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Research and application advances in rehabilitation assessment of stroke

Key words: Stroke; Rehabilitation assessment; Stroke assessment scales; Detection technology; Artificial intelligence

Research Summary

This review summarizes the assessment methods commonly used in research and clinical applications in the following aspects:

- **Assessment scales for stroke**
- **Biomedical detection technologies**
- **New technologies**

Innovation points

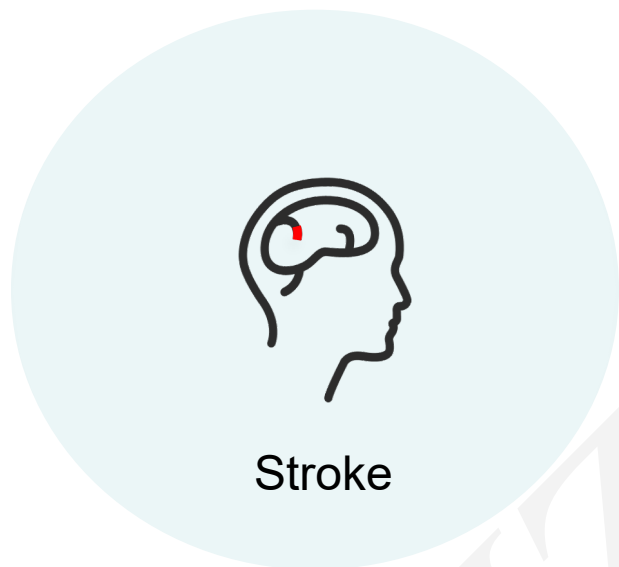


Table 1 Overview of assessment scales for stroke

Classification based on ICF	Content of evaluation	Commonly used scales	References	
Body structure and function	Overall neurological impairment	National Institutes of Health Stroke Scale (NIHSS)	(Goldstein et al., 1989)	
		Canadian Neurological Scale (CNS)	(Côté et al., 1989)	
		European Stroke Scale (ESS)	(Hantson et al., 1994)	
		Scandinavian Stroke Scale (SSS)	(Lindenstrom et al., 1991)	
		Stroke Impairment Assessment set (SIAS)	(Zhou N, 2002)	
	Sensory function	External sensory	Semmes-Weinstein monofilament method	(Weinstein, 1993)
			Two-point discrimination test	(Takara, 1971)
		Internal sensory	Weinstein enhanced sensory test	(Weinstein, 1993)
			Threshold to Detection of Passive Motion (TTDPM)	(Han et al., 2016)
	Motor function	Joint mobility	Joint Position Reproduction (JPR)	(Steinberg et al., 2019)
			Active Movement Extent Discrimination Assessment (AMEDA)	(Waddington et al., 2014)
		Muscle tone and spasticity	Ashworth spasticity scale	(Platz et al., 2005)
		Balanced walking	Beighton	(Schlager et al., 2018)
			Contompasis	(Schlager et al., 2018)
Cognitive function	Arthroscopic organ	Hospital del Mar Criteria (HdM)	(Bevilacqua, 2019)	
		Berg Balance Scale	(Blum and Komer-Bitensky, 2008)	
		Frenchay Dysarthria Assessment (FDA)	(Enderby, 1980)	
	Injury of general motor function	Brunnstrom Hemiplegia Scale	(Shah, 1984)	
		Fugl-Meyer Scale	(Fugl-Meyer et al., 1975)	
		(Simplified) Fugl-Meyer Motor Function Scale	(Gladstone et al., 2002)	
		Stroke Rehabilitation Assessment of Movement (STREAM)	(Ahmed et al., 2003)	
Overall cognitive impairment	Chedoke-McMaster Stroke Assessment	(Moreland et al., 1993)		
	Lindmark Motor Function Assessment	(Hamrin and Lindmark, 1988)		
	Rivermead Mobility Index	(Ekinci et al., 2021)		
	Mini-Mental State Examination (MMSE)	(Folstein et al., 1983)		
Activity function	Memory	Stroke Unit Mental Status Examination (SUMSE)	(Hajek et al., 1989)	
		Neurobehavioral Cognitive Status Examination (NCSE)	(Osmon et al., 1992)	
		Montreal Cognitive Assessment Scale (MoCA)	(Nasreddine et al., 2005)	
		Halstead-Reitan Neuropsychological Test Battery (HRNB)	(Reitan, 1955)	
		Loewenstein Occupational Therapy Cognitive Assessment (LOTCA)	(Katz et al., 1989)	
	Attention	Auditory Verbal Learning Test (AVLT)	(Guo Q et al., 2007)	
		Digit Span Test (DST)	(Ostrosky-Solis and Lozano, 2006)	
	Executive force	Shape Trail Test (STT)	(Zhao et al., 2013)	
		Stroop color and word test (SCWT)	(Scarpina and Tagini, 2017)	
	Language features	Verbal fluency test (VF)	(Diesfeldt, 1983)	
Boston naming test (BNT)		(Wang et al., 2019)		
Spatial visual function	Clock drawing test (CDT)	(Royall et al., 1998)		
	Katz index of independence in activities of daily living (Katz ADL index)	(Katz et al., 1970)		
	Simple and practicable ADL index)	(Katz et al., 1970)		
Participation function	Basic activities of daily living	Modified Rankin Scale (MRS)	(Sulter et al., 1999)	
		Modified Barthel Index (MBI)	(Shah et al., 1989)	
	Athletic activities	Physical self-maintenance scale (PSMS)	(Lawton and Brody, 1969)	
		Cognition and speech	Functional independence measure (FIM)	(Linacre et al., 1994)
Quality of life	Instrumental ability in activities of daily living	Katz Index of instrumental activities of daily living based on ADL index (Katz IADL index)	(Katz, 1983)	
		Functional Autonomy Measurement System (SMAF)	(Hébert et al., 1988)	
	Assessment of Motor and Process Skills (AMPS)	(Park et al., 1994)		
	Psychological assessment	Frenchay Activity Index (FAI)	(Holbrook and Skilbeck, 1983)	
		Functional Activity Questionnaire (FAQ)	(Pfeffer et al., 1982)	
	Observation and questionnaire	Ferrans & Powers Quality of Life Index (QLI-generic Version)	(Ferrans and Powers, 1985)	
36-item short-form survey (SF-36)		(Ware and Sherbourne, 1992)		
Stroke-specific quality of life scale (SS-QOL)	Ferrans & Powers Quality of Life Index (QLI-Stroke Version)	(Jaracz and Kozubski, 2003)		
	Stroke-specific quality of life scale (SS-QOL)	(Williams et al., 1999)		

Note: ICF: International Classification of Functioning, Disability and Health

Innovation points

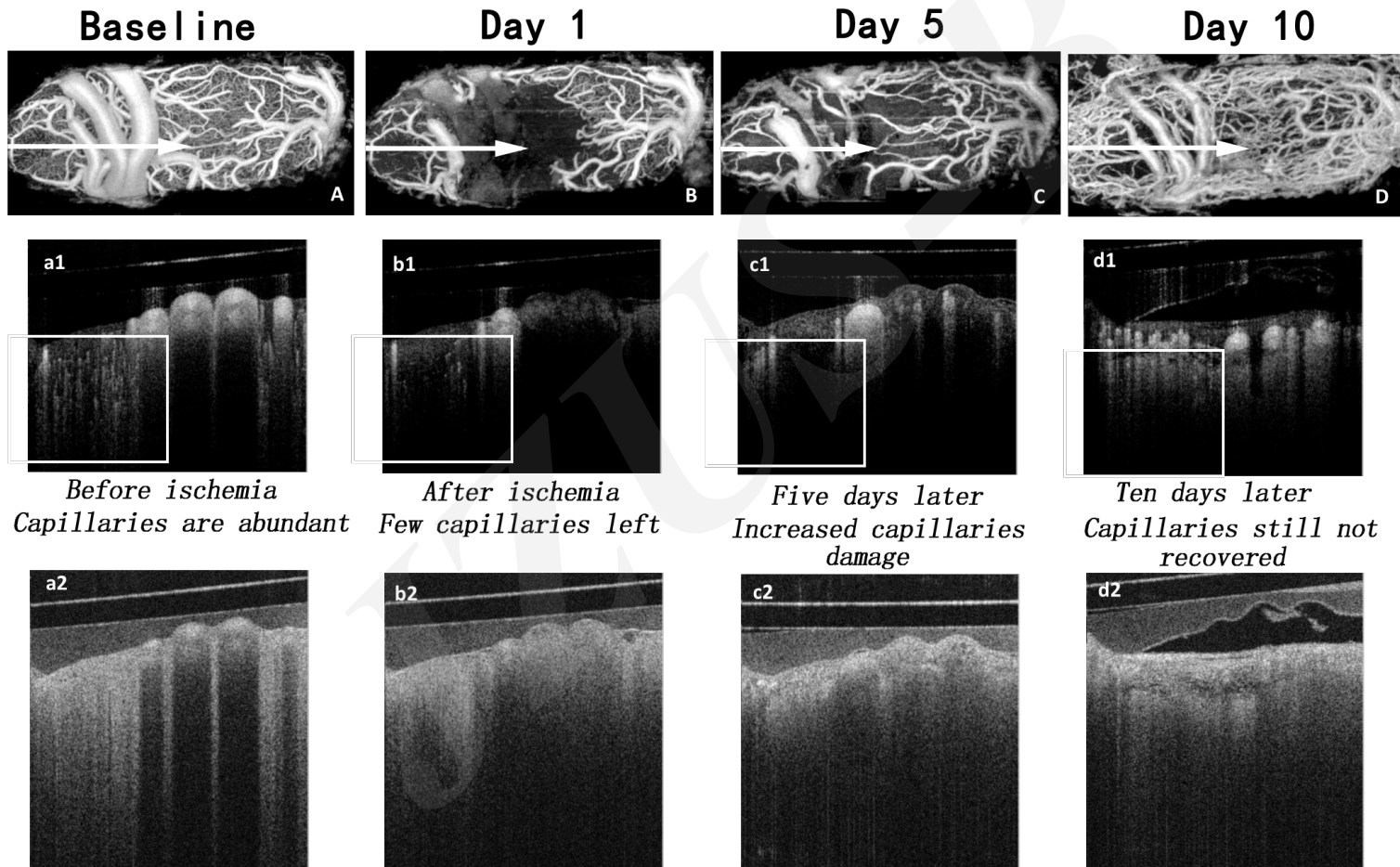
Table 2 Overview of biomedical technologies for rehabilitation assessments of stroke

Measurement technique	Advantages	Disadvantages	Application fields	References						
Surface electromyography (sEMG)	Non-invasive, safe, convenient and objective; Detects the surface muscle activity of various parts of the body.	Susceptible to external and nearby muscle interference; Limited to the superficial major muscle group; Inability to get signals from deep muscles	Upper limb Hand Lower limb Back Abdomen Swallowing External anal sphincter	(Kallenberg and Hermens, 2009) (Hu et al., 2015; Vinstrup et al., 2018) (Rozanski et al., 2020) (Li et al., 2014) (Yoon and You, 2017) (Park et al., 2019) (Dias et al., 2018; Dias et al., 2019)						
Motion analysis system	Non-invasive, safe and objective; A variety of sensors to obtain upper and lower limb motion parameters; Used for real-time rehabilitation training.	High requirements on-site and for equipment; Multi-parameter fusion analysis is complicated to practice.	Upper limb movement Lower limb movement Feedback of rehabilitation training effect Assisted robot adaptive correction	(Bosecker et al., 2010; Dokkum et al., 2014; Schwarz et al., 2019) (Kawamura et al., 2007; Rosa et al., 2014) (Caliandro et al., 2020) (Andrews et al., 2018)						
Transcranial magnetic stimulation (TMS)	Painless and non-invasive; Independent control of neural activity in specific brain regions; Neuroelectrophysiological examination in central nervous system;	The interpretability of the results is poor; The effect of functional recombination of brain regions cannot be eliminated.	Motor Somatosensory Swallowing Sensory function represented by vision	(McDonnell and Stinear, 2017) (Hwang et al., 2016) (Gallas et al., 2007; Barritt and Smithard, 2009) (Sack and Linden, 2003)						
Magnetic resonance imaging (MRI)	Diffuse MRI	Non-invasive, safe and objective; Reflects the integrity of subcortical white matter fiber bundles	No neurological function assessment is performed;	DWI	Prediction of ischemic outcome	(Yoo et al., 2010)				
			Part of the mode scanning time is too long;	DTI	Significant correlation between related parameters and motor function scores	(Parsons et al., 2010)				
			In the field of rehabilitation, it is mainly used for outcome prediction, but cannot be accurately assessed.	DTT	3D visualization of cortical fiber bundle injury	(Lindenberg et al., 2010)				
				DKI QSI	Reflects the change in microstructure of tissue	(Yamada et al., 2013; Umesh Rudrapatna et al., 2014)				
Functional MRI (fMRI)	Non-invasive, safe and objective; The functional activity of the whole brain can be obtained	Image accuracy is limited; Long scan and task time; The results are often unconvincing	rs-MRI	Motor and cognitive functional brain area assessment, longitudinal analysis reflects dynamic changes in patients' motor function	(Park et al., 2011; Golestani et al., 2013; Dacosta-Aguayo et al., 2014; Chen et al., 2018)					
			ts-MRI	Motor, sensory and cognitive functions assessment, and neurofeedback for efficacy assessment	(Calvert et al., 2000; Mintzopoulos et al., 2009; Kim and Winstein, 2017; Wang et al., 2018)					
Combination	TMS	Narrows the area of the brain to be examined to make it more accurate; Reduces the impact of functional restructuring; Improves the accuracy of functional assessment	EEG and NIRS have low resolution and accuracy. MEG and PET equipment have low penetration rates and are expensive; The interpretability of the results needs to be improved	Evaluation of motor and cognitive function and the mechanism of brain recovery and restructuring	(Sack and Linden, 2003; Hamzei et al., 2006; Auriat et al., 2015; Kim and Winstein, 2017; Pelliicari et al., 2018)					
						fMRI	EEG	Not only the activity and functional connection of brain regions, but also the activation sequence and the subordinate relationship between brain regions can be understood	Neural connectivity network analysis and functional rehabilitation assessment	(Lioi et al., 2020)
						TMS	Structural imaging	Neurological function and structure tests can predict the level of motor recovery in stroke patients	Assessment of motor functions and neural pathway integrity	(Stinear et al., 2012; Auriat et al., 2015)
						EMG	NIRS	The anterior nerve activity and terminal muscle activity of the nerve conduction pathway are detected at the same time.	Co-detection of muscle electrophysiological signals and brain hemodynamics in motor function	(Scano et al., 2019; Caliandro et al., 2020)

Innovation points

New technologies:

- AI
- OCT



OCT captures vascular perfusion data to provide data for combining stroke rehabilitation with artificial intelligence