An expert opinion: upper limb rehabilitation after stroke

Nick S Ward, MBBS, BSc, MD, FRCP,
is Professor of Clinical Neurology and Neurorehabilitation at UCL Queen Square Institute of Neurology, and Honorary Consultant Neurologist at the National Hospital for Neurology and Neurosurgery. His clinical and research interest is in stroke and neurorehabilitation and in particular the assessment and treatment of upper limb dysfunction. He uses structural and functional brain imaging techniques to investigate mechanisms of impairment and recovery after stroke.

Kate Kelly, MSc, BSc (Hons), BAOT,
is a Consultant Occupational Therapist at The National Hospital for Neurology and Neurology and is clinical lead for hyper-acute stroke, acute brain injury and neurorehabilitation OT services. She specialises in stroke rehabilitation and complex inpatient neurorehabilitation with a special interest in upper limb and vocational rehabilitation.

Fran Brander, MSc, Grad Dip Phys, MCSP,
is a Consultant Physiotherapist at The National Hospital for Neurology and Neurosurgery. She trained at Guy's Hospital School of Physiotherapy. She obtained her MSc in Advanced Neurophysiotherapy at UCL. She specialises in complex inpatient and stroke rehabilitation and has a special interest in upper limb rehabilitation.

Correspondence to:
Nick Ward,
The National Hospital for Neurology and Neurosurgery, Queen Square,
London WC1N 3BG.

Conflict of interest statement: None declared.

Provenance and peer review:
Submitted and externally reviewed.

Date first submitted: 15/4/19
Date resubmitted after peer review: 10/6/19
Acceptance date: 11/6/19

To cite: Ward NS, Kelly K, Brander F. ACNR 2019;18(4):20-22

UCLPartners
Centre for Neurorehabilitation

Key take home messages

1. Clinically meaningful improvements are possible in chronic stroke patients
2. The dose of rehabilitation treatment needs to be larger than currently delivered
3. Rehabilitation is a complex intervention that cannot be reduced to a single element

Somewhere between 50-80% of stroke survivors have upper limb symptoms after acute stroke[1] and persistent difficulty in using the upper limb is a major contributor to ongoing physical disability.[2] A commonly held view is that most recovery from stroke occurs over the first three to six months after which little improvement is possible, especially at the level of impairment.[3-6] We argue that this may be a self-fulfilling prophecy resulting in lack of provision of potentially helpful rehabilitation.

What is the best way to promote upper limb recovery after stroke? Most studies of behavioural interventions have investigated forms of constraint induced movement therapy (CIMT),[7,8] repetitive task training (RTT)[9] or robotics,[10] each of which focuses on increasing the activity of the affected limb. Kwakkel et al[8] suggested that motor function, arm-hand activities and self-reported arm-hand functioning in daily life, improved immediately after CIMT and at long-term follow-up, but the comparison was often with usual care. It is worth noting that CIMT approaches were said to be more likely to be successful in promoting long term benefits if the protocol included shaping, massed practice and a behavioural transfer package, whereas simple forced use therapy was ineffective.[8] RTT also has some evidence to support benefits over what is described as usual care, but the evidence for benefits over 'matched therapy' is less strong.[9] The use of robotics can increase the number of movement repetitions, but has failed to produce clinically meaningful effects.[10] Indeed, the recent RATULS study showed that compared with usual care, approximately 23 hours of robot-assisted training and matched dose 'upper limb therapy' did not improve upper limb function.[11] Overall, it would appear that asking patients to make simple repetitions of movement, however meaningful the task, is relatively ineffective without some way of actively translating any improvements into activities of daily living. Simply increasing the number of repetitions does not appear to be effective,[12] and this in itself should give us pause for thought.

A few studies have tested more complex therapies incorporating a number of different elements. The ICARE study[13] of upper limb treatment after stroke went beyond simple repetitions, using a structured, task-oriented motor training programme that was impairment focused, task specific, intense, engaging, collaborative, self-directed, and patient centred, starting about six weeks post-stroke. Outcomes were not improved by this approach, but on reflection it is likely that, as with many of the studies, the dose of 30 hours over ten weeks was too low (the usual care group received 11.2 hours over ten weeks). Despite scepticism that stroke patients would be able to 'tolerate' much higher doses,[12] one study managed to deliver 300 hours of upper limb therapy to chronic stroke patients over twelve weeks and reported changes in measures of both impairment and activity that were far greater than those in lower dose studies,[14] and in fact the findings of this study have recently been replicated by the same group.[15] We recently reported the findings of the Queen Square Upper Limb (QSUL) Neurorehabilitation programme,[16] a single centre clinical service that provides 90 hours of treatment focusing on the post-stroke upper limb. Most patients entering the programme were in the chronic stage (> 6 months post-stroke), but were able to complete the 90 hours of the programme, even though they exhibited a wide range of impairments and fatigue levels. Despite the time since stroke (median = 18 months) we observed (i) large clinically meaningful improvements in upper limb impairment and activity (of a magnitude similar to those reported by McCabe et al.), and importantly (ii) that these changes were maintained, or even improved upon, six months after treatment.

The first lesson to take from these studies is that post-stroke rehabilitation programmes and clinical trials are almost certainly under dosing patients. In future, clinical trials must investigate the effects of much higher doses

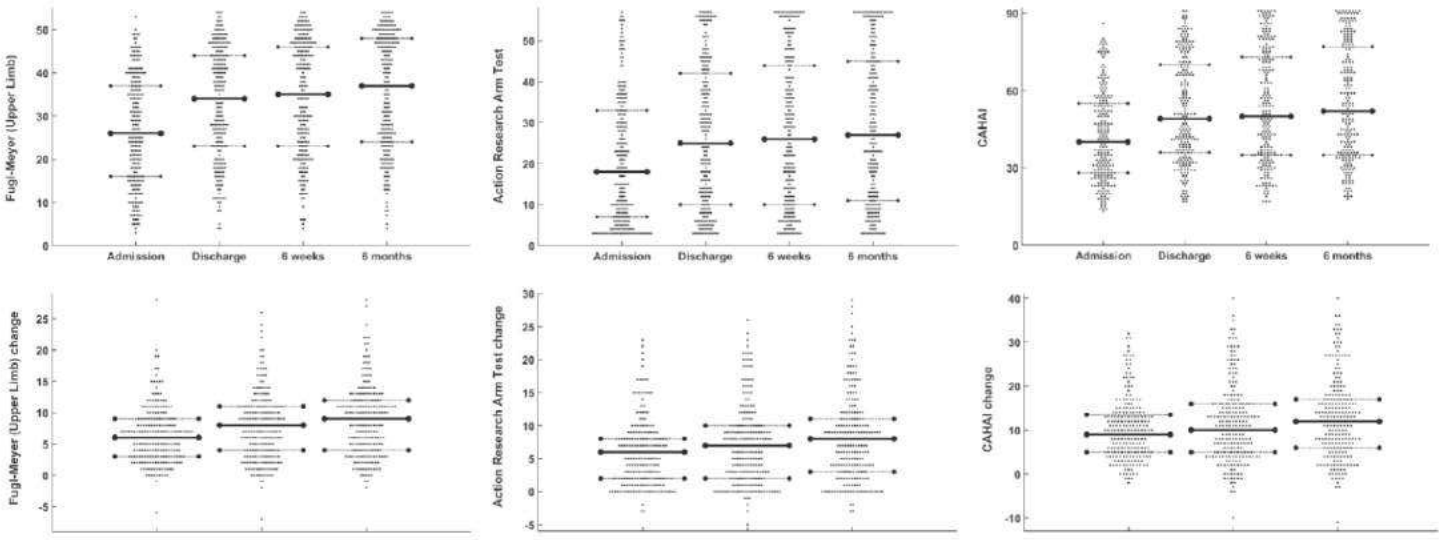

Figure 1. Outcome scores for all patients on the Queen Square Upper Limb Rehabilitation programme. Each data point represents a single patient. Top row shows individual scores at admission, discharge, six weeks and six months after discharge. Bottom row shows the individual difference scores for admission to discharge, admission to six weeks post-discharge, and admission to six months post-discharge. Scores are shown for modified Fugl-Meyer (upper limb), Action Research Arm Test and Chedoke Arm and Hand Activity Inventory (CAHAI). Median (solid line) and upper and lower quartiles (dotted lines) are shown. (Reproduced with permission from Ward et al. J Neurol Neurosurg Psychiatry. 2019 May;90(5):498-506).

than are currently being used. The second question to be raised is what are the key 'active ingredients' of an upper limb rehabilitation treatment? Whilst it is not clear what the optimal behavioural approach for promoting upper limb recovery should be, it is clear that simple protocol driven approaches have not led to large or sustained effects,[17] both of which are necessary to produce a step change in stroke recovery. Successful post-stroke neurorehabilitation is likely to require a combination of complimentary approaches. If we accept this premise, then we are unlikely to determine the optimal combination of active ingredients simply by studying each approach in isolation, because the interactions between these elements will also have to be considered.

So how do we work out what the 'active ingredients' of upper limb rehabilitation are? A more sensible way forward is to look at interventions that have already demonstrated a high level of efficacy and then begin to work out their key components. Here, it is important to say that we need to start with treatments that have a high chance of achieving minimum clinically important differences (MCID) rather than small changes that might be statistically significant. Both McCabe et al[14] and Daly et al,[15] as well as the QSUL programme,[16] produced large improvements on both impairment and activity limitation and both involved more complex treatment approaches, not restricted to one element. It is worth considering these in more detail.

- Analysis of movement and performance in activities of daily living. The initial assessment is crucial. The question, 'why does this person's hand and arm not work' should never be answered with 'because they have had a stroke'. There needs to be an appreciation of the range of potential contributory impairments (patterns of weakness, spasticity, loss of joint range, shoulder restriction and pain, sensory loss, apraxia, cognitive deficits, depression, apathy, fatigue etc.) because each of these becomes a therapeutic target. Our view is that without informed clinical reasoning based on the presence or absence of specific impairments, the correct treatment approach is unlikely to be selected.
- Identify and treat barriers. Avoid complications that will prevent participation in an active rehabilitation programme. We commonly see loss of passive joint range preventing people accessing finger or thumb movement, due to either spasticity or non-neural shortening. This can happen at most joints, but particularly in the hand. As well as increased finger flexion, be alert to loss of flexion at MCP joints which makes it difficult to shape the hand properly. Treatment involves splinting and optimal spasticity management. We also see pain and restriction of range in the shoulder. Restriction of external rotation in particular should raise the possibility of adhesive capsulitis. Despite the lack of a clear evidence base for treating post-stroke adhesive capsulitis, anecdotally we have had success with capsular hydrodilatation followed by physiotherapy.
- Preparation. Manual techniques are used to optimise and improve baseline at an impairment level, for example mobilising joints to improve range, lengthening and strengthening muscles to ensure they are at a biomechanical advantage to generate force, training sensory discrimination and improving postural control and balance.
- Reduction of impairment and re-education of quality and control of movement within activities of daily living. Individualised meaningful tasks are practiced repeatedly in order to facilitate task mastery with a focus on quality of movement. This is achieved through (i) adaptation of the task, e.g. decomposing tasks into individual components to be practiced; (ii) adaptation of the environment, e.g. fabrication of functional splints and adaptation of tools such as cutlery or screwdrivers, to enable integration of the affected hand in meaningful activities; (iii) assistance, e.g. de-weighting the arm to allow strengthening and training of movement quality and control through increased range.
- Coaching (involving instruction, supervision, reinforcement) was considered a key component of the QSUL programme, used throughout to embed new skills and knowledge into individual daily routines. Consequently, individuals increase participation and confidence in their desired goals, enhancing self-efficacy and motivation to sustain behavioural change beyond the end of the active treatment period.
- Sustaining change. Our view is that the approach described, delivered at a high dose is most likely to achieve clinically meaningful improvement together with improved self-efficacy and behaviour change that results in retention of gains or further improvement (something not routinely seen with many upper limb interventions that have been investigated).

Rehabilitation is often criticised for not following standardised approaches that lend themselves to investigation through clinical trials. However, when single elements are then studied in isolation the results are often not clinically meaningful and are not sustained.[18,19] Looking at the difference between these approaches and those taken by McCabe et al[14], Daly et al[15] and QSUL[16] should be informative, with a view to formally describing the key elements of a successful treatment. Whilst approaches at the activity and participation level will vary as they are tailored to an individual's specific meaningful goals, the overall therapeutic approach taken towards specific

impairments should be the same across all patients. Ideally, it should be possible to describe the principles of an optimal intervention using a format such as the TIDIER guidelines.[18,19]

There is a way to go before we can really say we understand both the treatment itself and the effects of the treatment on individuals. This will require careful assessment of both the 'input' (the nature of the behavioural intervention) and of the 'output' (the resulting behavioural change) at a level of fine-grained detail that is not currently achieved on a regular basis, for example using kinematic[20] or neurophysiological[21] assessment. In addition, this input-output relationship will be modulated by a number of patient characteristics, which could relate to behavioural characteristics (e.g. severity, presence of multiple impairments) or to biological characteristics (e.g. the nature and extent of brain damage, time since stroke, age, medication).

Overall, our experience suggests that much higher doses and intensity of upper limb neurorehabilitation can be delivered with beneficial effects. We have highlighted the need to consider the dose and the nature of the intervention as well as appropriate patient stratification in informing future clinical trial design.

REFERENCES

1. Lawrence ES et al. *Estimates of the prevalence of acute stroke impairments and disability in a multiethnic population.* Stroke. 2001;32:1279–1284.
2. Broeks JG, Lankhorst GJ, Rumping K, Prevo AJ. *The long-term outcome of arm function after stroke: results of a follow-up study.* Disabil Rehabil. 1999;21:357–364.
3. Kwakkel G, Kollen BJ, van der Grond J, Prevo AJH. *Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke.* Stroke. 2003;34:2181–2186.
4. Nakayama H, Jørgensen HS, Raaschou HO, Olsen TS. *Recovery of upper extremity function in stroke patients: the Copenhagen Stroke Study.* Arch Phys Med Rehabil. 1994;75:394–398.
5. Sunderland A et al. *Enhanced physical therapy for arm function after stroke: a one year follow up study.* J. Neurol. Neurosurg. Psychiatr. 1994;57:856–858.
6. Wade DT, Langton-Hewer R, Wood VA, Skilbeck CE, Ismail HM. *The hemiplegic arm after stroke: measurement and recovery.* J. Neurol. Neurosurg. Psychiatr. 1983;46:521–524 .
7. Corbetta D, Sirtori V, Castellini G, Moja L, Gatti R. *Constraint-induced movement therapy for upper extremities in people with stroke.* Cochrane Database Syst Rev CD004433 (2015). doi:10.1002/14651858.CD004433.pub3
8. Kwakkel G, Veerbeek J, van Wegen EEH, Wolf SL. *Constraint-induced movement therapy after stroke.* Lancet Neurol. 2015;14:224–234.
9. French B et al. *Repetitive task training for improving functional ability after stroke.* Cochrane Database Syst Rev. 2016;11:CD006073.
10. Veerbeek JM, Langbroek-Amersfoort AC, van Wegen, EEH, Meskers CGM, Kwakkel G. *Effects of Robot-Assisted Therapy for the Upper Limb After Stroke.* Neurorehabil Neural Repair. 2017;31: 107–121.
11. Rodgers H et al. *Robot assisted training for the upper limb after stroke (RATULS): a multicentre randomised controlled trial.* Lancet (2019). doi:10.1016/S0140-6736(19)31055-4.
12. Lang CE et al. *Dose response of task-specific upper limb training in people at least 6 months poststroke: A phase II, single-blind, randomized, controlled trial.* Ann. Neurol. 2016;80:342–354.
13. Winstein CJ et al. *Effect of a Task-Oriented Rehabilitation Program on Upper Extremity Recovery Following Motor Stroke: The ICARE Randomized Clinical Trial.* JAMA. 2016;315:571–581.
14. McCabe J, Monkiewicz M, Holcomb J, Pundik S, Daly JJ. *Comparison of robotics, functional electrical stimulation, and motor learning methods for treatment of persistent upper extremity dysfunction after stroke: a randomized controlled trial.* Arch Phys Med Rehabil. 2015; 96:981–990.
15. Daly JJ et al. *Long-Dose Intensive Therapy Is Necessary for Strong, Clinically Significant, Upper Limb Functional Gains and Retained Gains in Severe/Moderate Chronic Stroke.* Neurorehabil Neural Repair. 1545968319846120 (2019). doi:10.1177/1545968319846120.
16. Ward NS, Brander F, Kelly K. *Intensive upper limb neurorehabilitation in chronic stroke: outcomes from the Queen Square programme.* J Neurol Neurosurg Psychiatry jnnp-2018-319954 (2019). doi:10.1136/jnnp-2018-319954
17. Pollock A et al. *Interventions for improving upper limb function after stroke.* Cochrane Database Syst Rev. CD010820 (2014). doi:10.1002/14651858.CD010820.pub2
18. Hoffmann TC et al. *Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide.* BMJ. 2014;348:g1687.
19. Walker MF et al. *Improving the Development, Monitoring and Reporting of Stroke Rehabilitation Research: Consensus-Based Core Recommendations from the Stroke Recovery and Rehabilitation Roundtable.* Neurorehabil Neural Repair. 2017;31:877–884.
20. Balasubramanian S, Colombo R, Sterpi I, Sanguineti V, Burdet E. *Robotic assessment of upper limb motor function after stroke.* Am J Phys Med Rehabil. 2012;91:S255-269.
21. Cheung VCK et al. *Muscle synergy patterns as physiological markers of motor cortical damage.* Proc. Natl. Acad. Sci. U.S.A. 2012;109:14652–14656.

Editorial board and contributors

Dr Michael Zandi MA MB BChir PhD FRCP is Consultant Neurologist at the National Hospital for Neurology and Neurosurgery, Queen Square, London and Honorary Senior Lecturer at the UCL Queen Square Institute of Neurology Department, supported by the UCLH NIHR Biomedical Research Centre.

Todd Hardy Dr Todd Hardy BSc (Hons I), PhD, MBBS, FRACP, is Co-Editor of ACNR and is a Staff Specialist Neurologist at Concord Repatriation General Hospital, Clinical Associate Professor in Neurology at the University of Sydney, and Co-Director of the MS Clinic at the Brain and Mind Centre. His main interests are multiple sclerosis and other immune-mediated central nervous system disorders.

Ann Donnelly MB ChB BSc (Clin Neurosci) MRCP is Co-Editor of ACNR and a Locum Consultant in Neurology at the Royal Free Neurological Rehabilitation Centre. She completed undergraduate training at University of Glasgow Medical School, with Neurology postgraduate training at Kings College Hospital, National Hospital for Neurology and Neurosurgery, and Guys and St Thomas' Hospital. She is interested in neurorehabilitation with a focus on patients with multiple sclerosis.

Kirstie Anderson, BMedSci, MBBS, MRCP, DPhil (Oxon), runs the Regional Neurology Sleep Service with a clinical and research interest in all the sleep disorders. She is an Honorary Senior Lecturer at Newcastle University with an interest in the link between sleep and mental health.

Roger Barker MRCP, PhD, F.Med.Sci., is Consulting Editor of ACNR, Professor of Clinical Neuroscience at the University of Cambridge and an Honorary Consultant in Neurology at The Cambridge Centre for Brain Repair. His main area of research is into neurodegenerative and movement disorders, in particular Parkinson's and Huntington's disease.

Alasdair Coles PhD, is Consulting Editor of ACNR. He is a Professor in Neuroimmunology at Cambridge University. He works on experimental immunological therapies in multiple sclerosis.

Rhys Davies MA, BMBCh, PhD, MRCP, is Editor of our Book Review Section. He was accredited as a Consultant Neurologist on the specialist register in 2009 and is currently a Consultant Neurologist at the Walton Centre for Neurology and Neurosurgery in Liverpool and at Ysbyty Gwynedd in Bangor, North Wales. He has a clinical and research interest in cognitive neurology.

Imran Noorani MA, MBBChir, MRCS, is Neurosurgical Conference News Editor. He is an Academic Neurosurgery Foundation Trainee in Southampton General Hospital having trained in Cambridge. His academic interest is oculomotor neurophysiology, specifically models of saccadic decision and their potential application to neurological disorders.

Emily Thomas, BmBCh, MRCP, PhD is the Editor of our Rehabilitation Section. She is a Consultant in Rehabilitation working for Solent NHS Trust, Southampton. Her main interests are holistic brain injury, rehabilitation and spasticity management.

David Werring FRCP, PhD, FESO, is ACNR's Stroke Editor. He is Professor of Clinical Neurology at UCL Institute of Neurology, Queen Square, and Honorary Consultant Neurologist at University College Hospital and The National Hospital, Queen Square.

Peter Whitfield BM (Distinction in Clin Med), PhD, FRCS Eng., FRCS, SN, FHEA, is ACNR's Neurosurgery Editor. He is a Consultant Neurosurgeon at the South West Neurosurgery Centre, Plymouth. His clinical interests are wide including neurovascular conditions, head injury, stereotactic radiosurgery, image guided tumour surgery and lumbar microdiscectomy. He is an examiner for the MRCS and is a member of the SAC in neurosurgery.

Alastair Wilkins PhD, is our Case Report Co-ordinator and is Reader in Neurology, University of Bristol and Consultant Neurologist at Frenchay Hospital, Bristol. His research interests are the basic science of axon degeneration and developing treatments for progressive multiple sclerosis.

Angelika Zarkali MBBS, PGDip, MRCP, is the Editor of our Conference News section. She is a Research Fellow in the Dementia Research Centre, UCL and a Specialist Registrar in Neurology in St George's hospital. She has an interest in neurodegeneration and cognitive disorders.