Report of the Stack Travelling Fellowship 2023

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Introduction

The British Society for Surgery of the Hand (BSSH) awards this travelling grant to pay homage to Hugh Graham Stack to recognise his contribution and development within the field. He was instrumental in the formation of the BSSH itself from the merger of the two early societies providing scientific discourse and disseminating knowledge through the development of the journal. He was also a technical innovator in the field of hand surgery. Innovation begins with knowledge, we must seek to understand before we can hope to provide meaningful change. Stack published basic science works on anatomy (Stack 1962) and its role in pathology (Stack 1971 and 1969). He was also an early adopter of surgical safety publishing on the safe use of tourniquets (Stack 1973) and the importance of defined nomenclature to prevent wrong site surgery (Stack 1969). Perhaps he is most commonly known for his inventions, developing new surgical instruments (Stack 1960) and the splint for mallet finger bearing his name that is still in wide use today (Gerlac 2016) (Figure 1). To honour this spirit of innovation I chose to theme my Stack fellowship around the current innovators in Hand Surgery today.

Figure 1. Stack Splint

I am extremely grateful to have been awarded this opportunity by the BSSH. It has been a wonderful privilege to visit centres of excellence who are contributing to our knowledge, the development of new or improved techniques, instruments or implants and pushing the boundaries of anatomic possibilities. The initial inspiration, however, was conceived out of a different innovation, a new way of disseminating knowledge and providing world wide, expert led education free of charge. My thanks go to Carlos Heras-Pelou for the Pulvertaft webinars. These are responsible for not the sharing of knowledge and experience, but also new ideas and different perspectives to challenge to dogma and illuminate our blind spots. Personally, moments of piqued interest (see Figure 2), led a desire to explore beyond the possibilities of my training, and ultimately the life changing experience I share with you in this report.

Figure 2. The webinars which sparked an interest

Institut de la Main, Paris, France

My first visit was with Dr Caroline Le Clercq and Dr Nadine Sturbois Nachef to learn about the assessment and managements of patients with spasticity secondary to both brain and spinal cord injury. The majority of time was spent at the Institut de la main in Paris. However, I also visited specialist facilities around the city and further afield at the Institut Francois Calot and peripheral centres in Lens to assess and operate on neurologically injured patients (see Figures 3 and 4).

Figure 3. The team arriving at Institut Francois Calot for morning clinic and afternoon operating list. (Left to right Dr Liau international visiting fellow, Dr Le Clercq, Dr Sturbois Nachef and myself).

Figure 4. Travelling to Lens with Dr Sturbois Nachef

The team and I started in the new patient clinic, where they demonstrated the importance of assessment and collaboration. The clinic patients are assessed by both surgeons together in a 45 minute appointment. Further assessments and recordings; including videos to assess function and progress are made by the therapy team. The importance of accurate clinical examination and assessment of change over time and after intervention is an essential element of caring for patients with neurological injury. Their clinical assessment of spasticity includes the Tardeau score, House score and recordings of tone, posture at rest and range of motion.

The teams preferred surgical management for spastic muscles is hyper selective neurotomy (HSN). This involves identifying the motor branches to spastic muscles and dividing 2/3 of the fascicles in each branch. Dr Le Clercq explained to me that she first learned of this technique from Brunelli in Italy, although it was initially described by Lorenz in 1887 and Stoffel in 1913 (Fan et al 2020). Brunelli divided 50% of the motor branches to the spastic muscles, with good initial results (Brunelli and Brunelli 1983) but he was disappointed by some recurrence in symptoms. After their discussions she decided to reinvigorate the technique, taking more of the motor branch. This has lessened the recurrence rate and the patients maintain their strength (Le Clercq 2018).

Stoffel in 1913 writes *"The cause of spastic contractures is found in an affection of the cortical spinal conduits, the most essential of which in the human body is the pyramidal tract. According to Foerster's investigations the pyramidal tract has two functions; firstly, it conducts* *the impulses of volition from the cervical cortex to the spinal gray matter, and secondly it inhibits the spinal reflex excitability by maintaining the latter on that level, which we know in normal man. If any kind of noxious influence affects the pyramidal tract, the inhibitory fibers of the pyramidal tract are injured much earlier and much more severely than the innervating fibers, the paretic component in many cases even disappears entirely behind the spastic component. If now the sensory stimuli constantly flowing to the spinal gray matter are no longer weakened or subdued by the inhibitory fibers of the pyramidal tract but pour out their full strength upon the muscle, there is set up a hypertonicity.''.* Hyper selective neurotomy involves dividing the nerve fascicles as close to the target muscles as possible. This allows the motor neurons to rennervate the muscle thus maintaining the muscles power, but the sensory arc of the stretch reflex which causes spasticity is interrupted which causes a reduction in the aberrant feedback loop resulting in the spastic contraction.

Dr Le Clercq and her team have been instrumental in building the knowledge base with numerous publications providing detailed anatomical studies of the anatomy of the motor branches of the Musculo-cutaneous (Cambon-Binder and Leclercq 2015), Median (Parot and Leclercq 2016) and ulnar nerves (Paulos and Leclercq 2015).

I was privileged to observe several different HSN procedures for spasticity. In the first Dr Le Clercq demonstrated to me HSN of the hypothenar muscles. During this procedure, she first opened Guyon's canal, before identifying the motor branches to the hypothenar, which emerge before the deep motor branch dives deep into the palm to innervate the intrinsics.

Once identified sloupes are placed around the nerves. They have an established sloupe colour coding system: Red = main trunk, yellow = branches for neurotomy and blue = everything else (see Figures 5 and 6). Nerves with yellow sloupes have 2/3 of the fascicles cut and once the neurotomy has been performed the sloupe is removed allowing the surgeons to track their progress.

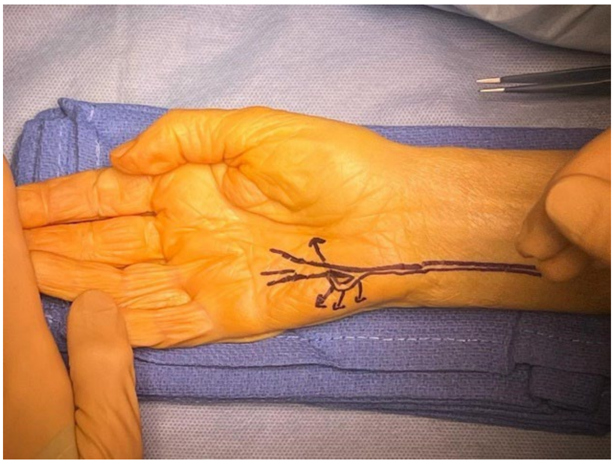

Figure 5. Pre operative markings of the motor branch of the ulnar nerve.

Figure 6. Intra operative demonstration of the motor branches to the hypothenar muscles.

The spastic muscle is not the only consideration. Spastic muscles contract over time and this may lead to contracture of underlying joints. The opposing muscles can become weak from disuse or paralysed from injury. I was shown by the team the use of Botulinum toxin and targeted local anaesthetic nerve blocks in assessing for underlying, muscle condition and contractures. Nerve blocks provide quick answers in the clinic, whereas Botulinum toxin is slower in onset but longer acting allowing a patient to 'trial' HSN and also gives a period where agonist muscles can be strengthened, contractures can be splinted and assessed allowing operative planning, however, clinically differentiating between muscle and joint contracture is challenging and requires the surgeon to be prepared and flexible.

Dr Le Clercq demonstrated this principle for me in a patient with elbow spasticity, where assessment after Botox injection revealed underlying flexor contractures. First the HSN's were performed for the musculocutaneous branches to biceps and brachialis and then radial branches to brachialis and brachioradialis (see Figure 7). HSN for ECRL and ECRB can also be performed here but these were not required for this patient. It is imperative to perform intra operative stimulation to correctly identify the branches. The muscle contractures were then relieved with biceps z-lengthening, fractional lengthening of the brachialis aponeurosis and myotomy of brachioradialis. Once the muscle contractures were released the joint capsule was not contracted and therefore joint release was not required.

Figure 7. Radial nerve (red) with branches to Brachialis and Brachioradialis in yellow sloupes, branches to ECRL is also seen below.

The clinic patients often have complex multi-level needs. The team here prefer to address as much as possible in single stage surgery combining HSN, with tenotomies or tendon lengthening, muscle or joint releases and tendon transfers. In another procedure a patient underwent a pectoralis major tenotomy and subscapular release for shoulder internal rotation, HSN for pronator teres and Flexor Carpi Radialis (see Figure 8), fractional lengthening of Flexor Pollicis Longus and Flexor Digitorum Superficialis to Flexor Digitorum Profudus transfers of the finger flexors.

Figure 8. Dr Le Clercq dissecting out the motor branches of the median nerve.

Along with HSNs I also witneesed techniques new to me: Latissimus dorsi transfer for shoulder function, nerve repair with sural nerve grafting, revision of failed pollicisation surgery and endoscopic carpal tunnel release. There was also the opportunity to gain new perspectives on familiar procedures, such as Dupuytren's (see Figure 9). Their technique for limited fasciotomy used was quite different to the style I was taught during my training, showing that different approaches can be successful.

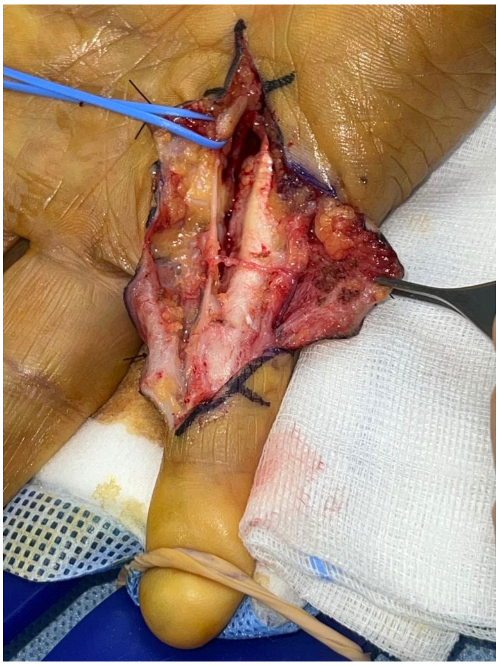

Figure 9. Fasciectomy showing transverse anastomosis in the finger.

Patients who have suffered spinal injuries are assessed using the Giens classification, which allows grading the level of dysfunction by what donors are available. This system was developed in the 1950's and provided a treatment protocol for tendon transfers. Innovations in nerve techniques have been transforming treatment and nerve grafts and transfers are now common. Although we cannot throw out tendon transfers just yet as motor end plate degeneration gives a finite time line for successful nerve recovery. It is also known that not all nerve transfers lead to meaningful recovery and it can be a challenge for decision making if potential nerve transfer means sacrificing muscles that could be used to power more reliable but less natural tendon transfers. Dr Le Clercq demonstrated the SPIN procedure for me, using supinator to power the posterior interosseus nerve for those with C5/6 level spinal injury.

Figure 10. Dr Clercq, Dr Sturbois Nachef and Dr Liau performing a SPIN at Institut Francois Calot

The goal for neurologically injured patients is to gauge what each individual patient requires. It is not possible to return these patients to 'normal' and expectations must be set according, therefore psychological support is an essential element of care. It is important to determine exactly what each individual's needs are; pain relief, hygiene, cosmesis, specific functional goals and tailor treatments to this combined with their clinical picture, social support, motivation and expectations. Hands which are non-functional require a different approach to those with useful power and voluntary control.

The team are developing new ideas borne from intergrating ideas from spine and brain injury treatments. It is possible to use spastic muscles (with voluntary control) in tendon transfers, and nerve transfers have become common place – can we use the motor branches cut to treat spasticity to augment weaker antagonist muscles? A germination of an idea, begins with investigating possibilities starting with, of course, basic science and anatomical cadaveric studies.

Dr Le Clercq not only educated me in hand surgery, but as one would expect in France gastronomically (see Figure 11). After a long journey to a peripheral clinic supper was provided including fresh bread, red wine, cheese and pate and Saindoux à la truffe, I was told I must try before she would tell me what it was, I did and it was delicious – it is whipped pork lard flavoured with truffle!

Figure 11. Enjoying a French almost midnight feast and al fresco Parisian lunch with Dr Le Clercq and fellow international fellow Dr Liau.

Nerve course, Bristol, UK

The Global Nerve Foundation hosted an innovative nerve masterclass with an international faculty and participants in three different time zones. The course included lectures, cadaveric dissection and simulated surgeries, as well as live surgeries. The teams demonstrated technological innovations allowing expert assistance to be provided to a remote team. This utilised specialised smart glasses with an inbuilt camera and screen so the expert surgeon could provide visual guidance in the form of marks and drawings visible in the glasses to the operating surgeon in real time.

Nerve conditions were the focus of the course. Day 1 focused on Nerve compression syndromes, day 2 on peripheral nerve injury and day 3 on brachial plexus lesions. Lectures were delivered in ‘person’ from each of the three venues; Bristol, Rotterdam and Kuala Lumpur (see Figure. 12) and also prerecorded. Each centre had a cadaveric lab with sessions including combined Carpal tunnel and Guyon’s canal release, cubital tunnel release with medial epicondylectomy – which included a research project on teaching new techniques, nerve repair, both direct and with graft and nerve transfers.

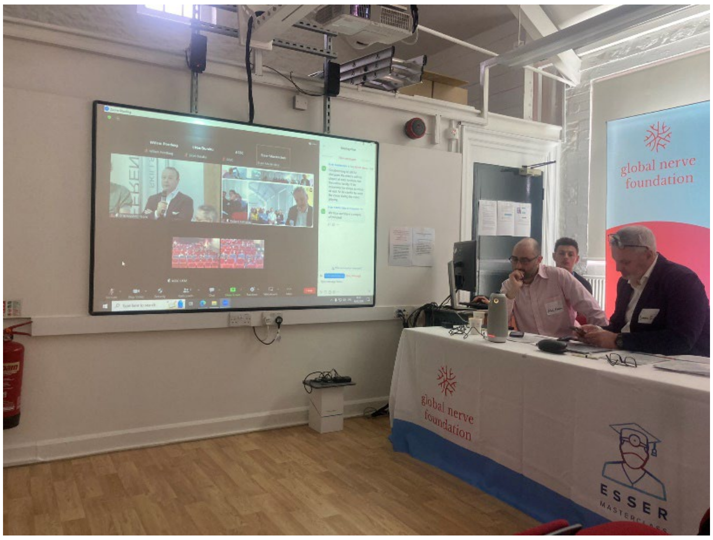

Figure 12. Lectures in three times zones, hosted by Mr Dominic Power (left).

Dominic Power is an innovator in communication. His focus is in the use of technology for education and dissemination of information. He has produced an excellent resource in Orthoracle and is heavily involved in the Global Nerve Foundation. This course showcased how interconnected we now are and the possibilities of providing expert help and education globally and particularly to remote areas and in low and middle income counties.

AZ Monica, Antwerp, Belgium

I visited to experience the use of 3D printing in hand surgery, which Dr Verstreken has championed (Michielsen et al 2019, Bodansky et al 2023, Peeters et al 2020, Michielsen et al 2018, Byrne et al 2017). The team have set up their own lab and employ an engineer to produce 3D printed guides (see Figure 13). The team also work with a company for 3D printed implants including custom designed carpal bone implants. These are based of the normal anatomy of the contralateral limb, but with adjustments to accommodate any elements of fixed collapse or rotational deformity within the carpus.

Figure 13. a) 3D printer b) Printed models and guides for intra operative use.

I am particularly interested in computer aided design and custom printed implants for deformity correction. Initially I learnt to create guides on intact bones, then design implants on reduced fractures (Figures 14 and 15).

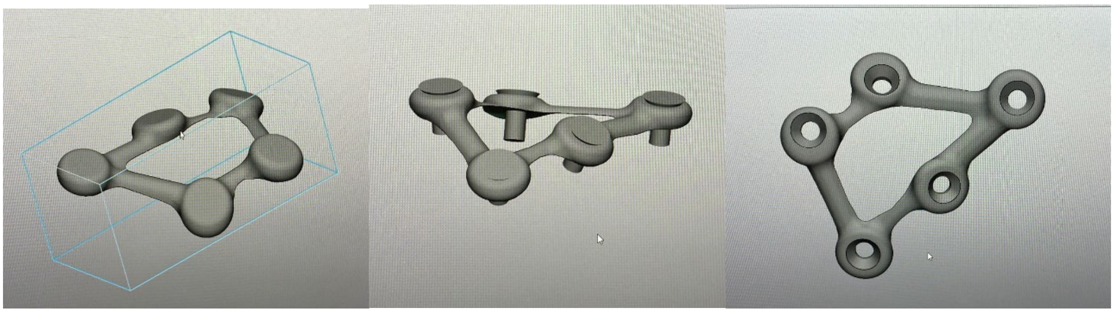

Figure 14. Designing a plate. a) Place screw points and link them with bars. b) Add in screws in decide direction c) subtract screws to create hole.

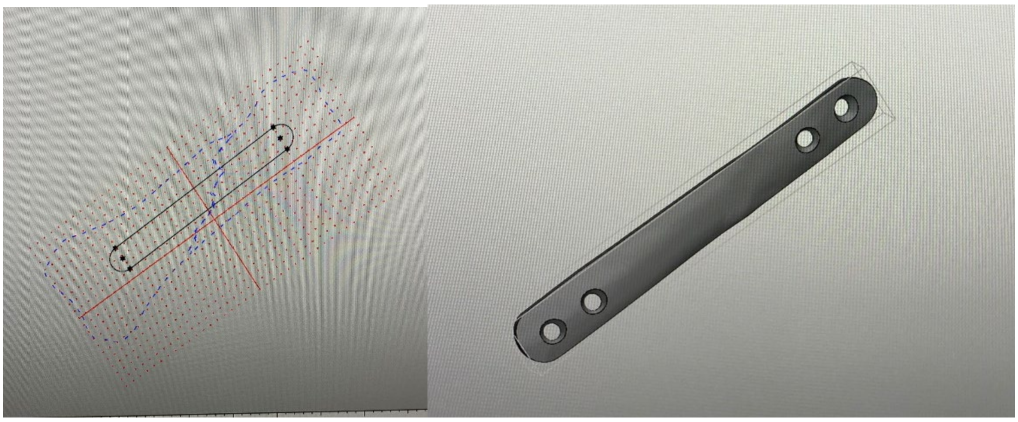

Figure 15. a) Reduced fracture with plate design drawn out. b) Solid plate design

I was then taught to use a CT scan to create my own 3D computer models. This allowed me to create a model of distal radius fracture. Once created I could separate the main fracture fragments. Allowing me to rotate and examine them pre-operatively, effectively performing the reduction and testing implants prior to the case (see Figure 15). The hardest part of performing the computer modelling was changing the language and using a different keyboard (see Figure 17).

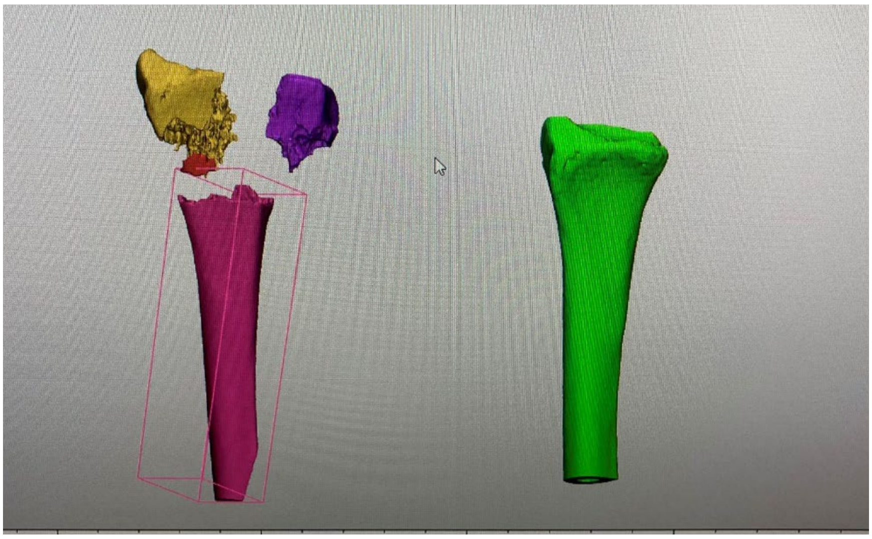

Figure 16. Distal radius fracture with normal contralateral side inverted as a template.

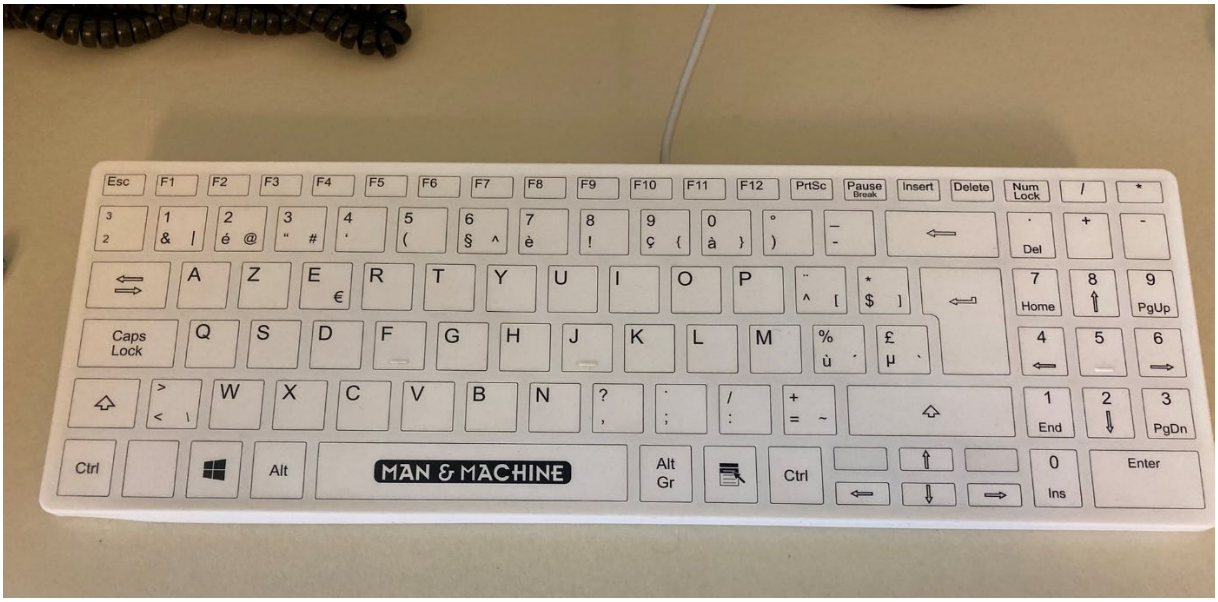

Figure 17. Belgian non-"qwerty' keyboard.

I was shown the use of guides intra-operatively in the case of distal radius osteotomy. The team had designed and printed a guide which is contour matched to the deformed bone and secured with k-wires. The guide includes drill guides for the screws, and saw slot for the osteotomy (see Figure. 18). Once the drilling and cutting is completed the distal plate is applied and used to control the distal fragment. The proximal drill holes are present for screw insertion and automatic deformity correction, which is a mirror image matched to the anatomy of the normal side.

Figure 18. Intra operative distal radius corrective osteotomy guides.

In complex deformity corrections there may be preoperative uncertainty this can be accommodated by providing multiple printed guides. For example, a severely shortened radius case had three guides printed to allow different degrees of lengthening depending on the soft tissue tension. Corresponding ulnar shortening measurements were provided to match – allowing reconstruction of the anatomy of the DRUJ. Guides were also printed for the iliac crest harvest to exactly match the shape of the graft to the defect (See Figure 19, 20 and 21).

Figure 19. 3D models of deformity, correction planes and final result.

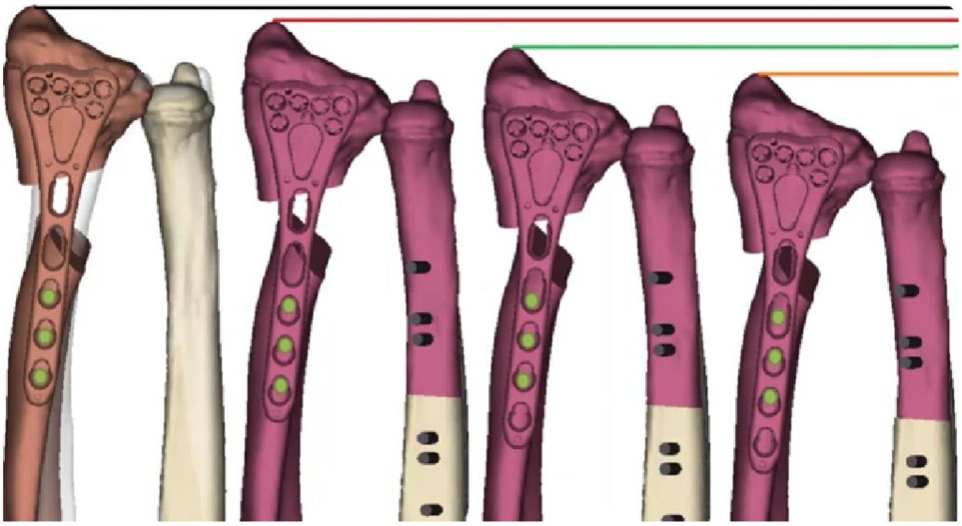

Figure 20. Different radial lengths plus ulna shortening

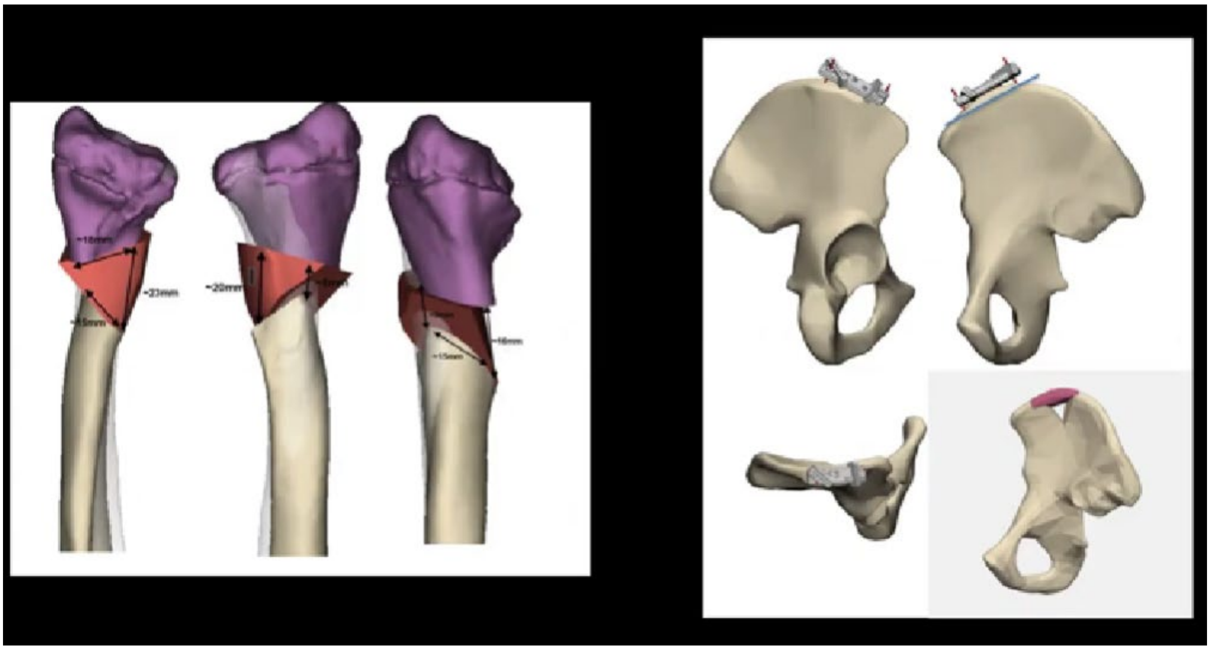

Figure 21. Plans for Iliac crest harvest.

The team utilise the printed guides for standard cases. They have produced a range of ulna shortening guides of different lengths (see Figure 22). This negates the need for adjustable guides. The guide is placed on the bone with two wires at each end (matching those on the plate). Six drill holes followed by two saw cuts. The guides slid off and the plate is applied to perform the reduction. Rotation and compression is already set by the screw holes. They chose a transverse osteotomy.

Figure 22. Ulnar shortening guide 3mm

I attended the team weekly meeting where difficult cases were discussed. A patient with lunate collapse and fragmentation was discussed. The outcome was that a lunate replacement with a 3D printed custom prosthesis shoulder be offered to the patient.

Dr Verstreken was a wonderful host; he and his wife took my to visit the art museum (see Figure 23) followed by a family dinner and we visited the chocolate line, where I found chocolate hands to take home to my team (see Figure 24). I was also generously invited to the hand team dinner (see Figure 25).

Figure 23. Dr Verstreken and I by the rotating hand sculpture at KMSKA.

Figure 24. The hand is the symbol of Antwerp. It is represented all over the city including in chocolate.

Figure 25. The hand team dinner, hosted Dr Verstreken (Left) and Dr Van Rees (Right).

University of Ohio, Columbus, Ohio, United Staes of America

I visited Professor Amy Moore in Colombus Ohio. Professor Moore is deeply passionate about helping people with peripheral nerve injury. She has a wide geographical practice treating people from across the US and internationally, utilising virtual assessments and collaboration with hand therapists to widen the accessibility. She has developed an amazing team, including the nurturing of a wonderful asset her physicians assistant Julie West, (see Figure 26). Julie has been trained in the assessment and management of patients, including surgical assistance and research aspects of the team. This is a shining example of embracing non-traditional team members to the benefit of the whole team and their patients.

Figure 26. Prof. Amy Moore, myself and P.A. Julie West.

I visited Professor Moore in her nerve clinic. All of her patients complete a detailed pain questionnaire each time they attend and Professor Moore and her team are clear in defining exactly what the patients main concern is and subsequently monitoring progress with subjective measures as far as practicable. Each patient has a detailed physical examination where particular attention is paid to pin pointing the exact point of maximal tenderness and Tinel's performed from multiple directions, particularly pre-surgery.

The surgical management of peripheral nerve injuries ranges from simple decompression to complex staged nerve grafting and transfer procedures and Professor Moore was kind enough to demonstrate many techniques for me. I witnessed a neck dissection for spinal accessory nerve dysfunction which required decompression. A delayed ulna nerve injury secondary to elbow arthroscopy resulted in the team performing a neuroma resection followed by nerve grafting using medial antebrachial cutaneous nerve supplemented with Tisseal and amnion for nerve gliding. The final step was to transfer the motor branch from the AIN to pronator quadratus in an end to side fashion into the motor fasciles of the ulnar nerve to supercharge the nerve and allow quicker regeneration and preservation of the motor end units. Both sites received post repair electrical stimulation (see Figure 27).

Figure 27. Ulna nerve gap, after resection of scar and end neuroma

Management of painful neuroma is notoriously challenging. Several techniques were demonstrated to me in a difficult case involving a blast injury to the hand which results in the patient had several painful neuromas within the palm. Initially the neuromas were carefully resected. For one nerve, a Regenerative Peripheral Nerve Interface (RPNI) technique was used which involved wrapping the ending in denervated muscle to allow the neurons to grow into the muscle. Soft tissue scarring and nerve length did not allow this for two branches and here a conduit was used to create a 'nerve to nowhere' guiding the regenerating neurons along a pathway to directed into deeper spaces. The soft tissue envelope was then supplemented with radial forearm fascial flap to create padding and a more accommodating soft tissue envelope (see Figure 28 and 29).

Figure 28. Pre op markings localising neuroma site

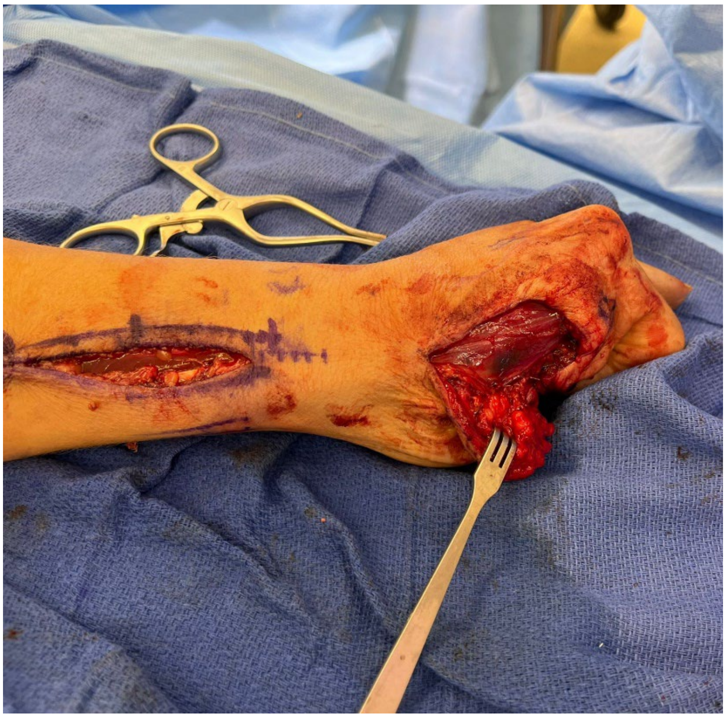

Figure 29. Post resection, RPNI, conduit placement and PIA fascial flap

We saw several patients with an isolated spinal accessory nerve palsy. The spinal accessory nerve is usually thought to be an expendable donor and it is regularly used for brachial plexus reconstructions in established transfers as it is usually thought to not leave a deficit. This may be true following plexus injury, due to loss of other function. Professor Moore after the initial notes review felt there was nothing to be offered. However, after seeing the patient and faced with his obvious functional issues, she in real time began to put her amazing anatomical knowledge to use and think of possibilities. She was honest and told the patient that she needed time to discuss with other experts and visit the cadaver lab to see what she could use for reconstruction. Above all, she gave him confidence that she would do her best to find a solution.

Professor Moore is in the process of developing easier access to intraoperative nerve stimulation based on Tessa Gordon's work on nerve stimulation as an adjuvant to nerve repair (Geremia et al 2007, Elzinga et al 2015, Brushart et al 2002, Al-Majed et al 2000). This showed the benefit of 60 minutes electrical stimulation using large unwieldy stimulators. Checkpoint surgical, a medical device company, have developed a wireless handheld stimulator and the team in Ohio are investigating benefits from shorter durations of stimulation (Moore 2022).

During my time in Ohio I was generously hosted for dinner by Professor Moore (see Figure 30) and also at the family home of Dr Ryan Schmucker. I was delighted to be invited to join in the hand surgery department social event and the plastic surgery research day.

Figure 30. Ice cream post dinner with Prof. Moore

Conclusion

Innovation is a practical implementation of ideas. The initial requirement for innovation is the desire to improve and the ability to see beyond the status quo. However, whilst many people have ideas, it is in the implementation that innovators are made. Everyone I visited has taken the action to investigate, develop, test, record results and disseminate their ideas to benefit our patients.

Innovation does not have to be completely novel. Many breakthroughs are made by building on the work of others, utilising techniques from other areas or recognising that the development of other technology renders something previously discarded now to be useful.

Wider technical innovations are now influencing our practice and not only in the development of bespoke instruments, guides and implants. Particularly with our nerve patients, advances in smart technology, robotics and biomechanics are increasingly meaning that small improvements in function can now open up the virtual world to patients who are often isolated and increasingly allow them greater interactions with the physical environment.

A repeated experience on this fellowship was witnessing the evolution of a plan with the patient and MDT team as a partnership. The first step is really listening to the patient and accepting their truth. I saw the bravery of admitting that the answer is not known, but also the excitement of an idea, the possibility of developing something new and the confidence in their own skills and experience to bring positive change to the lives of the patients we treat.

Acknowledgement

I would like to extend the utmost gratitude to the BSSH for the honour of this award. The award are afforded me the opportunity to explore and develop my interests to carry forward into my consultant career. The generosity, inspiration and education I received from all of my hosts was humbling and I will spend my career attempting to pass it forward. If I can show half their, skill, compassion and dedication I will consider myself successful.

I will be forever indebted to my husband. Without hesitation he solo parented our three small children (see Figure 31) for three two week periods. He has been a crucial support throughout my entire surgical career. He truly is the wind beneath my wings.

Figure 31. Returning to family life with Paris lego!

Finally and most importantly I wish to thank the patients who graciously allowed me in their lives and inspired me with their resilience, fortitude and strength. Innovation will continue to allow us to improve their lives and this must be our guiding light.

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