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Future Medicine Review Article

Title:

Upper limb rehabilitation following stroke: current evidence and future perspectives

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Tables and Figures:

Abstract / Summary

Stroke is a leading cause of disability worldwide, with risk increasing with age. Upper limb hemiparesis is common and associated with persistent impairments and associated disabilities. Older stroke populations often suffer multiple co-morbidities and restoring independence is complex. Recovery of upper limb function can be crucial for them to return to independent living and to participate in community life.

This review describes upper limb recovery post stroke, and some of the new therapeutic approaches available to promote recovery. Technologies (including virtual reality and telehealth) offer the opportunity for more home based therapies, longer programs, greater access to rehabilitation for older people however the trials continue to exclude older people so acceptability is poorly understood.

Introduction:

The World Stroke Organization awareness campaign highlights the global burden of stroke, promoting the statistic that 1 in 6 persons worldwide will suffer a stroke in their lifetime. Whilst stroke can occur at any age, age is a significant risk factor with 75% of strokes occuring in people over the age of 65 [1]. National Institute of Health [201] data reflect a doubling of stroke risk for each decade after 55 years of age (Table 1). With an increasing ageing population, rehabilitation programs need to incorporate evidence which is relevant, acceptable and applicable to an elderly population. Despite this, the majority of published research is not targeted towards the aged patient [2].

[Insert **Table 1**]

With improved survival and an ageing population, stroke continues to rank as a leading cause of long-term disability [3] and the most common problem reported by stroke survivors is associated with upper limb hemiparesis[4]. Up to 80% of survivors have upper limb problems in the immediate post-stroke period [5] with studies reporting significant rates of persisting impairment ranging from 30% [5] up to as high as 75% [6]. Recovery of upper limb dexterity and function is reported in the range of 30% [7] with as few as 5-20% achieving full functional recovery [8].

Many stroke survivors have somatosensory deficits but a large proportion of these may be missed in assessment. A prospective observational study of 70 stroke survivors identified 53% as having impaired tactile sensation, 89% with impaired stereognosis, and 63% with deficits in proprioception[9]. Other foci for intervention include coordination deficits, apraxia and complications of upper extremity involvement. Negative features of upper motor neuron syndrome such as weakness can lead to subluxation whilst positive features such as spasticity can lead to pain and contracture. The multifactorial etiology of hemiplegic shoulder pain [10] with or without the presence of subluxation [11] has made it resistant to most treatment approaches.

Using the World Health Organization International Classification of Functioning, Disability and Health (ICF) framework the burden of upper limb impairment after a stroke can be seen in terms of its impact on the potential activity and participation domains of a stroke survivor's future life (Figure 1). The lack of autonomy in daily tasks following stroke can impact an individual's self-image, willingness to go out and quality of life. Multiple interventions are often needed to address the shifting nature of problems over an acute, subacute and chronic period. Gains in motor recovery measures do not necessarily translate to equivalent improvements in functional upper limb use so there is a need to focus on both impairment and activity measures to guide intervention options [12].

[Insert **Figure 1**]

What does the evidence say about upper limb recovery after stroke?

Understanding patterns of upper limb recovery following stroke could potentially allow the application of targeted and appropriate interventions to stratified patient groups, resulting in a more efficient allocation of resources [13]. Rehabilitation can focus on compensatory strategies, and / or restorative approaches but decisions about who should receive which approach often vary. The Canadian Evidence-Based Review of Stroke Rehabilitation (EBRSR) [202] advises that restorative goals are appropriate for those patients who are expected to achieve greater upper limb motor recovery, whilst compensatory goals are more appropriate when poor motor recovery is anticipated [14]. In the absence of any recovery, prevention of secondary complications such as spasticity or shoulder instability might be the most suitable focus of treatment [13]. In practice, decisions on the therapy approach are often based on a combination of the therapist's experience and the patient's response to therapy.

Not surprisingly the severity of early motor impairment is an important factor associated with recovery [7, 15]. A recent systematic review summarized evidence-based clinical and neurophysiological factors associated with upper limb recovery (Figure 2).

[Insert **Figure 2**]

Combining the strongly predictive factors outlined above, an algorithm has been proposed to assist the clinician in prognostication and treatment selection. The algorithm [13] uses the following three components to stratify acute stroke survivors (mean age 70) into categories of complete, notable, limited or no recovery of the upper limb at 12 weeks:

- Shoulder abduction and finger extension strength grading at 72 hours post stroke

- Transcranial magnetic stimulation (TMS) to assess functional integrity of descending motor pathways at 2 weeks post stroke
- Magnetic Resonance Imaging (MRI) diffusion weighted image to assess structural integrity of posterior limb of internal capsule at 2 weeks post stroke

A prospective observational study of 299 stroke survivors [16] assessed upper limb capacity at the beginning and at the completion of rehabilitation in subjects with a mean age of 60 (11.1). With the use of the Stroke Upper Limb Capacity Scale (SULCS), a ten item clinical assessment of arm and hand capacity, this study also concluded that absence of early proximal arm control bodes a poorer prognosis for future hand capacity.

Neuroanatomical imaging may enhance clinical assessments, with increasing evidence that neurophysiological measures obtained from TMS may produce useful information [15]. Information regarding lesion size and lateralization can help to establish anticipated deficits and recovery patterns. Pure cortical involvement predicts recovery of up to 75% of patients with hemiplegic upper limb, as opposed to the significant decline in motor recovery to rates less than 5% when lesion location involves the corona radiata or posterior limb of the internal capsule [17]. In particular, evidence of integrity of descending motor tracts is closely correlated to functional recovery outcomes [18].

Decisions on the likelihood of recovery made in the acute post stroke period require ongoing evaluation to allow for false negatives, assess motivation and share information with the patient and family. The impact of personal and environmental factors (see Figure 2) should never be underestimated. Secondary analysis of a multisite randomized controlled trial described the involvement of caregivers as a more significant determinant of upper limb improvement than initial motor impairment or therapy intensity [19]. Patient perspectives, education and individualized goal-setting are important considerations in stroke rehabilitation.

The challenge of implementing evidence based practice in clinical settings

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> *Evidence-based practice involves the "integration of best external evidence with clinical expertise and patient values"*
>
> - Sackett et al [20]

The quantity of stroke rehabilitation research continues to increase, providing an expanding breadth of evidence on which to base clinical management. Decisions on therapy interventions have historically been predominantly based on clinical experience but while the shift towards practice grounded on research has occurred there is need for more evidence on which types of strokes will respond to particular interventions. However a key problem remains ensuring that current evidence is implemented

Evidence-based guidelines are designed to improve patient outcomes but national audits reveal uptake is inconsistent. The Australian National Stroke Foundation (NSF) audit of 2012 revealed that whilst 90% of strokes were admitted to hospital, only one third were accessing rehabilitation [21]. In patients accessing rehabilitation, there are missed therapeutic opportunities, with the majority of patient time still spent inactive [22]. Canadian research [23, 24] reflecting on the challenges of transferring evidence into practice identified the following problems: poor generalizability of research finding to the 'average' patient, limitations in the strength of evidence available, and difficulties with the practicalities of adhering closely to evidence based guidelines [23].

The Australian NSF casenote audit in 2012 [21] included an assessment of the level of implementation of evidence-based guidelines for upper limb impairment management post stroke. This case series audit was conducted across 101 hospitals with a total of 2801 patients. Data collected indicated that of 69% stroke survivors with upper limb impairment, 93% received at least one treatment recommended in the guidelines, and 14% received none of the guideline interventions. Higher rates were reported for 'repetitive task specific training' and 'other therapy', 83% and 50% respectively. CIMT and mechanically assisted therapies were used less often with reports of 6% and 9% respectively. The lower rates reported for these items may well reflect a more acute patient population than currently indicated for CIMT, and limited access to equipment for newer mechanically-assisted therapies. Disappointingly, these figures demonstrate little improvement in incorporation of evidence into practice when compared to earlier audits [25]. Implementation of technology in clinical practice similarly remains low [26]. Therapist experience [27] and the practical issue of therapist time constraints in accessing, understanding and implementing evidence also affect the implementation of evidence.

Increasing the amount of therapy has been a focus in many centres and dedicated stroke rehabilitation units are trending towards additional weekend therapy, benchmarking hours of therapy per day and providing more task-specific therapies [21]. Other potential methods for increasing dose and augmenting conventional therapies lie in the adoption of novel methods of service delivery, including technology-assisted options.

Identifying the research to practice gap, a five-phase tool for successful implementation of technology in upper limb stroke rehabilitation has been proposed [26]. The five phases are designed to motivate and enable therapists to employ new practices [26], and include:

i. Orientation: establishing awareness of new technology to therapists
ii. Insight: providing information and understanding of potential of new therapies
iii. Acceptance: therapist and patient motivation to incorporate new therapies
iv. Change: introducing new therapies with opportunities for training, and implementation of an easy-to-use system
v. Retention of change: incorporation into existing practices and protocols

The practicalities of funding and resource allocation are likely to continue to limit access and older people are at risk of being excluded. New technologies such as telehealth offer the opportunity for more equitable access to clinical expertise. For example, a case series reviewing a combination of CIMT with remote technology reported gains in function, with good adherence and patient satisfaction [28].

What are the current and emerging rehabilitation strategies for treating upper limb impairments after stroke?

"Stroke rehabilitation is a progressive, dynamic, goal orientated process aimed at enabling a person with an impairment to reach their optimal physical, cognitive, emotional, communicative and / or social functional level"

– Teasell, Heart and Stroke Foundation, Ontario [203]

The current clinical approach framework

It is widely accepted that optimal care for the stroke survivor is achieved in an acute stroke unit followed by either treatment in a stroke rehabilitation unit, early supported home rehabilitation program or a dedicated outpatient unit. There is no evidence to support excluding stroke patients from stroke units on the basis of age. Stroke units are staffed by experienced nursing, medical and allied health clinicians who work with a coordinated, interdisciplinary team approach to provide optimal rehabilitation. Mortality and dependency rates are reduced with this model, with best outcomes achieved with integrated acute and rehabilitation care [29]. There is increasing evidence suggesting that intense rehabilitation should commence early after stroke to facilitate task-specific repetition, with evidence that this has a positive impact on both physical recovery and quality of life measures [30, 31].

The National Stroke Foundation (NSF) [204] provides the clinical guidelines for evidence-based stroke care in Australia. The guidelines stipulate high grade evidence supporting the structure of rehabilitation to enable maximal practice for the patient within the first 6 months post stroke (Level A, NSF). Research supports the key elements driving upper limb rehabilitation to be intensity, specificity and repetition. Practice dose can be maximized with task-specific circuit class training or video selfmodeling (Level B, NSF). Circuit class therapy has been established as a safe and effective rehabilitation technique [32] and achieves comparable results to those achieved in one on one therapy sessions [33].

In general there is a demand for increased dose and task-specificity [26, 34] within the established framework of rehabilitation to maximize recovery through restoration of function, adaptation to impairment, and reduction of secondary complications. However, skilled staff are scarce and rehabilitation units are limited. The future of stroke rehabilitation increasingly includes technological approaches [35]. In approaching the application of new technologies, a collaborative approach is required between researchers and clinicians [34]. Key elements for success are outlined [34] as encompassing understanding of the pathophysiology of brain disease and appropriate hypotheses to guide treatment, as well as the need for ongoing clinical assessments of efficacy and systematic approaches with which therapists can apply new technologies. Focus must necessarily remain on the individual, with an understanding that purpose-driven goals impacting patient attention and motivation are vital parameters in motor relearning [36].

The type, timing and intensity of interventions are the focus of ongoing research. Technological and conceptual therapeutic advances advocate early focus on motor relearning, but extend beyond the acute period with evidence additionally supporting the important impact of interventions in the chronic post stroke period. Advances in rehabilitation applications enable stroke survivors with severe hemiparesis to participate in restorative therapies [37], rather than be limited to compensatory strategies.

Langhorne et al [38] conducted a systematic review of interventions to promote upper limb motor recovery following stroke summarized in Figure 3.

[Insert **Figure 3**]

The role of Non-Invasive Brain Stimulation

> *"Knowledge of the capability of the brain to compensate for lesions is a prerequisite for optimal stroke rehabilitation strategies"*
>
> - Johansson BB [39]

Neuroplasticity is the 'inherent capacity for cortical reorganization or development of new functional connections in response to learning and experience' [40]. Functional brain imaging techniques, such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) corroborate the model of neuroplasticity as a contributor to motor recovery following stroke [41, 42]. Importantly, functional imaging supports the ability of post-stroke therapies to influence and be influenced by neuroplastic changes [43, 44]. Cortical representation is enhanced by rehabilitative training.

Repetitive transcranial magnetic stimulation (rTMS) and transcranial direct-current stimulation (tDCS), both non-invasive brain stimulation techniques, are postulated to have an adjuvant role in priming neural structures for maximizing therapeutic outcomes [44, 45]. The mechanism for improving responsiveness to therapy is hypothesized to stem from achieving greater balance of excitability between ipsilesional and contralesional motor corticies [45], hence optimizing enhanced plasticity secondary to motor practice [46].

A double-blind study [47] compared rTMS priming by inhibition of the unaffected motor cortex with sham priming prior to motor retraining in a cohort of chronic stroke patients. The authors demonstrated an induced increase in motor cortex excitability with positive influence of motor retraining hand task sustained to one week. A recent review article of 15 studies assessing tDCS in stroke therapy [48] concluded a consistent positive effect in promoting motor recovery in chronic stroke populations, and more so in those with milder degrees of impairment. A 2013 randomized controlled trial [43] demonstrated the benefit of cathodal tDCS in reducing upper limb muscle tone, with flow-over impact on function and activities of daily living. While more work is needed to establish protocols and identify those most likely to benefit it seems likely that priming the cortex will enter practice in the next decade.

Established concepts in upper limb rehabilitation post stroke

Repetitive, task-specific training

There is robust evidence to support [202] repetitive task-specific training as an approach for improving measure of upper limb function. The neuroscientific premise for task-specific training as a portal to motor learning are based on the experience- and learning-dependent aspects of neuroplasticity [49]. For example, a randomized controlled trial of 103 stroke survivors compared task-specific training with the standard neurodevelopmental technique of Bobath therapy over 4 weeks and demonstrated better outcomes for the task specific group which were maintained [50]. Maximum benefit from task-orientated training is achieved with intensive and early post-stroke application [51]. The 5 key elements for successful implementation of task-specific training [49] include:

i. Tasks which are relevant to the patient and context
ii. Random and changing tasks
iii. Repetitive tasks with massed practice
iv. Part and whole task practice
v. Reinforced with positive and timely feedback

Task-specific training is easy to implement in a variety of clinical settings and is a meaningful and motivating therapy approach for individuals. As a result there is widespread uptake of this approach.

Bimanual training

The evidence base for bimanual training is less secure. The approach is based on theoretical models [52] in which bilateral simultaneous movement may result in interhemispheric disinhibition and sharing of 'normal' movement commands from the contralesional hemisphere[53]. There is conflicting evidence regarding the treatment effect of bilateral upper limb training, with older reviews [54] supporting the interventions and more recent systematic reviews failing to find positive outcomes [55, 56].

Constraint-induced movement therapy

Constraint-induced movement therapy (CIMT) involves constraint of the unaffected limb combined with intensive practice, in a cohort of patients with sufficient finger flexion and wrist extension to allow use of hemiparetic upper limb. Sunderland and Tuke [57] outline the theory on which CIMT is based, with the hypothesis that impairment and subsequent reduction in function are exacerbated by learned non-use and subsequent reduction of upper limb cortical representation. Despite this, compensatory strategies, as opposed to reductions in impairment, are favored as the mechanism of CIMT [58].

CIMT is effective in improving spontaneous use of the hand in a select group of sub-acute and chronic stroke patients [38]. Patient selection is made on basis of motor impairment [4] and on ability to tolerate constraint impacts the applicability of this intervention [38], so less than 30% of potential candidates were able to participate in trial settings [59]. Compliance, fatigue and the time consuming nature and practicality of associated therapy are additional potential limitations [38, 59]. The EXCITE trial [60] assessed CIMT as compared to standard therapy, with a mean age of 61 (standard deviation 13.5) in the intervention group. Increasing age may well reduce the impact of traditional CIMT. At this stage, CIMT is less likely to be used in acute or even subacute inpatient settings than in an outpatient setting. However modified CIMT protocols for use in acute stroke rehabilitation are being assessed [61], with the goal of restoring function and preventing development of compensatory strategies.

Neuromuscular electrical stimulation

Neuromuscular electrical stimulation (NMES) to peripheral nerves can improve motor performance and cortical excitability following stroke [62]. NMES can be applied to promote functional tasks (functional electrical stimulation; FES), with or without active participation by the patient. A 2006 Cochrane review [63] on the effectiveness of electrical stimulation in upper limb functional recovery stated that there is insufficient evidence to guide clinical practice. National guidelines reflect the current level of evidence, with the National Institute for Healthcare and Excellence (NICE) Guidelines recommending against routine use of electrical stimulation for the arm and hand, whilst the Canadian Best Practice Recommendations for Stroke Care promotes use of FES to reduce impairment and improve function (see Table 2).

A systematic review of 19 clinical trials [64] concluded that stimulation triggered by voluntary effort was consistently more effective that passive stimulation of a paretic limb. This concept was further explored and supported by results of a recent small study in which electrical stimulation was able to be systematically reduced as upper limb voluntary effort and motor performance improved [65]. In exploring the role of electrical stimulation in the non-functional hemiplegic upper limb, a 2012 single blind randomized controlled trial [66] of 90 subjects demonstrated a positive effect on distal motor performance, but did not show a significant effect on function. Importantly, this study involved a more representative sample with mean age of 74.6 (standard deviation 11.0). NMES has also been shown to reduce post-stroke spasticity [67] and hemiplegic shoulder pain [68]. One of the potential advantages of this approach is that families can be taught to deliver the treatment and it can be delivered at home.

Emerging interventions in upper limb rehabilitation post stroke

Robotics

Robotic / device-driven rehabilitation systems offer the promise of providing an efficient approach to delivering an increased dose of therapy and providing practice which includes specificity of movement pattern generation, feedback and repetition [69] . A Cochrane review concluded that [70] that robotics may improve function and activities of daily living post stroke, but do not improve upper limb strength.   An earlier systematic review [71] also reported trends towards greater functional improvement with robotic use, but raised the question regarding whether gains were due to the treatment type, or the increased treatment dose and intensity. A 2012 systematic review [72] comparing dose equivalence between robotics and standard therapy, did not demonstrate better outcomes in motor recovery or function. There is some evidence for robotics use with the upper limb treatment across the spectrum of recovery phases, from acute [70] to subacute and chronic stages of recovery [73, 74]. One problem confronting clinicians is that while the evidence suggests robotic approaches are useful in improving functional and motor outcomes at the shoulder and elbow [202] there is little evidence for their use at the wrist and hand where gains are most functional. Patient satisfaction and adherence appear good with this approach possibly because many robotics include high quality gaming approaches which engage and motivate patients [75].   In summary, which evidence continues to emerge at present robotics appear useful as a complement to conventional approaches as a way of achieving higher “doses” of therapy.

Virtual reality and gaming strategies

Henderson et al [76] describe virtual reality "as a computer-based, interactive, multisensory simulation environment that occurs in real time". Virtual reality offers goal-directed and reward-based task training [77], with an immersive virtual environment potentially aiding task-specificity and patient motivation [76]. Feedback is predominantly visual, but can also be provided through other sensory modalities and interfaces. Multisensory feedback has an established role in promoting motor learning [78].

Using virtual reality in neuro-rehabilitation is based on the hypothesis that activation of neural motor areas occurs both as a result of motor execution and imagery of that same task [79]. The correlations between observation of computer generated imagery and generated actions are hypothesized to engage bilateral motor cortices. As with robotics, one of the principle contributions of virtual reality may be its potential for providing increased therapy dose. A 2011 Cochrane Review of the evidence for virtual reality approaches in stroke rehabilitation [80] reviewed 19 trials with a total of 565 participants, surmising that overall there is still limited evidence for virtual reality when compared to the same dose of conventional treatment. However there is promising evidence that virtual reality approaches improve upper limb recovery and impact positively on activities of daily living. Problems were noted in generalizing the findings to older people as most trials included younger people in the chronic phase. Only 34% of screened patients were recruited to studies suggesting there are significant barriers to the uptake of this approach. This raises concern about the generalizability of this intervention to an older population with no experience of gaming systems [81].

Studies evaluating patient perspectives have reported positively on acceptability [82], enjoyment, purpose and challenge [83]. However most of these studies continue to focus on younger stroke survivors while patient reports from a Discrete Choice Experiment of older patients in a geriatric rehabilitation ward [81] found older patients preferred traditional therapy over Wii Fit.

Telerehabilitation

Telerehabilitation is a subset of telemedicine and describes that application of telecommunications and health information technologies to improve access to rehabilitation and services, and to support independent living. The term is used to include assessment, monitoring, prevention, intervention, supervision, education, consultation, and counselling [206]. As countries improve their communication technologies it is becoming a realistic option for delivering rehabilitation to those who live in remote areas and to those who find it difficult to leave home. While many studies attempt to combine regular visits by therapists and nurses with remote contact (phone or videoconferencing) to support stroke survivors in risk factor management [84] or with psychosocial issues [85] several studies have assessed telehealth approaches to improving upper limb function using customised computer based training programs [86-88] but the trials are small and the results have been mixed. If the results are similar the important outcomes will be costs which are still high. Forducey (2012) assessed independence in activities of daily living following a telerehabilitation intervention (12 occupational and physio therapy sessions focused on education, retraining of self-care, functional mobility and posture, therapy to improve function in impaired limbs) delivered via video phone compared with delivered in person. Both groups improved but there were no significant differences in outcomes between the groups post intervention [89] . While the potential advantages are obvious, systematic reviews are inconclusive focusing on the highly selected populations, the absence of older people with cognitive impairment in the studies and the lack of information on cost effectiveness [90, 91].

Prevention and treatment of secondary upper limb complications

Rehabilitation of motor deficits post stroke must additionally aim to prevent and treat secondary complications affecting the upper limb. Commonly identified upper limb secondary complications include spasticity and contracture, subluxation, hemiplegic shoulder pain and distal oedema [25]. The NSF guidelines [204] summarize the evidence in recommending prevention and management options for these complications. Level of evidence is graded from A-D, or as a Good Practice Point (GPP) based on experience and opinion. The highest grade of evidence for management of upper limb complications is level B, defined as “a body of evidence that can be trusted to guide practice in most situations”, and is only recorded for one treatment and two preventative strategies in total. The remainder of evidence is level C, D and GPP, reflecting limited new preventative or interventional opportunities for upper limb complications. The paucity of evidence to support the clinician in best prevention and management of common upper limb complications is an area in great need of future focus. Complications can contribute to pain, depression, and poorer ability to participate in specific neurorehabilitation. The impact of such factors on functional outcome is significant.

Spasticity and Contracture:

Incidence of focal upper limb spasticity post-stroke is estimated at approximately 20% [92, 93], with approximately 4% with disabling levels of spasticity [93]. Increasing tone is associated with poorer outcomes in terms of pain and dependence [94]. It is generally accepted that early comprehensive physical and occupational therapy may reduce development of spasticity. Evidence does not support hand splinting [102] or stretching regimes [95] to reduce spasticity or prevent contracture nor is intervention recommended in mild to moderate spasticity that does not impair function (good practice point) [204]. Botulinum toxin A, in combination with targeted therapy, has been demonstrated to reduce upper limb spasticity [96]. Research has previously reported low-on effect to functional outcomes measures [97], though a 2013 systematic review and meta-analysis of ten randomized controlled trials [98] has importantly concluded improvements in both activity and performance. A Cochrane review published this year outlines need for ongoing research to establish optimal types and intensities of multidisciplinary rehabilitation to improve impairment and activity following Botulinum toxin treatment [99].

Subluxation:

Rates of subluxation have been variably reported in the literature, with incidence ranging from 17-64% [100]. Correlation between subluxation and development of hemiplegic shoulder pain remains controversial, with reviews of literature not concluding a causative association [101]. Not all patients with subluxation have pain, and not all patients with pain have subluxation. Even though a causal link has not been definitively established, it remains prudent practice to protect the shoulder with careful positioning, supportive devices and education. Supportive devices have not been demonstrated to prevent subluxation, though remain recommended in treatment of established subluxation [204]. Electrical stimulation is advocated in prevention, but has not been demonstrated to reduce actual measures of subluxation [100].

Hemiplegic Shoulder Pain:

Hemiplegic shoulder pain is a common complication of, with overall rates affecting approximately 30% of stroke survivors [102]. A paper assessing correlations between upper limb function and the ICF model found shoulder pain to be the variable most associated with limitations in participation [101, 103]. This area is an important focus of future research as up to 20-30% of patients experience pain refractory to current treatment modalities [100].

The paucity of high-grade evidence for treatment options is reflected in current Australian and United Kingdom guidelines, which do not cite any evidence-based therapeutic options specific to a stroke population [204,205]. Older research outlined careful handling, electrical stimulation, movement with elevation, strapping and avoidance of overhead pulleys as potentially effective interventions to reduce or prevent hemiplegic shoulder pain [104]. There is limited evidence for botulinum toxin for shoulder pain [105], and evidence against use of intra-articular corticosteroids [11]. A 2001 Cochrane review found inconclusive evidence regarding electrical stimulation, though a systematic review and meta-analysis completed since this time demonstrated long term benefits of intramuscular electrical stimulation [11]. Developing implantable electrical stimulation techniques are reporting high success rates in treatment of previously refractory subluxation associated shoulder pain [100]. A recent randomized controlled trial has provided evidence for the use of suprascapular nerve block in treatment of hemiplegic shoulder pain [106].

Distal Oedema:

Hand oedema following stroke occurs in at least 1/3 of survivors [107]. There is limited evidence that dynamic pressure garments, electrical stimulation, and elevation may assist in prevention of oedema [202, 204], whilst pneumatic compression has not been shown to treat established oedema [102].

Table 2 outlines current national guidelines on upper limb rehabilitation from the United Kingdom, Canada, Australia and the United States of America

[Insert Table 2]

Conclusion:

Stroke rehabilitation of the upper limb is an exciting and evolving area of specialty interest. Therapeutic and technological advances are enabling greater access to the benefits of neuroplasticity and focused individualized therapy frameworks. Research is establishing treatment options across all phases of rehabilitation, and identifying potential treatments for previously refractory complications. A focus on technologies acceptable to all age groups is vital to ensure applicability of available treatment options, and clinician and therapist support must be central in attempts to successfully maintain an implementation of change that is relevant to the client population.

Future Perspective:

Rehabilitation of the upper limb in older stroke survivors continues to be a research frontier which has been energized by new technologies but which is grounded in the basic need to find ways to allow older people to recover independence. The growth of online stroke survivor communities providing peer support, information and advice is increasing the demand for therapy and recovery.

The enduring foci of rehabilitation involve: providing patients and families with goal focused therapy which they feel they have input to, improving access to rehabilitation, increasing the proportion of active therapy time during rehabilitation, and providing a range of settings in addition to the standard inpatient hospital rehabilitation ward. New technologies such as robotics, gaming, telehealth and telerehabilitation are likely to allow remote provision of therapy and exercise therapy, though attention to acceptability and support in older populations is crucial.

Once the cost effectiveness of telerehabilitation approaches has been established clinicians require more information on acceptance patterns of older adults and modifying factors before widespread uptake is likely. It has been suggested that technology acceptance in older adults may be lower because they weigh the time required to learn the technology against the perceived usefulness [108]. As a result new skills are needed from therapists delivering rehabilitation using technologies and in particular providing older stroke survivors with a motivating context related benefit is likely to be important [109]. Older people are heterogeneous and many are familiar with technologies but it seems likely that older people with minimal exposure to technologies will require longer training times than younger patients. Fear of failure is known to be a greater problem in older populations compared to younger patient groups so identifying prior experience with technologies should influence the amount of time allocated for training [109] . Overall the effective introduction of technologies to deliver rehabilitation requires highly usable designs which are appropriate for people with impairments (vision, dexterity, cognition) and adequate training.

Finally despite the emergence of novel technological therapies there has been little progress with key secondary complications of the upper limb post stroke which are more common in older stroke survivors [110] and can significantly impact on quality of life. Complications such as shoulder pain and spasticity are extremely common and warrant particular focus of research. In fact, prevention or effective management of these complications in turn will allow the stroke survivor to more successfully access emerging technologies.

Executive Summary:

Executive Summary
Prognostication of Upper Limb Recovery Post Stroke
▪ After a stroke not all affected upper limbs will recover so it is important those people most likely to benefit from therapy. ▪ Early, accurate assessment of the likelihood of an upper limb recovering motor function would assist in targeting / stratifying appropriate interventions ▪ Predictors of potential motor recovery include initial severity of motor impairment, location and size of lesion, and integrity of descending motor tracts; caregiver support is also predictive. ▪ Age alone is not a strong predictor of rehabilitation or recovery potential
Rehabilitation Strategies for Upper Limb Restitution and / or Compensation
▪ Repetitive task specific training is supported by evidence and offers and meaningful context to patients; evidence for bimanual training is less robust. ▪ Virtual reality and gaming strategies may offer an adjunct to therapies, though applicability in an older population needs further research. ▪ Constraint-induced movement therapy is an effective treatment option in a select group of compliant patients with sufficient motor activity. ▪ Neuromuscular electrical stimulation may reduce shoulder pain and spasticity, but evidence is conflicting regarding effect on motor recovery.
Implementation of Evidence into Practice
▪ Audits of the implementation of National Guidelines on Stroke Rehabilitation for upper limb continue to reveal uneven implementation of best practice e.g. constraint therapy protocols are rarely implemented. ▪ There is consensus on many effective therapies for upper limb rehabilitation which should start early and be provided in an adequate "dose". However when resources are rationed older people may be excluded from accessing stroke rehabilitation therapies. While older people and carers have direct access to information on best practice rehabilitation via national stroke organisaton websites they have little input into decision making on program priorities. New funding models which include consumers and carers in decision making are needed.
Future Perspectives
▪ Rehabilitation for the upper limb is evolving but simple treatments for secondary complications of the upper limb post stroke eg shoulder pain lags. ▪ One strategy to deal with the increasing demand for rehabilitation is earlier decision making around whether therapy is focused on compensatory or restorative goals. New protocols combining early TMS and repeated standardised clinical assessments in the first weeks are being tested and seem likely to change clinical practice.

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