite prosthetic, orthotic and podiatric workshops ensure abrupt casting, fabrication and fitting times and the MDT works together to enable patients to achieve their individual goals.

**Findings:** The Clinical Specialist Physiotherapist for Amputee Rehabilitation here is Louise Tisdale. As the Vice Chair of British Association of Chartered Physiotherapists in Amputee Rehabilitation
(BACPAR), Louise has helped establish the World Confederation for Physiotherapists in amputee rehabilitation group (WCPT), an international professional network that enables learning and sharing of good practice strategies between physiotherapists and other professionals involved in amputee rehabilitation. As a member of this group it was an exceptional opportunity to meet Louise in person and the findings of this fellowship will be shared across this international platform. The 2016 BACPAR best practice guidelines[5] recommend the use of early mobility aides (EMAs) such as Pneumatic Post Amputation Mobility (PPAM) aids in this population for the benefits of enhanced healing, reduced oedema and both physical and psychological recovery. As a valuable assessment tool, these aids assist in predicting the patient’s ability to safely function with a prosthetic limb. In turn, this minimises the unnecessary costs of inappropriate prosthetic prescription. In contrast to Western Australia, the UK deems this as standard practice and it gave me a valuable hands-on opportunity to learn the application and skills required to use these aids with similar patients to my own. It is worth noting that in WA, prosthetic provision is funded largely on theoretical assessment of potential ability and patients cannot ‘try’ a limb beforehand. In reality, the physical and cognitive challenge of using a prosthesis and a transfemoral one in particular, often becomes too much and a substantial number of amputees give up prosthetic use in subsequent years. In WA, facilities where prosthetic provision is off site or in situations where interim casting is delayed, early mobility aids that get patients up and standing would promote multiple systemic health and psychological benefits. In the context of current WA funding protocols, the opportunity to trial prosthetic use, would avoid unnecessary patient stress and empower them to experience the realities, without obligation to prescription. This would provide a viable and cost-effective method for appropriate initial limb prescription.

Louise introduced me to the Multidisciplinary Care Plan (MCP) that is protocol for all patients. It remains within the patients’ medical file and documents the medical and allied health pathway of assessment, treatment and follow-up starting from first admission to the Maltings Mobility Centre and extends to long-term rehabilitation outcomes up to two years later. This record of patient data is a valuable tool for team communication and the evaluation of both service provision and patient outcomes that assist in quality improvements.

The scope of physiotherapy at the Maltings extends to community care and I was privileged to attend
two home visits with Louise and Sue Hayes (OT). These aimed to assess and educate patients, their families and carers in managing their amputation and prosthetic use in the community. All aspects of these visits are recorded in patient’s MCP. Such visits provided insights into the unique needs of older amputees living in the community that can be transferred back to WA.

Within the NHS, physiotherapists with appropriate extended scope practice training can legally prescribe certain medications. In the amputee population, this includes medications frequently used for PLP, nerve and musculoskeletal pain, and skin disorders associated with socket irritation. This is not, within the scope of practice for Australian physiotherapists and it was excellent to observe the positive impact on patients through the immediacy and efficiency of care that this service provides. The amputee rehabilitation physiotherapist tends to see patients more frequently than other health providers making them well placed to observe and monitor medication compliance, pain frequency, intensity, and its impact on quality of life. Louise has been instrumental in initiating this shift in responsibility and the opportunity to discuss with her how this change in the NHS health policy is providing real benefit to patients was an excellent learning experience.

Recommendations and Resources:

- Advocate early mobility aids for appropriate patients, to promote both the psychological and physical benefits of early standing mobility and reduce time spent sedentary or immobilised in the pre-prosthetic phase.
- Investigate the cost effectiveness of using EMAs for assessment of prosthetic potential and as a method of reducing unnecessary prosthetic costs and educate stakeholders in advantages to enhance patient quality of life and rehabilitation outcomes.
- Open discussions with the SCGH amputee rehabilitation team about the benefits versus practicalities of developing a multidisciplinary care plan to provide a central hardcopy document for MDT clinicians to record, liaise and review patient progression across all facets of rehabilitation.

St. Mary’s Hospital, Roehampton UK

Background: Amputee rehabilitation has been an established service at Queen Mary’s Hospital, Roehampton for over one hundred years. The first service of its kind, it was founded by Mary Eleanor Gwynne Halford in 1915 whose vision was to promote access to the most scientifically advanced rehabilitation and prosthetic limbs possible for those suffering limb loss as a result of World War I. In 2006, the clinic relocated to a new hospital within the same grounds and now incorporates the acclaimed Douglas Bader Rehabilitation Centre, named after Douglas Bader, the RAF pilot who lost both his legs in World War 2 which continues to provide a specialised and multidisciplinary service to amputees from south west London extending to the borders of Surrey and Sussex.
Findings: My hosts at St. Mary’s Roehampton were Sara Smith and Maggie Walker, both exceptionally experienced specialist physiotherapists in amputee rehabilitation. Sara has been a leading contributor to the development, and implementation of the BACPAR guidelines, the internationally considered gold standard practice for amputee physiotherapy management. Maggie is a leading authority on the osseointegration procedure in the UK having facilitated the physiotherapy protocol for the first UK OPRA system pilot trial implemented within the NHS in 2003 and still being evaluated today.

Sara provided my initial orientation to the excellent facilities that include a spacious physiotherapy gym where intense rehabilitation is provided for four hours daily, five days a week, the purpose-built prosthetic department that provides all onsite casting, fabrication and modification for interim prosthetics and orthotics; and the Gwynne Halford inpatient ward where patients can stay during their initial prosthetic rehabilitation. Additional clinic and private consultation rooms for medical reviews are also available.

A multidisciplinary model of care is central and the team is extremely well resourced with:

- Five physiotherapists;
- One rehabilitation assistant;
- Nine prosthetists/orthotists;
- Two rehabilitation consultants;
- Clinical psychology;
- Dietetics; and
- Occupational therapy

A generous donation bequeathed by a patient has recently been used to employ a research scientist. This role audits patient-therapist time as well as assessing patient expectations of therapy and how these can be best addressed to achieve optimal outcomes.

Patients undergo surgery and their initial pre-prosthetic rehabilitation before arriving at St. Mary’s. Initially they will attend physiotherapy for a maximum of 49 days as an inpatient but in certain circumstances can extend this to ninety days of care. Sara explained in depth the structured referral pathways, outcome measures and treatment paths employed providing valuable comparisons to our own service in WA. At St Mary’s patients attend intense 1:1 physiotherapy between 10am and 2pm.
each day with additional group sessions. Those not yet mobilising begin on EMAs and those with prior experience are appropriately progressed to prosthetics. Prosthetic prescription, fabrication and evaluation are onsite and full interdisciplinary teamwork is standard policy. The multi-disciplinary clinic appointments run for 45 minutes and in a similar format to SCGH. Each patient at Roehampton is assessed for prosthetic potential by the whole team with all disciplines recording baseline situation, goals of rehabilitation and treatment recommendations. A key quality of care policy is that once a patient is deemed appropriate for prosthetic casting this must occur within one week and, that subsequent rehabilitation must then begin within another week. In contrast to WA, the Roehampton team have fostered extensive clinical networks with community based providers and in particular the centre enjoys excellent relationships with local GPs. This has promoted collaborative management strategies that ensure continuity of two-way specialist care extending into and out of the community after discharge.

Images: The Physiotherapy Gym at St. Mary’s Hospital, Roehampton, London, UK

The equipment in the physiotherapy gym is standard with four sets of parallel bars, cardiovascular bikes, balance and strength equipment, treatment plinths and gait retraining equipment. As per BACPAR guidelines, rehabilitation begins with assessment and treatment with an early mobility aids such as a PPAM aid for below knee amputees or the ‘Femurett’ for above knee. This is progressed with a strong focus on functional independence and patients are routinely taught how to manage a fall, and how to transfer back up from the floor. Standardised outcome measures are incorporated throughout rehabilitation process and chosen as appropriate to the patient. The BACPAR outcome measures toolbox is the preferred guideline and contains several evaluation tools validated for use with the amputee population. [34]

For advanced rehabilitation, there is a purpose-built therapy garden incorporating different surfaces, gradients and cambers to promote proficient wheelchair mobility and develop community level balance and walking skills. The Douglas Bader Gymnasium is staffed by qualified fitness instructors and available to patients independently of their hospital based rehabilitation. Regular education sessions are held in the physiotherapy gym and focus on topics such as falls prevention, PLP and medication compliance. Self-management strategies are the central lesson and a comprehensive algorithm for the diagnosis and management of post amputation pain developed by the team at Roehampton and is now widely followed across the UK (Appendix D).

The osseointegration experience in the UK

In collaboration with the Swedish team led by Rickard Brånemark and Kerstin Hagberg, Maggie Walker has been a leading authority and treating physiotherapist for the 2003 UK NHS pilot trial of the OPRA
procedure [35]. This trial involved the recruitment of public funded NHS transfemoral amputees selected as suitable to undergo osseointegration under the medical consultancy of the now semi-retired Dr Sellaiah Soori. Patients have been followed up as dictated by the Swedish protocol (Appendix B) for almost 20 years. This robust picture of the long-term outcomes, challenges and benefits of this rapidly emerging procedure provides valuable insights into the benefits and barriers encountered. Discussing these issues with the key clinicians involved throughout the trial was a highlight of the fellowship and has given me an excellent perspective on the types of multidisciplinary and physiotherapy specific guidelines and protocols that should be considered for a similar programme at SCGH. As these protocols have already proven to be safe and effective within a comparable healthcare system, the NHS trial can be instrumental in informing future treatment of patients in WA.

My disappointment at missing a visit to the Ossur Academy in Orlando, Florida, was rectified by a chance opportunity to attend a course Ossur were hosting at Roehampton during my visit. This was a fantastic course on the ‘Rheo Knee” with presentations from prosthetists and physiotherapists that included patient demonstrations and a practical learning. Learning first-hand, the capabilities and limitations of this componentry and how to facilitate patients to gain the most benefit from them was very useful as these advanced units are now becoming more available to the general amputee population. Whilst these units are not usually covered by the West Australian Limb Service for Amputees (WALSA) funding, in 2016 the prescription of microprocessor componentry was endorsed by the NHS after a review of evidence revealed the heightened stability, safety and quality of life benefits they provide to lower mobility amputees at higher risks of falling. This is an exciting positive shift in policy from within a comparable health system to our own that may encourage similar progression in WA.

**Recommendations**

- Adopt the Roehampton OPRA trial protocols as valid guidelines for the development of a rehabilitation pathway for public funded osseointegration patients in WA.
- Expand this by using the Roehampton protocols to assist with developing educational resources to upskill multidisciplinary clinicians in this new area of amputee rehabilitation
- Utilise the Roehampton pain pathway to create a unified approach between the SCGH Pain and Amputee clinical teams for capturing the prevalence and presentation of amputee pain more accurately and enhance safe management.

**Reviews of Prosthetic Companies visited**

**Fillauer, Stockholm, Sweden**

**Background:** My host in Stockholm was Kevin Moore, the president and managing director of Fillauer Europe. Fillauer began trading as a family business in Tennessee in 1914. Initially known as Red Star pharmacy it evolved into Fillauer orthopaedic in 1934 and continues to lead prosthetic and orthotic innovation globally.

**Findings:** I was fortunate to receive a tour of the new fabrication facilities to see how the cosmetic covers for both upper and lower limbs are produced and was amazed to see each cover is made by hand. Fillauer prides itself on being a family business owned and run by prosthetists themselves. This provides a unique opportunity for the immediate trial and development of new ideas and there is an obvious depth of knowledge and expertise that is impossible to match by bulk manufacturing...
methods. The company also collaborates with leading hospitals in Sweden to develop advanced machinery used in the fabrication of prosthetic items, actively supports research and has created the revolutionary dynamic walk orthosis for individuals suffering foot drop. Observing the Fillauer workshop gave a deeper understanding of the fabrication process, the skill involved, and the value of a personalised approach to the manufacture of cosmetic accessories and components of prosthetic limbs.

![Images: Brass moulds for making synthetic covers and dynamic ankle foot orthoses at Fillauer-Stockholm, Sweden](image1)

Fillauer enjoys a close working relationship with the major hospitals in Stockholm and very kindly arranged my visit to Sfären Rehabcenter on the same day, which is documented earlier in this report.

**Ottobock US Headquarters, Austin, Texas, USA**

**Background:** The new headquarters in Austin Texas is extremely impressive and is now the central administrative centre for all US services. A tour of the state of the art building introduced me to the company history. Ottobock was founded in 1919 by a German prosthetist called Otto Bock in response to the need for prosthetic componentry created by casualties from World War I. Prosthetic design advanced from wooden limbs to man-made materials when the company developed synthetic foam. This invention generated a number of different manufacturing lines that have since made Ottobock a multifaceted world leader in foams for medical use, the automotive and upholstery industries to the most recent innovations leading the orthotics and prosthetics field.

It was a pleasure to spend two days with the Director of Professional and Clinical Services for Ottobock USA, Mark Edwards who introduced me to the team and explained his role and connections to local clinical services associated with Ottobock in the Austin area.

**Findings:** One of Mark’s key objectives is to promote clinical and technical support through training and education for Certified Prosthetist Orthotists (CPOs) and other health providers working in this field. This is done through regular webinars, online training and hands on workshops. He is also available to all clinicians for advice and one-to-one training with specific prosthetic/orthotic systems. The structure of the current US health system has created numerous challenges for the process of preparing prescription claims and I was privileged to sit in on a webinar Mark presented to assist CPOs with this process. Ottobock continues to lead progressions in prosthetic technology and I was fascinated to be shown a number of new designs pending market release. Inter-professional development and learning is another prime focus in Ottobock’s vision for the future and I was grateful to be given access to new clinical training programmes including the latest casting and fitting methods,
and advances in suspension systems and componentry. Australia lags behind in these areas so this gave me fantastic insight into the future of prosthetic availability and the kind of rehabilitation methods we need to advocate for in WA.

Images: Ottobock’s New Adjustable and Flexible Transfemoral Socket Prototype

With the first OPRA programme now running at UCSF, I was interested to learn Ottobock is the only FDA approved provider in the US of the crucial connector component. This is vital for the attachment of a prosthetic limb to the abutment of the bone implant and currently a disputed area for funding in Australia. This progression may be useful to the future OPRA programme in WA.

Unfortunately, there are no clinical services at the HQ in Austin. I was, however, invited to visit two clinical facilities, one run by competitor prosthetic company Hanger and the other, St David’s Rehabilitation Hospital in Austin (covered earlier in this report). Hanger is one of the largest and long-term providers of clinical services in the US and it was interesting to visit one of their patient clinics.

These clinics are run autonomously from other amputee rehabilitation disciplines with a primary focus on casting, fabrication and fitting. Collaboration with physiotherapists or, rehabilitation consultants is rare thus most clients are independent and high functioning. Patients are usually surgeon referred and follow-up dictated by insurance cover. The laser casting technique is preferred for below knee sockets due to the ease and speed in which they can be made; however, more complex and labour-intensive methods are also used. The on-site training room is well equipped and all fabrication and modifications are done here. Interestingly one of the lead CPOs is herself a congenital above-knee amputee and hearing her personal experience and how it has influenced her work was fascinating and inspiring.

Recommendations

- Promote MDT knowledge and skills advancement by disseminating Ottobock educational resources through TRACS WA knowledge hub platforms, proposed webinars and rural workshop forums.
- Embrace the sharing of video gait analysis, pressure plate analysis and microprocessor
technologies to expand interdisciplinary collaboration between physiotherapy and the prosthetic industry both in training and in the clinical setting.

- Advocate for instigation of trial prosthetic components such as MPKs in public hospital facilities to streamline appropriate and cost-effective strategies of prosthetic prescription.

**ABC Prosthetics and Orthotics, Orlando, Florida, USA**

**Background:** Unfortunately, I wasn’t able to visit the Ossur Academy in Orlando, Florida, due to unplanned construction work so a visit to ABC Prosthetics and Orthotics was offered as a substitute. This is a small independent company founded in 1998 with two locations in Florida incorporating both upper and lower extremity prosthetics, custom made orthotics and ‘Pawsitive Prosthetics’ which provides artificial limbs to animals.

The sole prosthetist at ABC was in her residency year and worked autonomously in her clinical role under the mentorship of the practice owner. The ABC referral network includes local hospitals, outpatient clinics, nursing homes, and in-home care providers, with patients from all backgrounds and stages of rehab eligible according to their insurance cover. Hand casting is the preferred method and without a technician on site all aspects of socket fabrication, modification and delivery are the prosthetist’s responsibility.

There is no protocol for applying outcome measures and instead decisions are made on a patient’s needs basis. A patient centred approach was clear and efforts to minimise the financial burden were resourceful. The standard protocol of allowing patients to trial accessories and componentry before final prescription minimises stock wastage and again all assessment, documentation and gait analysis is technologically based. In contrast to Australia, a trend towards 3-D printing in the healthcare arena is now commonplace in the US and is utilised to fabricate trial singular designs, small accessory components and custom-made orthoses. This enables rapid temporary modifications that patients can trial safely before submitting their funding application. ‘Pawsitive Prosthetics’ provides animal services and it was fun to observe the fitting and trial of a prosthesis for Hannah, a nine-month old pitbull terrier with a front leg amputation. The prosthetic design was ingenious providing a low-cost socket attached to a basketball ‘foot’ and it was a great experience to be invited to participate in Hannah’s first trial on her new limb.

**Recommendation:**

- Embrace the concept of trialling prosthetic componentry to minimise unnecessary prescription costs and inefficient use of prosthetists’ professional time.

**Blatchford, Crystal Palace, UK**

**Background:** Founded in 1890 as Chas. A. Blatchford & Sons Ltd, Blatchford’s is the oldest prosthetic provider in the UK. It became internationally famous for its ‘Blatchford Stabilised Knee’ and is the most extensive prosthetic innovator in the UK. It provides clinical services to the NHS, the British Military and private clinics and plays a significant role in research and professional development. During my fellowship, the opportunity presented to meet Principal Prosthetist & Commercial Manager, John Ross and tour the Lambeth Community Rehabilitation Centre and Bowley Close Clinic.
Findings: Lambeth Community Rehabilitation Centre Amputee Rehabilitation Unit (ARU) is an award-winning, 12-bed purpose built specialist centre that provides amputee inpatient rehabilitation centre for vascular patients from Guys and St Thomas Hospitals. It provides specialist multidisciplinary care seven days a week and seamless access to personalised prosthetic limb services. The opportunity to view a modern purpose built facility for the mainly vascular/diabetic cohort provided an excellent comparison to SCGH. Whilst there is no prosthetic department on site, CPOs visit daily and patients receive up to two to three physiotherapy/occupational therapy sessions per day, each lasting one to two hours. Overall length of stay is usually six weeks but can be accelerated to four if the patient has already started training on an early mobility aid or been prescribed with their interim prosthesis. In contrast to Australia, an open wound policy means medical clearance to cast over a wound from day 10 post operatively. Active healing must be evident however, and the patient receives specific and aggressive wound management. In addition, the centre employs a discharge coordinator responsible for facilitating community reintegration following successful rehabilitation.

There is usually a full MDT at the Crystal Palace Limb Centre although not all were present at the time of my visit. The clinic provides medical consultants, prosthetists/orthotists, physiotherapists, OT’s, psychology, and podiatry. It also caters for separate male and female fitting rooms, and provides patient specific care from traditional aluminium to modern socket design. A wonderful aspect of this rehabilitation unit was the therapy garden and the policy of having all patients be out of bed, appropriately dressed in every day attire and actively engaged in daily activities such as meals and socialising - a stark contrast to hospital inpatient settings in Australia.

Blatchford remains at the forefront of prosthetic research. Current projects underway include the development of an elevated vacuum socket with hydraulic pump that drains sweat and maintains vacuum in each step and pressure sensing sockets that feedback into smartphone receivers similar to those being trialled in Miami. My day with John was very informative and will continue to promote professional collaboration that will be shared with colleagues in Australia.

Research Centres Visited

The University of Texas; Cockrell School of Engineering, Austin, Texas, USA

Background: The Cockrell School of Engineering at the University of Texas was founded in 1882 and conducts research informing the areas of human health, sustainability and energy. Chair and Head of Department of the Mechanical Engineering Department, Dr Rick Neptune is internationally lauded for his considerable contribution to expanding the understanding of biomechanical and neuromotor control in human movement. His particular interest is in the unique nuances of amputee gait underpinning advanced prosthetic foot and socket designs. Effective rehabilitation techniques must reflect the fact that the energy costs and biomechanical loads placed on the musculoskeletal system are inherently higher for those with limb loss than for those without. Gait deviations can impede recovery, rehabilitation and prosthetic success. Understanding the causal relationships between the mechanical properties of the prosthesis and dynamic human kinesiology is integral to research programmes visited at the University of Texas.

Findings: As a physiotherapist, understanding the mainspring of gait deviation is core to effective rehabilitation outcomes, however, unless you live with limb loss, it is impossible to truly understand the reality of walking with a prosthesis. To increase understanding, Dr Neptune and his team use
dynamic computer simulation and experimental analysis techniques to create complex musculoskeletal models that can compare and analyse theoretical relationships between normal and deviant movement patterns.

In the 1980s, the invention of the selective laser sintering technology (SLS) was achieved at the University of Texas and has generated a new method of producing prototype prosthetic and orthotic models for the purpose of research in this population. I was fascinated and fortunate to be given a tour of the workshop, the machine itself and learn about its many applications. The postgraduate students at the faculty kindly presented their current projects and explained how influential this SLS process has become in the prosthetic research area.

Images: Prototype prosthetic limb (socket and foot) created with Selective laser sintering 3D Printer centre at School of Cockrell Engineering at the University of Texas

The ReNeu and Rewire Engineering Laboratories

Visiting these two subspecialty laboratories introduced me to rehabilitation robotics and whilst this lies outside my scope of practice it was a great opportunity to learn more about the cutting-edge developments in this fast expanding health field. Rehabilitative robots aim to augment clinical practice in neuro-rehabilitation fields and the robotic designs here are focused on advancing upper limb functionality. It was fascinating to learn about exoskeletons that are revolutionising bidirectional assessment and treatment techniques and prosthetic hands that can replicate fine motor control to match a human. In the Rewire lab, advances in the neuro feedback arena aim to expand knowledge of the potential therapeutic benefits created through virtual reality mediums and practical methods to apply them in the context of futuristic prosthetic limbs.

A highlight of visiting the Rewire lab was the invitation to try out the dual treadmill. This has two moving belts, one under each foot which can provide force plate analysis and be set to different
speeds. This is connected to state-of-the-art gait analysis equipment, and from a research perspective creates a unique opportunity to analyse, induce and modify both normal and pathological gait patterns. For example, in deviant gait patterns where timing is asymmetrical, the differences between left and right limb belt speeds can be firstly, accommodated safely, and secondly, manipulated for therapeutic effect. Conversely, in normal subjects, a symmetrical gait pattern can be disrupted to induce gait deviations and the compensatory movement patterns adopted by the user then analysed. This was an excellent way to experience the sensation of an enforced gait deviation as may be similar to those experienced by amputees. It gave me a great appreciation for challenges that my patients may face and enriched my understanding of human gait.

Images: Dual belt treadmill for inducing gait deviation and Robotic hand technology demonstrating fine sensory and motor control at School of Cockrell Engineering at the University of Texas

**Recommendations and resources**

- Embrace evidence emerging from current University of Texas research to inform multidisciplinary clinical practice where applicable.
- Utilise information and contacts gained from the University of Texas to expand a knowledge bank of contemporary research project links and share through the TRACS WA network.
- Rick Neptune Research at [http://www.me.utexas.edu/~neptune/research.php](http://www.me.utexas.edu/~neptune/research.php)

**The University of Miami and the F.O.R.E. Centre, Miami, Florida, USA**

**Background:** Dr Gailey has been at the forefront of amputee rehabilitation and research for more than 30 years within the Department of Physical Therapy at the University of Miami’s Miller School of Medicine. He is an international authority on prosthetic gait retraining and author of gold standard outcome measures “the Amputee Mobility Predictor” (AmpPro) and the “Comprehensive Mobility Predictor” (CHAMP). He is also affiliated with the Veteran Affairs Medical Center as a Research Scientist and the Director of the ‘Functional Outcomes research and Evaluation Centre’ also at the University of Miami.

It was an inspiring meeting and our discussion centred on historical progressions in amputee prosthetic and physical rehabilitation with his perceptions and advice for the future. Traditionally these two professions have remained separate despite the obvious common goal of optimal patient outcomes. Having gained a PhD in Prosthetics and Orthotics early in his career he has been uniquely placed to tackle this divide and credits much of his success to this vantage point.
Findings: Dr Gailey explained his tireless drive to unite clinicians from both sides within the rehabilitation and research settings. In his experience, approximately 90% of gait deviations assumed to be the fault of the prosthesis are in fact, induced by poor physical training and that through collaboration from both the prosthetist and physical therapist improved outcomes are possible. This echoes the opinions of other teams I visited and will be a major lesson to bring back to Australia.

Over recent years health professions have recognised the need to extend their scope of practice, two examples being nursing and physiotherapy and in Dr Gailey’s opinion the prosthetics profession should join them. The development of subspecialty streams of practice within the two professions in the US has already been proposed but has not been embraced by the prosthetics profession. Two excellent examples he used to explain the potential benefits and implications were firstly, the current US government stipulation that prosthetic prescriptions for MPK units will have prior endorsement by a physiotherapist which must be lodged before acceptance and payment of the claim. Secondly, the emerging popularity of osseointegration surgery may leave prosthetists facing deskilling in socket fabrication and volume of business. Whilst neither of these would directly threaten Australian services it was an excellent discussion.

Presenting my fellowship to Dr Gailey, his research students and the wider faculty within the University’s Department of Physical Therapy generated interesting discussion around barriers and enablers to successful rehabilitation. The issues of access to prosthetic technology, bureaucracy of funding systems and the inconsistencies in multidisciplinary care were highlighted in this discussion.

The Functional Outcomes Research and Evaluation Centre (F.O.R.E.) houses current amputee specific research projects. This unique facility provides collaboration between specialists from the Departments of Musical Engineering, Physical Therapy and Technology. The centre boasts state of the art gait analysis equipment, 3D printing technology and advanced computer software. These are being used to devise novel gait retraining strategies through wearable movement sensors (custom printed) that detect the user’s walking pattern. They detect when a gait deviation occurs that could increase the risk of pressure ulcers or fatigue and communicates this to the user by either enhancing or distorting the music they are listening to! This ingenious invention can be used anywhere and data collected by the sensors can be downloaded via Bluetooth technology. This trial is sponsored by Ossur and Dr Gailey explained some unforeseen benefits that are arising from this trial. Specifically, data gathered so far is also revealing unexpected correlations between deviation patterns and patient physical characteristics which could in the future help to predict the risk of specific deviations in certain patient cohorts.

Finally, I was introduced to the researchers involved in the 2016 project, The Mobile Device Outs-based Rehabilitation Program (MDORP) incorporating the Rehabilitative Lower Limb Orthopedic Accommodating-feedback Device (ReLOAD) [36], This uses special insoles sensors to record the users’ movement and gait pattern. Information can be gathered from patients anywhere, fed back to a central server and the data collected stored and analysed thus avoiding the need for supervised assessments. This project being funded through the US Department of Defence and Veteran Affairs will provide unique gait training methods for users in remote areas.
Recommendations and resources

- Embrace multimedia software technology as an essential contemporary means for assessment therapeutic intervention and evaluation.
- Advocate for joint educational and clinical and research professional training between prosthetic and physiotherapy professions.
- The F.O.R.E Center website can be accessed here [http://fore.miami.edu/](http://fore.miami.edu/).

**Chalmers University of Technology, Gothenburg Sweden**

**Background:** Dr Max Ortiz-Catalan founded the Biomechatronics and Neurorehabilitation Laboratory at Chalmers University of Technology in Gothenburg, and is Associate Professor for Biomedical Signals and Systems. He has been at the forefront of the ‘Osseointegration Human Machine Gateway’ (OHMG) Trial that is in partnership with the C.A.R.E team at Sahlgrenska University. This is creating direct bone, nerve and muscle connections that enable neural messages from the patient’s nervous system to travel directly to their prosthetic limb via the osseointegrated bone anchored implant used in the OPRA procedure. Dr Rickard Brånemark led the world’s first surgery of this kind in Sweden in January 2013 where neuromuscular Brånemark led the world’s first surgery of this kind in Sweden in January 2013 where neuromuscular electrodes were permanently implanted in an upper limb amputee and 3 years later it continues to provide improved accuracy, precision and energy efficient movement control. This technique is now being offered as a realistic treatment progression for patients undergoing upper limb osseointegration surgery under Dr Brånemark in the UCSF trial in San Francisco. Having witnessed Dr Brånemark discussing this with potential patients during my visit to UCSF it was fascinating to be able to revisit this topic with Dr Catalan, meet the Swedish research team involved, and learn his perspective. A short video is accessible from the recommendations and resources section below.

**Findings:** Dr Ortiz-Catalan has also been at the forefront of research into Phantom Limb Pain (PLP) and is currently running the international multi-site Neuromotus trial. This non-invasive technique employs principles from neural plasticity and myoelectric pattern recognition to detect and decode muscle activity in a patients’ residual limb. It is directed at chronic PLP sufferers who have failed to gain meaningful relief from other conservative and medical treatments and is one of the first treatment methods to be appropriate for both unilateral and bilateral/ multiple amputees. Patients are directed to interact with their phantom pain in a relieving way, a process he calls *Phantom Motor Execution*. This is translated via the ‘BioPatRec’ software platform [37] to a screen in the form of an augmented virtual reality. Whilst traditional PLP treatments have largely been passive in nature and heavily weighted to using visual trickery to create illusions of a restored limb, Neuromotus engages both motor and sensory input in engaging tasks driven and controlled actively by the patient.

I was extremely fortunate to experience in detail how the Neuromotus device works first-hand. Observing a treatment session with a long-term participant from the initial trial (they are now onto stage two) followed by the opportunity to use it myself gave me a wonderful patient perspective and insights into how engaging and motivating the therapy activities are.
14 patients with intractable chronic phantom limb pain, for whom conventional treatments failed, were enrolled. Patients received 12 sessions of phantom motor execution using machine learning, augmented and virtual reality, and serious gaming. Changes in intensity, frequency, duration, quality, and intrusion of phantom limb pain were assessed by the use of the numeric rating scale, the pain rating index, the weighted pain distribution scale, and a study-specific frequency scale before each session and at follow-up interviews 1, 3, and 6 months after the last session. Changes in medication and prostheses were also monitored.

The results were extremely promising with PLP reduced 47%, intrusion of phantom limb pain in activities of daily living and sleep was reduced by 43%, and significant reductions in medications needed. Improvements remained 6 months after the last treatment. [19]

The Neuromotus trial began in 2014 and the following is taken from the abstract:

“14 patients with intractable chronic phantom limb pain, for whom conventional treatments failed, were enrolled. Patients received 12 sessions of phantom motor execution using machine learning, augmented and virtual reality, and serious gaming. Changes in intensity, frequency, duration, quality, and intrusion of phantom limb pain were assessed by the use of the numeric rating scale, the pain rating index, the weighted pain distribution scale, and a study-specific frequency scale before each session and at follow-up interviews 1, 3, and 6 months after the last session. Changes in medication and prostheses were also monitored.’ The results were extremely promising with PLP reduced 47%, intrusion of phantom limb pain in activities of daily living and sleep was reduced by 43%, and significant reductions in medications needed. Improvements remained 6 months after the last treatment.” [19]

It was then arranged for me to visit Orebro University on my way to Stockholm and observe a trial session for a lower limb amputee. This gave me an excellent opportunity to learn the lower limb protocol, how the electrodes must be set up and provided another chance to see the programme in action.

The second phase of this project is now underway as an international multisite trial made possible by the generosity of Dr Catalan in providing the ‘BioPatRec’ software platform as open access. This will generate an international dataset and boost our understanding of PLP prevalence, characteristics and response to this novel treatment. Long-term, this may provide a cost effective conservative treatment that would directly lessen the burden of PLP and potentially reduce the long-term reliance on prescription pain relief in this population. An absolute highlight of this visit was Dr Ortiz-Catalan’s generosity in providing me with a Neuromotus Unit to bring back to Australia and with ongoing support from his team in Sweden and the SCGH Amputee Clinic, this fellowship will result directly in this treatment becoming available to patients within SCGH. Should this trial be successful future collaboration with both the SCGH pain team and other WA hospitals will be explored.
Recommendations and Resources

- Ensure dissemination of Neuromotus trial, patient selection criteria, the expected benefits, and protocols for use across clinical networks in WA.
- Expand this to develop multi team involvement with appropriate education and skills advancement for physiotherapy, pain, neurological and amputee specialty teams in the near future.
- Implement ‘BioPatRec’ software platform at SCGH and introduce the Neuromotus treatment within SCGH Amputee service on appropriate and informed patients.
- Replicate current trial protocol so that data collected can be used to compare and contribute to the international database being developed through the multi-site trial.
- Continue to collaborate with Dr Ortiz Catalan and his extended team to ensure maximum support for the initiation of an Australian Neuromotus programme and to stay informed of progressions in osseointegrated neurally controlled prosthetics.

http://www.thelancet.com/cms/attachment/2088307802/2074917737/mmc2.mp4
Consolidated list of recommendations

Clinical Focus

- Embrace the UCSF iCORES MDT pathway for OI rehabilitation and use the professional connections and experience gained to inform and secure a potential OPRA programme for publicly funded patients in WA.
- Transfer the applicable elements of the UCSF physiotherapy, prosthetic and research protocols as model components to inform a WA based OPRA programme.
- Combine the C.A.R.E and I CORES interdisciplinary clinical standards into a model to inform a coordinated rehabilitation pathway for the care of osseointegration patients in WA.
- Embrace the C.A.R.E physiotherapy and prosthetics collaborative approach toward functional rehabilitation to improve transition between healthcare and community settings.
- Investigate the cost effectiveness of using IPOPs and EMAs for the assessment of prosthetic potential and as a method of reducing unnecessary prosthetic costs.
- Advocate early mobility aids for appropriate patients, to promote both the psychological and physical benefits of early standing and mobility and reduce time spent immobilised and sedentary in the pre-prosthetic phase.
- Educate all WA amputee rehabilitation stakeholders in the potential enhancements to patient quality of life and rehabilitation outcomes that IPOPs and EMAs provide.
- Advocate multidisciplinary collaboration to minimise treatment delays and maintain optimal patient care between all facets of rehabilitation. Ensure all stakeholders from both public and private care sectors are educated and proactive in following collaborative care guidelines.
- Consider using the CFI MDT clinic format as a template for improving the time and clinical efficiency of the SCGH service and subsequent patient experience.
- Adopt the PACE Rehabilitation teams’ ethos for collaborative clinical excellence that ensures optimal rehabilitation outcomes. Educate MDT colleagues in the scope of practice and treatment methods being provided by PACE.
- Increase focus on rehabilitation outside of the clinic by utilising community based rehabilitation professionals and facilities to generate advanced activity options in the future.
- Consider using the buddy programme examples from PACE, Sweden and St. Mary's Roehampton as templates to inform future WA based programmes.
- Open discussions with current SCGH amputee rehabilitation team about the benefits versus practicalities of developing a multidisciplinary care plan to provide a central hardcopy document for MDT clinicians to record, liaise and review patient progression across all facets of rehabilitation.
- Advocate for WA based joint educational and clinical and research professional training between prosthetic and physiotherapy professions mentored by major prosthetic leaders such as Ottobock and Ossur.

Prosthetic and Technological Rehabilitation Focus

- Introduce discussions around the long-term patient benefits and cost analysis of modular casting systems in rural centres.
- Consider implementing force plate technology for both OI and general gait retraining programmes to improve accuracy and safety of treatment and generate research data.
• Embrace the use of multimedia to assist with multidisciplinary assessment, therapy and evaluation of rehab milestones.
• Embrace the sharing of video gait analysis, pressure plate analysis and microprocessor technologies to expand interdisciplinary collaboration between physiotherapy and the prosthetic industry both in training and in the clinical setting.
• Advocate for instigation of trial prosthetic components such as MPKs in public hospital facilities to streamline appropriate and cost-effective strategies of prosthetic prescription.
• Advocate the provision of a three-way (PT, CPO and patient) problem solving approach where qualitative patient feedback is central to a joint treatment session as routine clinical practice.

Research Focus
• Implement ‘BioPatRec’ software platform at SCGH and introduce the Neuromotus treatment within SCGH Amputee service on appropriate and informed patients.
• Replicate current trial protocol so that data collected can be used to compare and contribute to the international database being developed through the multi-site trial.
• Expand this to develop multi team involvement with appropriate education and skills advancement for physiotherapy, pain, neurological and amputee specialty teams in the near future.
• Identify ways to increase evidence based practice in local rehabilitation services and employ strategies to transition international evidence more immediately to the clinical environment.
• Embrace evidence emerging from the current leaders in amputee related research such as the University of Texas, the F.O.R.E center in Miami and EACE at the CFI to inform multidisciplinary clinical practice where applicable.
• Utilise information and contacts gained from the research facilities visited to expand knowledge bank of contemporary research projects and share through TRACS WA amputee rehabilitation webpage.

Future Progressions
• Progress and evaluate WA methods of amputee care through ongoing professional networks generated by this fellowship.
• Continue the professional networks generated by this fellowship to progress on going physiotherapy skills specific to the OPRA procedure.
• Develop open access educational resources to guide clinicians practising outside of major WA rehabilitation centres.
• Ensure dissemination of Neuromotus trial, patient selection criteria, the expected benefits, and protocols for use across clinical networks in WA.
• Continue to collaborate with Dr Ortiz Catalan and his extended team to ensure maximum support for the initiation of an Australian Neuromotus programme and to stay informed of progressions in osseointegrated and neurally controlled prosthetics.
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Thank you to all members of the WA Committee for the guidance and motivation you have given me, I feel privileged to become part of such an inspiring group.

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To Leanne Cormack, thank you for unwavering passion to improve amputee rehabilitation and for being such an inspirational and motivating mentor.

To Dr Richard O'Donnell and the Sarcoma Care Unit clinicians at UCSF, your generosity and willingness to include me and share your knowledge was extraordinary and will provide lasting benefit to WA.

To Leo, Brandon, James, Ben and all the staff at the CFI for making me feel so welcome and opening my eyes to the most exceptional facilities, clinical collaboration and professionalism I could only previously have imagined.

To Mark Edwards (Ottobock), Kevin Moore (Fillauer) and John Ross (Blatchford) for going out of your way to make me welcome in your profession and setting up visits with key facilities and clinicians who I would otherwise have missed.

To Kirstin Hagberg and Dr Max Ortiz Catalan in Gothenburg for sharing your enormous wealth of knowledge and coordinating such an informative, inspiring and valuable itinerary across Sahlgrenska, Chalmers and Orebro Universities.

To Sara and Maggie and Dr Soori at St Mary’s, Roehampton. Your generosity in sharing the NHS experience will be instrumental in guiding future developments in OI rehabilitation in WA.

To all the people and facilities that I was fortunate to visit. Thank you for your wonderful geniality in inviting me into your workplaces. I sincerely appreciate your boundless generosity and passion to share and improve all things amputee rehabilitation and look forward to keeping in touch to expand on the benefits you have all afforded me.

To my husband Sean for helping to make ‘Beck and Sean’s big adventure’ an amazing experience! Thank you for your incredible vision, drive and patience and continually making me believe I was capable even when I was sure I was not!

Finally, and most importantly thank you to all the amputees I met on this fellowship who so graciously allowed me to experience their rehabilitation and to the patients here in WA who never cease to inspire me to improve. This is for you.

“Don’t listen to anyone who tells you that you can’t do this or that. That’s nonsense. Make up your mind, you’ll never use crutches or a stick, then have a go at everything. Go to school, join in all the games you can. Go anywhere you want to. But never, never let them persuade you that things are too difficult or impossible.”

-- Douglas Bader
## Appendices

### Appendix A: Dissemination Plan and Timeline

<table>
<thead>
<tr>
<th>Month</th>
<th>To Whom</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2017</td>
<td>Dr Robert Gailey and Physiotherapy faculty at University of Miami, USA</td>
<td>Presentation of fellowship experience and Churchill Memorial Trust</td>
</tr>
<tr>
<td>June 2017</td>
<td>Dr Kirsten Hagberg and Amputee Rehabilitation Team at Sahlgrenska University, Gothenburg, Sweden</td>
<td>Presentation of fellowship experience and Churchill Memorial Trust</td>
</tr>
<tr>
<td>July 2017</td>
<td>Sir Charles Gairdner Hospital (SCGH) Amputee Clinic, Perth WA SCGH Amputee Rehabilitation Service SCGH Dept of Orthopaedic Surgery; Professor Richard Carey Smith</td>
<td>Direct presentation and discussion with clinicians and consultant to discuss and plan immediate implementation of new techniques and strategies to improve day to day service Meeting with SCGH consultant to contribute findings to business case planning for proposed Amputee Rehabilitation Centre of Excellence at Osbourne Park Hospital Meeting to present and discuss implementation of MDT and physiotherapy protocols following Osseointegration procedures (gathered from Sweden, UCSF and UK)</td>
</tr>
<tr>
<td>August 2017</td>
<td>Rotary Lions Club North Perth TRACS WA SCGH Neurosciences Team, Physiotherapy Department</td>
<td>Presentation of fellowship experience and Churchill Memorial Trust Presentation of fellowship findings and planning for dissemination of resources to WA Health through TRACSWA internet portal Presentation of Fellowship experience and findings</td>
</tr>
<tr>
<td>September 2017</td>
<td>Churchill Memorial Trust TRACS WA</td>
<td>Submission of final report Discuss instigation of outcomes via internet hub, simulation training and wider WA Health internet</td>
</tr>
<tr>
<td>Month</td>
<td>Location/Organisation</td>
<td>Activities</td>
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<tr>
<td>October 2017</td>
<td>Australian Orthotists and Prosthetists Association (AOPA)</td>
<td>Presentation of fellowship findings to Annual Congress Conference</td>
</tr>
<tr>
<td></td>
<td>OAPL Prosthetics and Orthotics (at AOPA Congress)</td>
<td>Assist with practical amputee mobility workshop at Congress in collaboration with prosthetist hosting course</td>
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<tr>
<td></td>
<td>Joondalup Health Campus</td>
<td>Guest presentation for physiotherapy upskilling course in amputee rehab</td>
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<tr>
<td>November 2017</td>
<td>SCGH Physiotherapy Department</td>
<td>Presentation of fellowship experience and findings</td>
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<tr>
<td></td>
<td>Fiona Stanley Hospital Amputee Rehabilitation Service</td>
<td>Presentation of fellowship experience and findings</td>
</tr>
<tr>
<td></td>
<td>Hollywood Private Hospital</td>
<td>Presentation of fellowship experience and findings</td>
</tr>
<tr>
<td>December 2017</td>
<td>SCGH Amputee and Pain Clinics Limb4Life</td>
<td>Initiate Neuromotus programme Share findings with this not for profit group</td>
</tr>
<tr>
<td>January 2018</td>
<td>SCGH Physiotherapy Department WCPT amputee rehabilitation Focus Group</td>
<td>Launch travelling skills advancement programme to rural facilities in WA Share fellowship findings with international colleagues across this forum to inform and generate discussion Link Amputees in WA to the PACE ‘Couch to 5k’ programme</td>
</tr>
<tr>
<td>February 2018</td>
<td>WA Health Department multidisciplinary state-wide webinar</td>
<td>Community of Practice TRACS WA to plan OPRA programme and new Model of Care</td>
</tr>
</tbody>
</table>
Appendix B: OPRA Protocol for Physiotherapy C.A.R.E Sahlgrenska I.C. Sweden

TREATMENT PROCEDURE
An overview of the treatment process. Individual variations may occur.

Operation Seans 1
- 5–7 days hospitalisation
- Socket prosthesis can be used again after 6–8 weeks
- End bearing in the socket should be avoided!

Operation Seans 2
- 3–6 months after Seans 1
- 10–14 days hospitalisation

6 weeks after surgery Seans 2
- Follow-up with medical team
- Rehabilitation starts using short training prosthesis
- Instructions for daily training at home over the next 6–8 weeks
- Possible 1–2 extra visits to Dept. for Prosthetics and Orthotics for new training instructions

12 weeks after Seans 2
- Follow-up with medical team
- Rehabilitation starts using long prosthesis
- Instructions on how much the prosthesis may be used and gradual increase of activities
- Possible 1–3 extra visits to Dept. for Prosthetics and Orthotics for prosthesis adjustment and new instructions

6 months after Seans 2
- X-ray
- Follow-up with medical team
- Possibly start walking without crutches
- Extra visits to Dept. for Prosthetics and Orthotics for cosmetic finalisation and possible replacement of prosthesis components

1 year after Seans 2
- X-ray
- Follow-up with medical team
- Visit to “walking school” at Dept. for Prosthetics and Orthotics

2 years after Seans 2
- X-ray
- Follow-up with medical team
- Visit to “walking school” at Dept. for Prosthetics and Orthotics

Continued follow-ups
- 3, 5, 7, 10, 15, 20 and 25 years after Seans 2, including X-ray examination
### UCSF OPRA Protocol

#### Appendix C

<table>
<thead>
<tr>
<th>Week 1-2 post-op Stage 2 (S2)</th>
<th>Stay immobilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 3 post-op</td>
<td>Suture removal and physical therapy will guide patient through active movement of training the hip joint</td>
</tr>
<tr>
<td>Week 6 post-op Stage 2 (S2)</td>
<td>Initiate loading with short training prosthesis that only reach to the knee joint, and an initial load of maximum 20 kg. Avoid rotations. Increase approximately 10 kg per week until full bodyweight is reached. However, the load must be adapted to the patient’s body size and strength. Exercise 2x15 minutes per day, increasing to 2x30 minutes/day. If pain occurs above 5 on a Visual Analogue Scale (VAS) - the patient should abstain from all training for 1-2 days or until pain has decreased to a more pain-free level. Return to training using a decreased load. If pain remains above 5, the patient should contact the treating physician.</td>
</tr>
<tr>
<td>Week 10-14 post-op Stage 2 (S2)</td>
<td>With training prosthesis, if full body weight is reached and training conducted without pain: General fitness exercises including kneeling in all four and kneeling down. Return to the treating physician for a decision concerning full-length prosthesis.</td>
</tr>
<tr>
<td>With Full-length prosthesis:</td>
<td>. Initiate training with full-length prosthesis and an initial load of maximum 20 kg while walking. Increase approximately 10 kg per week. Use the prosthesis maximum 2x60 minutes daily indoors. Walking exercises should be carried out with parallel bars and with 2 crutches. In a standing position, the maximum load is half bodyweight. Do not use training prosthesis.</td>
</tr>
<tr>
<td>As rehabilitation continues, if pain occurs above 5 on a VAS, rest completely from all kinds of training during 1-2 days. Return using decreased load. If pain remains above 5, the patient should contact the treating physician.</td>
<td></td>
</tr>
<tr>
<td>Week 12-16 post-op Stage 2 (S2)</td>
<td>. Training of balance and gait pattern. Always use 2 crutches. Use of stairs. Fitness cycling with light load. Sitting down and sitting down to standing up. Fitness training with training prostheses. Week 14-18 post-op Stage 2 (S2) Prostheses might be used the entire day. Transferring of body weight while standing. Walking up-hill with two supports. Week 16-24 post-op Stage 2 (S2) Walking exercises with one support at the physiotherapist and at home. Always use 2 crutches for longer walks outdoors. Walking slightly uphill, in rough terrain, over obstacles. Turning. Fitness training with full-length prostheses.</td>
</tr>
<tr>
<td>Week 22-26 post-op Stage 2 (S2)</td>
<td>If full body weight is reached and training conducted without pain: Walking without support during training. Return to the treating physician for a decision about the use of one support more frequently while walking.</td>
</tr>
</tbody>
</table>
Appendix D: Roehampton Pain Management Algorithm

A guide to amputee pain management

Purpose
- Acts as a tool to guide pain management of residual limb pain and/or phantom limb pain, providing an overview of the pain management pathway for the amputee receiving rehabilitation at Roehampton.
- Highlights available resources and modalities within the Centre e.g. therapy interventions.
- Pathway can guide selection of appropriate treatment and management options.
- Suggests alternatives if pain not successfully managed i.e. proceed to next stage in the pathway or onward referral beyond the Trust as necessary.

Abbreviations
- Ac: Assessment
- Rx: Treatment
- Tx: Therapy
- NTE: Neurological
- PT: Physiotherapy
- XRT: Radiotherapy
- Mgt: Management
- HO: Hydrocephalic
- LBP: Lower back pain
- CS: Cognition
- MOD: Motor imagery
- PTSD: Posttraumatic stress disorder
- CRPS: Complex regional pain syndrome
- US: Ultrasound scan
- GMI: Graded Motor Imagery

Assessment considerations
- Presence of pain acknowledged and identified via routine physical Ac.
- N.B. Include questions to eliminate pain referred from spine.
- Routine post-operative care, patient information and reassurance frequently sufficient for effective pain management.
- Select appropriate investigations e.g. ultrasound to confirm muscle tear.
- If pain persistent and interfering with rehabilitation, perform more specific pain? Ac using modified McGill Questionnaire and visual analogue scales.
- Where pain is unresolved consider most appropriate member of the team to assess and investigate, which may depend on presentation of pain.

Evaluation & documentation
- What is the most effective intervention?
- Be aware of simultaneous interventions (a combination of interventions may be the most effective form of pain management).
- Be systematic with recording Rx interventions and evaluation.
### Glossary of Terms and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADLs</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>AOPA</td>
<td>The Australian Orthotic Prosthetic Association</td>
</tr>
<tr>
<td>BACPAR</td>
<td>British Association of Certified Physiotherapists in Amputee Rehabilitation</td>
</tr>
<tr>
<td>CFI</td>
<td>Center for the Intrepid</td>
</tr>
<tr>
<td>CPO</td>
<td>Certified Prosthetist Orthotist</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defence, USA</td>
</tr>
<tr>
<td>EACE</td>
<td>The Extremity Trauma and Amputation Centre of Excellence</td>
</tr>
<tr>
<td>EMAs</td>
<td>Early mobility aids</td>
</tr>
<tr>
<td>EQ 5D</td>
<td>EuroQuol standard quality of life questionnaire</td>
</tr>
<tr>
<td>F.O.R.E</td>
<td>Functional Outcomes Research and Evaluation Centre</td>
</tr>
<tr>
<td>IPOP</td>
<td>Immediate post-operative prosthesis</td>
</tr>
<tr>
<td>MDT</td>
<td>Multidisciplinary Team (care)</td>
</tr>
<tr>
<td>MOBIS</td>
<td>Mobility scale devised by Ottobock</td>
</tr>
<tr>
<td>Neuromotus</td>
<td>Phantom Limb Pain Treatment system (Sweden)</td>
</tr>
<tr>
<td>NHS</td>
<td>National Health Service (UK)</td>
</tr>
<tr>
<td>OPRA</td>
<td>Osseointegrated Prostheses for the Rehabilitation of Amputees</td>
</tr>
<tr>
<td>OI</td>
<td>Osseointegration (general term)</td>
</tr>
<tr>
<td>OT</td>
<td>Occupational Therapist</td>
</tr>
<tr>
<td>PLP</td>
<td>Phantom Limb pain</td>
</tr>
<tr>
<td>PPAMs</td>
<td>Pneumatic post amputation mobility aid</td>
</tr>
<tr>
<td>Physiatrist</td>
<td>A physician who specialises in physical medicine and rehabilitation</td>
</tr>
<tr>
<td>PT</td>
<td>Physical Therapist/ Physiotherapist</td>
</tr>
<tr>
<td>Plus-M</td>
<td>Mobility Outcome Measure</td>
</tr>
<tr>
<td>SIGAM</td>
<td>Special Interest Group in Amputee Medicine Mobility predictor</td>
</tr>
<tr>
<td>TFA</td>
<td>Transfemoral Amputation (amputee)</td>
</tr>
<tr>
<td>TTA</td>
<td>Transtibial Amputation (amputee)</td>
</tr>
<tr>
<td>TRACS WA</td>
<td>Training Centre in Subacute Care Western Australia</td>
</tr>
<tr>
<td>UCSF</td>
<td>University of San Francisco</td>
</tr>
<tr>
<td>SCGH</td>
<td>Sir Charles Gairdner Hospital</td>
</tr>
<tr>
<td>VA</td>
<td>Department of Veterans Affairs, USA</td>
</tr>
<tr>
<td>WA</td>
<td>Western Australia</td>
</tr>
</tbody>
</table>
Resources Collected

Equipment:

1. Neuromotus PLP machine, Sweden

Protocols:

1. OPRA, Sweden
2. OPRA, UCSF
3. OPRA, St. Mary’s Hospital, Roehampton, UK
4. Physiotherapy for OPRA system, Sweden
5. Myoelectric training protocol for upper limb, CFI
6. Microprocessor knee unit prescription protocol, NHS, UK
7. Microprocessor unit trial protocol, NHS, UK
8. Neuromotus PLP treatment, Sweden

Clinical Practice Guidelines

1. Physiotherapy for lower limb amputees, CFI, USA
2. Occupational therapy for upper limb amputees, CFI, USA
3. Post amputation pain management, NHS, UK
4. Falles Screen for amputees, NHS, UK
5. Ossur, Rheo Knee Training Guidelines, Ossur, Iceland (NHS, UK)
6. Early Mobility Aids, NHS, UK
7. MDT Care Bundle Flowchart for Adults with Lower Limb Amputation, NHS, UK
References


17. Weir M. Injuries of nerves and their consequences. [Place of publication not identified]: Smith Elder; 1872.


