Stroke rehabilitation: what's important now?

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The impact of stroke on the individual and on wider society is substantial. Stroke is a major public health challenge, hence research into rehabilitation after stroke has been at the forefront of recent developments. Important principles underpinning modern stroke rehabilitation include intervening early after onset, and the use of repetitive, task-specific activity. It is known that physiotherapy is important in ameliorating some of the effects of stroke. Physiotherapists are well placed to meet the challenge of delivering rehabilitation according to the identified principles within modern healthcare systems.

Learning outcomes

1. Recognise the importance of stroke rehabilitation research that addresses the primary needs of stroke survivors.
2. Identify the key neuroscience principles that underpin modern stroke rehabilitation, via critical evaluation of current evidence.
3. Consider how to apply the identified principles in stroke rehabilitation practice to optimise outcomes for stroke survivors.

Stroke is important

Stroke is one of the top three causes of death and the largest cause of disability in the United Kingdom (Intercollegiate Stroke Working Party, Royal College of Physicians 2012). There are 152,000 strokes in the UK each year, causing a greater range of disabilities than any other condition (Stroke Association: Stroke Statistics 2013). Direct costs to the NHS are over £3 billion a year within a wider economic impact of up to £8 billion (Department of Health, National Audit Office 2010).

More than 1.1 million people in the UK have had a stroke and many live with persistent consequences. Of those who survive the initial stroke, 58% will have some form of disability with 36% having disability categorised as moderate, severe, or very severe (Stroke Association: Stroke Statistics 2013). In England alone, more than 300,000 people are living with moderate to severe disabilities as a result of stroke (Department of Health, National Audit Office 2010), including deficits of motor function. Indeed, restrictions in muscle activity and mobility are the most widely recognised deficits caused by stroke (Langhorne *et al* 2009a). Stroke is a life-altering condition with potentially devastating sequelae.

This recognition of its far-reaching impact has driven extensive research into stroke recovery in the last 30 years. While there is little doubt that research into the medical management of stroke is of importance, it is research into rehabilitation after stroke that has been at the forefront of recent developments, with recognition that interventions that do not rely on costly scanning and drugs are likely to be most beneficial (Langhorne *et al* 2009b). Investment in rehabilitation research is justified. Whereas most patients with stroke will survive the initial event, it is the ensuing consequences that have the greatest impact on stroke survivors, their families and society (Langhorne *et al* 2011). After initial medical input, rehabilitation is the primary treatment option available for stroke survivors with on-going deficits, using restorative and adaptive strategies to enable and maximise independence. Stroke rehabilitation is often regarded as cyclical, involving assessment, goal setting, intervention and reassessment (Langhorne *et al* 2011); with members of a skilled multi-disciplinary team working alongside patients, their families and carers. Physiotherapists are, of course, an integral part of this stroke rehabilitation team.

Physiotherapy is important

The education of motor function via movement experience is central to the physiotherapist's role in stroke rehabilitation. Whether immediately after onset, or in the following months and years, we enable people to move better. Current neurophysiological evidence shows that this behavioural experience drives reorganisation of brain neural networks after injury such as stroke; this knowledge provides the scientific rationale for our therapeutic interventions (Nudo 2006).

Therapy after stroke aims to drive neural plasticity with afferent stimulation through a variety of interventions (Pomeroy & Tallis 2002). While it is clear that stroke recovery is a complex process occurring via multiple mechanisms, beneficial cortical reorganisation has been demonstrated following therapeutic activity in the upper limb (e.g. Askim *et al* 2009) and in the lower limb (e.g. Perez *et al* 2004). However, debate is on-going regarding the type and intensity of rehabilitative training required.

It is important that we understand how factors such as therapy intensity might affect the central nervous system, so that we can maximise recovery. There are currently no definite recommendations (Wahl & Schwab 2014). It is, therefore, unsurprising that physical therapy approaches and interventions

are on-going priorities for stroke research (Pollock *et al* 2012). A recently updated Cochrane review found that, while no single therapeutic approach was superior to any other in improving function and mobility after stroke, physical rehabilitation consisting of various components and approaches was effective. The authors concluded that therapy should consist of well-defined, evidence-based interventions (Pollock *et al* 2014). Knowledge that therapy works is powerful; we now have further work to do to define more clearly and test specific interventions that might contribute most to effective rehabilitation training programmes. We also need to be cautious in the adoption of interventions without sufficient testing of efficacy, avoiding the "menace of evidence tinged rehabilitation" (Pomeroy & Tallis 2003). For example, various devices for lower limb cycling exercise are commonplace in stroke rehabilitation departments, and though the general benefits of exercise after stroke are well documented, there is currently insufficient evidence of the specific effects of pedalling exercise on motor function after stroke (Hancock *et al* 2012). Similarly, over the past decade, many therapy units have installed treadmills to enable stroke survivors to participate in body weight support treadmill training (BWSTT); however, results of the effectiveness of BWSTT on walking outcomes after stroke have shown no benefit over established over-ground walking training, despite a number of well-designed, randomised controlled trials (Dobkin & Duncan 2012).

As clinical therapists, we must be mindful that, just as rehabilitation training can drive functionally useful brain changes, it may also contribute to changes that drive maladaptive plasticity and limit recovery (Kleim & Jones 2008). For example, establishing compensatory behaviours early after stroke might reduce future recovery potential (Levin *et al* 2009). While there is no simple recipe for promoting high-quality stroke recovery through rehabilitative training, it is essential we enhance our understanding of the principles underpinning how to drive useful, functional recovery after stroke. Through this understanding, we might best inform our current practice. The following sections discuss these principles in more depth.

Early intervention is important

It is known that the aforementioned mechanisms of neural plasticity are particularly active early after cortical damage (Kleim *et al* 2003). It is also known that most spontaneous recovery tends to occur in the first three months (Cramer 2008; Cauraugh & Summers 2005), with significant spontaneous recovery of some motor functions within 30 days (Nudo 1999). It is possible that motor learning mechanisms are active during this spontaneous recovery and are integral to rehabilitation training at this time (Krakauer 2006).

However, while early rehabilitation intervention is currently encouraged after stroke (Intercollegiate Stroke Working Party, Royal College of Physicians 2012), the optimal time window for provision of rehabilitation therapies to exploit the potential for behaviourally driven brain reorganisation is still uncertain. Hence, research into the most appropriate time to initiate rehabilitation activity after stroke is gaining momentum. Indeed, Cramer (2008) describes a "golden period" for initiating restorative therapies, starting in the first days after onset and continuing for several weeks, as repair-related events within the brain are at peak levels. Such molecular and cellular events include, for example, an increase in growth associated proteins and increased neuronal sprouting and dendritic branching; all of which are important biological targets for promoting repair after stroke (Nudo 1999). The prominence of these events at this time might suggest that they could best be shaped to enhance recovery by the behavioural experiences offered by physical therapy, implemented in the first days to weeks after stroke. Certainly, improvements in upper limb function persisting to five-year follow-up have been demonstrated following intensive training instigated early (two to five weeks) in people after stroke (Feys *et al* 2004). Additionally, findings from a large, multi-centre randomised controlled trial suggest that mobilisation within 24 hours of stroke, and regularly thereafter, is associated with faster return to walking and good functional outcome at three and 12 months, in comparison to standard care controls (Cumming *et al* 2011).

It should be noted that animal studies have led to some caution in recommending intense activity very early after stroke due to possible exaggeration of lesion size and associated behavioural deficits (Kozlowski *et al* 1996). However, this study in rats involved intense, forced use of the affected limb with constraint of the non-affected limb for long periods from day one after an induced lesion, a situation unlikely to be repeated in clinical practice with human stroke survivors. Indeed, Krakauer *et al* (2012) state that an overall consensus from animal studies suggests rehabilitation initiated from five days has no adverse effects.

Concern has also been expressed that delaying rehabilitation onset after stroke might lead to established compensatory behaviours that could impair future recovery (Levin *et al* 2009), and immobility might also prevent the brain from making the neurophysiological changes required to reacquire movement. After stroke onset, the brain will not discriminate between "appropriate" and "inappropriate" movements and only make neurophysiological changes in response to the former; there is response to all behavioural inputs. On balance, initiating therapies in the early period after stroke is logical. It is, therefore, up to us as physiotherapists to shape that early input, using our expert knowledge of movement, as we educate stroke survivors in their recovery.

Practice of task-specific activity is important

There is ongoing scientific debate about the optimal intensity of therapy required to maximise neuroplastic change and the possible consequences in terms of functional recovery (e.g. Kwakkel 2006). However, it is known that the repetition of skilled motor activity can produce changes in brain representation maps. Animal studies have established a relationship between repeated behavioural experiences, such as the practice of a skilled upper limb task to retrieve food, and beneficial alterations in cortical representation maps (e.g. Kleim *et al* 2002; Plautz *et al* 2000; Nudo *et al* 1996). Animal model research found that up to 400 repetitions were required in a 30-minute session to induce changes in cortical representations (Kleim *et al* 1998).

Such animal models have provided a basis for further research in human subjects. Karni *et al* (1995) trained a small sample of healthy young adults in a finger-tapping task and, unsurprisingly, found that daily, repetitive practice of the movement increased the speed and accuracy of that movement. These improvements were accompanied by specific neuroplastic changes in the primary motor cortex, suggesting that the repetitive training led to a gradually evolving improved cortical representation of the skilled movement over time, supporting the concept of repetitive practice of a motor skill to enhance beneficial functional brain changes. There have also been indications that beneficial neuroplastic changes occur in the primary motor area when skilled lower limb activity is practised (Perez *et al* 2004). Although these studies were carried out in healthy volunteers who did not have the altered neural networks associated with stroke, these studies provide useful foundations for work with stroke survivors.

Johansen-Berg *et al* (2002) have, however, carried out such work with stroke survivors. They explored, through a clearly defined, graded upper limb exercise programme, the effects of repetitive practice on brain activity in a small group of chronic stroke survivors. Beneficial brain changes in the premotor and sensorimotor cortices that correlated with therapy associated improvements in motor function were demonstrated, suggesting that the repetitive, graded therapeutic activity was having a beneficial effect on brain activity after stroke.

It has also been suggested that functional benefit may be gained from goal directed activity; hence the salience of a task is considered an important element in rehabilitation programmes (Kleim & Jones 2008). Findings from a systematic review of 14 trials of specific, goal directed, repetitive activity reported moderate improvements in lower limb function, particularly on walking outcomes (French *et al* 2009). This review provides some support for developing task specific lower limb training programmes after stroke in addition to usual care; though it should be noted that there was no evidence of sustained training effects from any included programme.

The need for salient lower limb rehabilitation interventions is further reinforced by knowledge that stroke survivors themselves cite recovery of walking as a primary goal (Dickstein 2008) and they, therefore, wish to engage in therapeutic activity contributing to this aim. However, practising relevant activities to improve walking after stroke can be challenging for patients and therapists. Stroke survivors often have substantial weakness and require considerable support to take just a few steps. While patients may be able to practise component parts of the activity, opportunities for repetitive practise of complete, reciprocal, antagonistic lower limb activity in walking-like postures can be limited, particularly early after onset. Work is under way by our research team at UEA to try to address this challenge (Hancock *et al* 2011).

It is important to provide stroke survivors with numerous opportunities for repetitive practice of skilled functional activity. Such practice should not just be incorporated into specific prescribed exercise programmes, but be exploited at every opportunity throughout the day. Education of the individual and those around them is essential to take advantage of the brain's fantastic capacity for remodelling as a result of practising a task personally relevant to each stroke survivor. An individualised approach to such practice is vital; where, for one person, rehabilitation training might focus on safely standing from a chair and taking a few steps, for another it may be centred on a return to sporting activity. As physiotherapists, we have the skill and expertise to work in a team with stroke survivors and their families to meet their individual needs, promoting optimal quality of life after stroke.

New ways of delivery are important

Healthcare is changing more rapidly than at any time since the inception of the NHS. It is well known that current healthcare drivers support earlier transfer of stroke survivors from hospital to home, but that specialist community rehabilitation services are often limited in terms of intensity of direct patient provision. We need to consider the increasing demand for more specialist rehabilitation in people's homes and other community settings after the patient's discharge from hospital stroke services. This discharge is occurring earlier than ever and, as stated previously, these early weeks provide an important window for targeting physical therapy. Opportunities for early, targeted functional activity must be available in settings beyond the hospital. Tele-medicine is increasingly available in acute medical situations. A recent systematic review demonstrates that research into tele-rehabilitation is gaining momentum (Laver *et al* 2013) and although much further work is required, including consideration of cost effectiveness, we may need to consider this further investigation of tele-rehabilitation for remote implementation and monitoring of rehabilitative training beyond traditional settings.

Conclusion

The role of physiotherapy throughout the stroke rehabilitation pathway cannot be underestimated. Research in the last 25 years has enlightened our ability to shape and interpret the recovery of the central nervous system after injury such as stroke. Recent advances in stroke rehabilitation research have enabled the emergence of key neuroscience principles about exogenous means of driving recovery, and an understanding of this science underpinning rehabilitation is crucial for physiotherapists, to be able to provide their patients with the best care as integral members of the multi-disciplinary team. We need to assess, treat and educate people early after a stroke; by encouraging repeated practice of functionally relevant interventions, we can optimise the potential for recovery of high-quality motor skill after this life-changing event. As methods of delivery and locations change, we need to be flexible in our approach, supporting people to participate in rehabilitative training in their homes and other community locations. We need to engage with new technologies such as tele-rehabilitation, while continuing to practise what we already know works. It is unlikely that we can continue to justify working in the historical silos of pure clinical specialism; it is creative thinking and transferable, evidence-based skill that will best serve those who have survived stroke and are dealing with its effects every day.

About the author

Dr Nicola Hancock is a lecturer in physiotherapy and researcher with the Acquired Brain Injury Rehabilitation Alliance (ABIRA) in the School of Health Sciences at the University of East Anglia. Her primary research interest is the recovery of lower limb function after stroke, with particular focus on people who, early after stroke, have substantial weakness. She represents the Association of Chartered Physiotherapists in Neurology (ACPIN) on the Intercollegiate Stroke Working Party at the Royal College of Physicians.

Acknowledgements:

Professor Valerie Pomeroy, Professor of Neurorehabilitation, School of Health Sciences, UEA, for her helpful comments on the draft of this article.

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