Z Gerontol Geriat 2015 · 48:15–21
DOI 10.1007/s00391-014-0845-0
Received: 15 October 2014
Revised: 24 November 2014
Accepted: 9 December 2014
Published online: 21 January 2015

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Motor cognitive dual tasking

Early detection of gait impairment, fall risk and cognitive decline

Introduction

Gait is neither a simple motor activity nor is it simply a motor activity. Gait is a complex activity that is as much a cognitive as a motor task. Complex processes in the brain enable and control walking. Disruption of these processes, as in neurodegenerative disease, causes not only cognitive impairment but also functional impairment, including walking difficulties. Studies have shown a close association between gait and cognition. Older adults with gait deficits have an increased risk of developing cognitive deficits [29] and in turn, cognitive deficits are associated with worsened gait [6, 11]. Both gait impairments and cognitive impairments are risk factors for falls [17]. An objective assessment of functional mobility, fall risk and cognition should be an integral part of every comprehensive geriatric assessment.

Falls in older adults

» Falls are the leading cause of accidental injury and hospitalization in people over 65 years old

Walking difficulties, cognitive impairments and falls are prevalent among older adults and the incidence of each one increases with age. Compared to healthy older adults, those with gait or cognitive impairments have higher rates of morbidity and mortality, greater functional decline and more falls [17]. Falls are the leading cause of accidental injury and hospitalization in people aged 65 years and older [5] and 1 in 3 older adults aged 65 years or older falls at least once each year [12, 13, 22]. Of these, 20–30 % will suffer moderate to severe injuries, such as head injuries and fractures which make it difficult for them to live independently and increase the risk of early mortality [1, 22, 25]. In older adults 60–80 % with moderate to severe cognitive impairment fall each year, a rate twice that of cognitively healthy older adults [28]. Older fallers with cognitive impairments are also five times more likely to be admitted to a care institution than older non-fallers without cognitive impairments [19].

The prevalence of dementia is 8 % in adults aged 65 years and older and 35 % in those aged 85 years and older [18], currently affecting approximately 30 million people worldwide [16]. With ever-increasing life expectancies, the number of individuals with dementia is predicted to be more than 100 million by the year 2050 [9]. In older adults with dementia, gait worsens as cognition progressively declines. With the estimated increase in prevalence of dementia, there will be an associated dramatic increase in the number of gait difficulties and falls in the senior population.

These changes will have a serious impact on social systems, healthcare costs and the quality of life in older adults and their caregivers.

Age-related changes affecting gait

It generally takes humans more than 1 year to learn how to walk and approximately another 10 years to master the gait pattern of an adult. Once learned, gait for young healthy adults can in some ways be considered an automatic task requiring minimal attention. Although walking difficulties in older adults are not an inevitable consequence of aging, walking in older adults often loses a degree of automaticity.

Age-related changes, such as decreased muscle strength, primarily due to sarcopenia and decreased sensory input (i.e. proprioception, vision and hearing) impair systems responsible for postural control.

It is easy to understand that someone with clouded vision due to cataracts needs more concentration in order to maneuver around obstacles or cross a street that someone with normal vision.

Each person possesses a certain maximum capacity of attentional reserves. When more of that attention is needed to compensate for deficits in sensory input, less attention is available to be allocated to safe walking. As more attentional resources are needed for safe walking during multitask or dual task situations, walking occurs with less automaticity. Those affected rarely notice that they need more attention for walking, at least in the early stages of such gait difficulties. Many do, however, develop sensations, such as vague dizziness, tiredness or unsteadiness while walking.

Executive functions

Executive functions belong to a cognitive domain that includes attention as well as working memory, reasoning and problem solving. Executive functions are responsible for the planning and coordination of complex processes, placing task events in

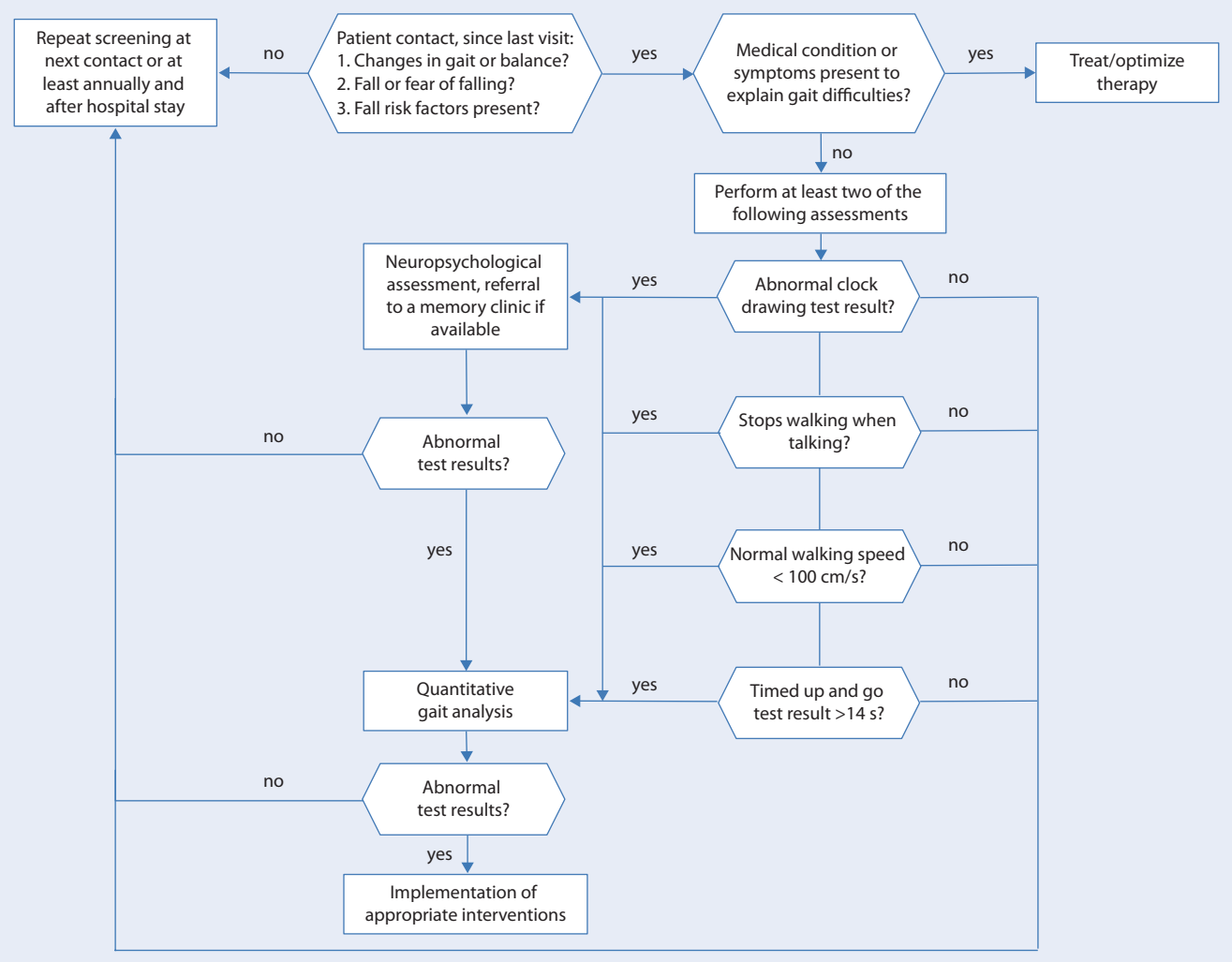

Fig. 1 ▲ Algorithm for mobility assessment

the correct order and allocating the necessary amount of attention to each task. Executive functions thus enable two tasks to be performed simultaneously, also known as dual tasking.

» Dual tasking is an integral part of daily life

Dual tasking is an integral part of daily life, with such simple examples as walking while carrying a cup of coffee or walking while talking to someone. Particularly in older adults, the degree of attention distribution between walking and simultaneously performing a second task is of interest. If there is not enough attentional reserve available for both tasks in a dual task situation, then the performance in one or both tasks will decrease. Executive dysfunctions, to which deficits in attention and divided attention belong, are associated with gait deficits, falls and cognitive decline.

Dual task test paradigms

Dual task test paradigms, e.g. walking while simultaneously performing a second task, are now commonly used to investigate the associations between gait and cognition in older adults. Dual tasking challenges executive functions and can be thought of as a cognitive stress resistance model [5, 27]. Dual task test paradigms allow the assessment of the effects of divided attention on motor performance and gait control, permitting the detection of gait deficits which under the single task condition of walking alone may otherwise remain undetected. When even subtle executive dysfunctions are present, the result is often slowed walking speed (or even stopping altogether) and a worsening of gait regularity (increased gait variability). These gait changes under dual task conditions are referred to as motor cognitive interference and indicate the presence of cognitive deficits which are associated with an increased fall risk in older adults. Motor cognitive interference under dual task conditions is generally greater in older than in younger adults, in fallers compared to non-fallers and in cognitively impaired compared to cognitively healthy older adults [6].

Assessment

Walking involves several aspects of mobility, including planning and neural motor control of movements, balance, coor-

Abstract · Zusammenfassung

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S. A. Bridenbaugh · R. W. Kressig

Motor cognitive dual tasking. Early detection of gait impairment, fall risk and cognitive decline

Abstract

Background. Gait and cognition are closely associated. Older adults with gait deficits have an increased risk of developing cognitive deficits and cognitive deficits are associated with worsened gait. Both gait and cognitive impairments are risk factors for falls in older adults.

Objectives. The aims of this article are (1) to highlight the association between gait and cognition, particularly executive function, (2) to present motor cognitive dual tasking test paradigms and (3) to provide an algorithm for standardized mobility tests that can quickly and easily be performed in a private practice or on a hospital ward.

Materials and methods. A Pubmed review of current literature on the topic as well as the personal experience and recommendations of the authors are presented. Assessments summarized: clock drawing test, stops walking when talking test, normal walking speed, timed up and go test, regular, as a dual task and imagined.

Results. It is recommended that at least two of the presented assessments should be performed at each clinical visit in all patients age 65 years or older. If one of the assessments presented provides abnormal results, patients should be referred to a gait specialist for an in-depth quantitative gait analysis.

Conclusion. Assessments of functional mobility, fall risk and cognition should be an integral part of every comprehensive geriatric assessment. Quantitative gait analysis allows not only the early detection of gait deficits and fall risk, but also of cognitive deficits. Early detection allows for timely implementation of targeted interventions to improve gait and/or cognition.

Keywords

Gait · Cognition · Falls · Aged · Geriatric assessment

Motorisch-kognitive Doppelaufgaben. Früherkennung von Gangdefiziten, Sturzrisiko und kognitiven Beeinträchtigungen

Zusammenfassung

Hintergrund. Gang und Kognition sind eng assoziiert. Ältere Erwachsene mit Gangdefiziten haben ein erhöhtes Risiko, kognitive Defizite zu entwickeln. Kognitive Defizite sind mit einer Gangverschlechterung assoziiert. Sowohl Gang- als auch kognitive Beeinträchtigungen sind Sturzrisikofaktoren bei älteren Menschen.

Ziele. 1) Die Assoziation zwischen Gang und Kognition, insbesondere Exekutivfunktionen, zu beleuchten, 2) motorisch-kognitive Dualtask-Testparadigmen darzustellen und 3) einen Algorithmus für standardisierte Mobilitätsuntersuchungen zu präsentieren, die sich schnell und einfach in Praxis oder Klinik durchführen lassen.

Material und Methoden. Vorgestellt werden die Ergebnisse einer Sichtung der aktuellen Literatur in PubMed sowie persönliche Erfahrungen und Empfehlungen der Autoren. Zusammengefasste Assessment-Verfahren: Uhrentest, SWWT(„stops walking when talking")-Test, normale Gehgeschwindigkeit, Timed-up-and-Go-Test (normal, als eine doppelte Aufgabe und imaginär).

Ergebnisse. Empfohlen wird, bei jedem klinischen Besuch mit allen Patienten, die 65 Jahre alt oder älter sind, mindestens 2 der erwähnten Untersuchungen durchzuführen. Falls sich bei mindestens einem Test Auffälligkeiten ergeben, sollten Patienten einem Spezialisten für eine gründliche quantitative Ganganalyse zugewiesen werden.

Diskussion. Untersuchungen zu funktioneller Mobilität, Sturzrisiko und Kognition sollten in jedes umfassende geriatrische Assessment integriert sein. Quantitative Ganganalysen erlauben nicht nur eine Früherkennung von Gangdefiziten und Sturzrisiko, sondern auch von kognitiven Defiziten. Eine Früherkennung ermöglicht den zeitgerechten Einsatz gezielter Interventionen, um Gang und/oder Kognition zu verbessern.

Schlüsselwörter

Gang · Kognition · Stürze · Ältere Erwachsene · Geriatrisches Assessment

Table 1 Risk factors for falls

Risk factor	Relative risk	Range
Muscle weakness	4.4	1.5–10.3
History of falls	3.0	1.7–7.0
Gait deficits	2.9	1.3–5.6
Balance deficits	2.9	1.6–5.4
Use of assist device	2.6	1.2–4.6
Visual deficits	2.5	1.6–3.5
Arthritis	2.4	1.9–2.9
Impaired activities of daily living (ADL)	2.3	1.5–3.1
Depression	2.2	1.7–2.5
Cognitive impairment	1.8	1.0–2.3
Age > 80 years	1.7	1.1–2.5

Summary of univariate analysis of 16 studies [18]

dination, integration of sensory input to adapt movements to the surrounding environment and muscle strength. Equally multifactorial are the causes of gait impairments and falls. There is currently no single, gold standard assessment of mobility that encompasses all of these aspects across the full spectrum of cognitive and physical functionality within geriatric populations.

Some mobility assessments in older adults provide information not only about the gait but can also provide information about the possible presence of cognitive deficits. The following sections describe mobility assessments that are quick to administer, well-tolerated by patients, easy to score, provide meaningful results and are suitable for a variety of settings (**Fig. 1**). Assessing mobility and fall risk needs to be done in a comprehensive manner, taking the individual as well as the multifactorial causes into consideration. It is recommended to perform at least two of the following mobility assessments in older adults. If abnormal results are obtained with these screening assessments, referral to a specialist for in-depth neuropsychological assessment and/or gait analysis under dual task conditions should be considered.

Patient history

It is important to regularly ask (at least annually and after each hospital stay) patients aged 65 years or older the following questions:

1. Changes in gait or balance?
2. Fall or fear of falling?
3. Fall risk factors present?

Subjective changes in gait or balance are often accepted as a normal consequence of aging and not spontaneously mentioned.

» Always ask if a fall has occurred since the last visit

It should also always be asked if a fall has occurred since the last clinical visit. What a patient and what a physician or therapist understand under the term fall is often quite different. A fall is defined as an event which results in a person inadvertently coming to rest on the ground or floor or another lower level. For an older adult, a fall is likely to be viewed as an event resulting in severe injuries, such as a laceration that needs to be sutured or a fractured bone. All other falls are likely to be described as a trip, slip, stumble or clumsiness. It should also be asked if the person is afraid or concerned that a fall could occur while walking. Lastly, each patient history should include a review of the presence of fall risk factors (**Tab. 1**) [23].

Clock drawing test

If memory or other cognitive disturbances are suspected, the mini-mental state examination [10] is often administered (MMSE, maximum 30 points, higher scores are associated with better cognition). The MMSE is a global test of cognition but does not include a test of executive function. As executive dysfunction and gait impairment are closely associated, a general test of executive function belongs to a geriatric mobility assessment.

» A quick and easy test is the clock drawing test

A quick and easy test is the clock drawing test, in which the patient should draw a clock with all numbers and hands and draw the questioned time on the clock [24]. It is not a rarity to see that older adults achieve an MMSE score of 28 points yet draw a strikingly abnormal clock (**Fig. 2**). Whatever scoring system is used, if the drawn clock and/or the recorded time are abnormal, the person is likely to have some degree of executive dysfunction. Accordingly, the same person is likely to have gait difficulties, particularly under dual task conditions.

Stops walking when talking

The seminal paper that aided the launch of the current research field of dual tasking to investigate the association between gait and cognition was published by Lundin-Olsson et al. in 1997 [14]. They noted that some older adults stopped walking in order to answer a simple question. Their work showed that 80 % of older adults who could not perform the dual task of simultaneously walking while talking fell at least once in the ensuing 6 months. The stops walking when talking test is now a widely used general assessment of mobility and cognition in older adults. A simple way to apply this is to ask the patient a simple question while being accompanied to the office or examination room. Patients who stop walking in order to answer that question may have limited dual tasking ability. From a motor standpoint this suggests the presence of executive dysfunction and is associated with an increased risk of falling.

Normal walking speed

Gait speed is an important indicator of health and functional mobility. Reduced speeds during normal walking at a self-selected pace are often the forerunners to mobility impairments. A safe, normal walking speed for an older adult is considered to be at least 1 m per second. Those who walk slower have an increased incidence of falls, hospitalization, disability and being institutionalized compared to people of the same age with a normal gait speed. Studenski et al. showed that in older adults, every 0.1 m/s reduction in gait speed is associated with a 12 % increase in mortality [26].

In healthy aging, gait speed slows with increasing age [5]. Several studies have shown that an accelerated decline in gait

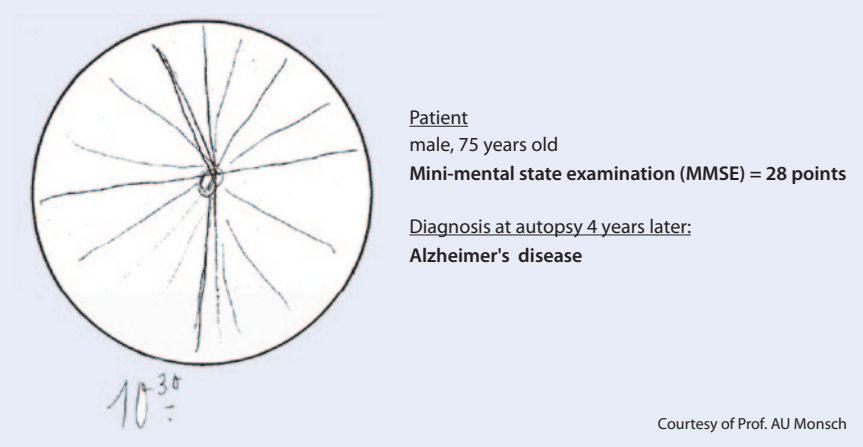

Fig. 2 ▲ Example of a clock drawing test and patient details

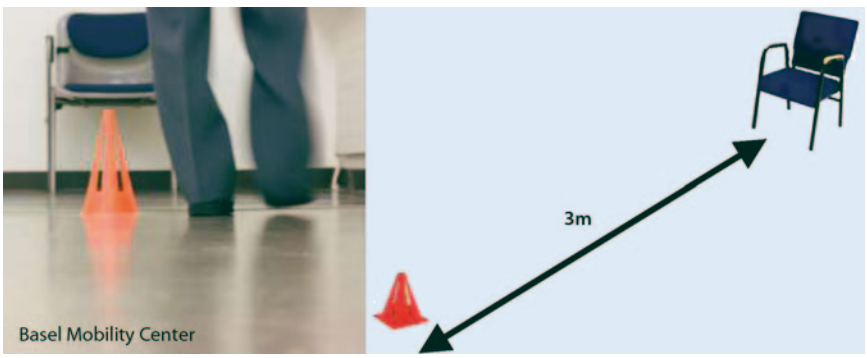

Fig. 3 ▲ Example of the timed up and go test as a photograph (*left panel*) and a sketch of the floor plan (*right panel*)

speed may predict the onset of cognitive impairment [8]. A study involving 204 older adults with initially normal cognition reported that a marked worsening of gait speed occurred up to 12 years before the onset of mild cognitive impairment (MCI) [8]. Recently, the concept of a motoric cognitive risk syndrome was introduced [30] in which the presence of MCI and slower gait in an older person are better predictors of developing dementia than either MCI or slower gait alone [30].

In the clinical practice or hospital, gait speed can be measured with a stop watch. Patients should walk straight ahead at a self-selected normal pace over a distance of 8–10 m.

Timed up and go test

A simple, quick and widely used test of general mobility in older adults is the timed up and go (TUG) test [21]. The time needed to stand up from a chair, walk 3 m (at a normal self-selected pace) to a mark on the floor, walk back to the chair and sit down is measured in seconds (**Fig. 3**). The time taken to complete the test correlates with functional mobility [21] and test times of up to 13.5 s are considered normal. Longer test times are indicative of impaired mobility.

Although the TUG test was initially and still is a good test of basic mobility, it has often been used as a screening tool to assess fall risk with cut-off times ranging from 10 s to 33 s [2]. Retrospective studies have identified a significant association between TUG test times and a past history of falls, yet the ability of TUG test times to predict future falls remains controversial. Recently, Barry et al. performed a systematic review (25 cohort studies and/or randomized controlled trials) and a meta-analysis (10 studies) to investigate whether the TUG test with a cut-off time of > 13.5 s is a useful predictor of falls in community dwelling older adults [2]. The authors concluded that the TUG test has limited ability to predict falls in community dwelling older adults and should not be used as a single assessment to determine fall risk [2].

TUG test as a dual task

In one study the TUG test was used as a motor dual task, whereby older adults in an assisted-living facility carried a cup of water while performing the TUG test. An absolute difference between the TUG test times and the TUG dual task time of 4.5 s or more could predict falls (odds ratio, OR 0.21, 95 % confidence interval, CI) in this population of frail older adults. Another TUG dual task study could not confirm that the difference between TUG test and TUG dual task test times predicted falls; however, the older adults in that study were vigorous community dwellers participating in an exercise intervention [20].

Imagined TUG test

Recently, an imagined version of the TUG (TUGi) test implementing mental motor imagery was introduced as a new tool to assess gait in older adults [3]. After performing the real TUG (TUGr) test as described, patients remain seated and are instructed to imagine performing the TUG test. Time is measured in seconds, started at the word "go" and stopped when the patient says "stop" (when the subject is mentally reseated). Although cut-offs or data ranges have not yet been provided, it was shown in older adults that the TUGi test times were much faster than the TUGr test times and this time difference was significantly greater in older compared to younger adults [3, 7].

Another study reported that large time differences between TUGr and TUGi test performances in older adults were associated with large dual task-related decreases in walking speed [7]. The TUGr and TUGi tests were performed as described. Gait speed was measured during the single task of normal walking (at a self-selected speed, normal walking) and a working memory dual task (normal walking while simultaneously performing serial subtractions from 50 by factors of 2 out loud, dual task). Older adults who walked con-

Fig. 4 ◀ Quantitative gait analysis showing the walkway system for measuring stride length (*left panel*) and from the examiner's perspective (*right panel*)

siderably slower while dual tasking compared to normal walking had a greater difference between the TUGr and TUGi test times than those with less dual task-related gait interference [7].

It was proposed that large discrepancies between TUGr and TUGi test times underline the influence of cognitive functions on gait and suggest the presence of higher level gait and balance disorders [3, 7]. The TUGr and TUGi tests could be used in various settings to determine which older adults may have an underlying dual task-related gait disturbance and require an in-depth functional gait assessment [7].

Another recent study proposed that increased delta times between TUGr and TUGi tests may be able to aid in the early diagnosis of MCI [4]. The authors suggested that cognitive impairment, particularly executive dysfunction accounts for large time differences between TUGr and TUGi test times [4].

Quantitative gait analysis

If one of these mobility assessments provides abnormal results, quantitative gait analysis can be used to identify gait deficits, fall risk and possible cognitive deficits. Various gait analysis systems are available for the objective measurement of gait, such as optoelectronic systems, force platforms, shoe-integrated wireless sensor systems, accelerometers, angular velocity transducer systems and electronic walkways with integrated pressure sensors. Which system is best depends on the research and/or clinical questions addressed. The authors employ the GAITRite©electronic walkway system (CIR Systems, Sparta, NJ) for spatial-temporal gait measures as the focus is on clinically relevant, functional and dynamic gait analysis (**Fig. 4**).

In recent years, several spatial-temporal gait parameters have been identified as fall predictors.

Stride variability is currently viewed as one of the gait parameters most sensitive to change.

It represents the difference in time or length from one stride to the next. Stride variability can be thought of as a marker of gait automaticity, with low variability representing regular, stable gait. Maki showed that a change of just 1.7 cm from one stride to the next was associated with an almost doubled risk of older community dwellers falling within the next 6 months [15]. In a retrospective study Verghese et al. [29] reported that increased gait variability predicts future risk of cognitive decline and dementia in initially non-demented older adults.

Using quantitative gait analysis with dual task paradigms, it has been shown that as cognition worsens gait slows and becomes more variable.

Gait was analyzed in older adults with normal cognition, MCI, mild Alzheimer dementia (AD) and moderate AD. Under the single task condition of normal walking, stride time variability was significantly increased in the group with moderate AD. Compared to stride time variability during normal walking, the stride time variability under cognitive dual task conditions was significantly increased even in the group with MCI. Early detection of these mobility impairments may be used as a tool to aid diagnosis of those persons in the earliest stages of cognitive impairment.

» Quantitative gait analysis is necessary for early detection of gait deficits

Quantitative gait analysis is necessary for early detection of gait deficits. Early detection of gait deficits allows the early detection not only of fall risk but also of cognitive deficits. This allows for timely implementation of targeted interventions to improve gait and/or to maintain cognition.

Conclusion

- **There is a strong association between gait and cognition.**
- **Older adults with gait deficits have an increased risk of developing cognitive deficits.**
- **Cognitive deficits are associated with worsened gait.**
- **Both gait impairments and cognitive impairments are risk factors for falls.**
- **Assessment of functional mobility and executive function should be an integral part of every comprehensive geriatric assessment.**
- **Dual task test paradigms are often more sensitive for detecting mobility impairment than single task conditions.**
- **Early detection of gait deficits allows the early detection not only of fall risk but also of cognitive deficits.**
- **Early detection allows for timely implementation of targeted interventions to improve gait and/or to maintain cognition.**

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Compliance with ethical guidelines

Conflict of interest. S.A. Bridenbaugh and R.W. Kressig have no conflicts of interest to declare.

This article is a literature review and does not include studies on humans or animals.

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Buchbesprechung

Vorsorge und Begleitung für das Lebensende
Thomas Sitte

Sitte, T (2013) Vorsorge und Begleitung für das Lebensende. Springer Berlin Heidelberg, ISBN 978-3-662-44346-0, EUR 19,00

Thomas Sitte, Anästhesist und Palliativmediziner, hat ein Buch geschrieben, mit dem er lehren und anregen möchte, sich mit dem Sterben und der Begleitung von Sterbenden auseinanderzusetzen. Zur Veranschaulichung der in elf Kapitel unterteilten Themenbereiche – von der „Zeit vor der Krankheit" bis zur „Zeit des Erinnerns" – begleiten den Leser die Geschichten von vier Menschen mit sehr unterschiedlichen Lebenswegen und Krankheiten durch das Buch.

Der Leser erhält eine Fülle von sehr nützlichen und gut verständlichen Informationen, die die komplette oben genannte Zeitspanne abdecken. Es geht um Vorsorgevollmacht/Patienten- und Betreuungsverfügung, um den Umgang mit der Verkündung einer infausten Diagnose, um die Hoffnung, dass diese Diagnose nicht zutrifft, um die Möglichkeiten, Hilfe bei der Betreuung Sterbender zur erhalten und letztlich um Abschiedsrituale sowie die Zeit nach dem Tod. Den größten Raum nimmt das gut geschriebene Kapitel über Symptomkontrolle ein, in dem auch Themen wie die Verkehrstauglichkeit und Reisen unter Opioidmedikation behandelt werden. Die Bedeutung von „Tötung auf Verlangen", „Beihilfe zum Suizid" und „passive Sterbehilfe" werden erklärt und der Autor nimmt klar Stellung: Tötung auf Verlangen ist in seinen Augen keine ärztliche Aufgabe. Um Menschen nicht in Situationen zu bringen, in denen sie dies wünschen, braucht es ein breit verankertes Wissen über Palliativmedizin und ihre Möglichkeiten.

Das Buch leistet hierzu einen wertvollen Beitrag, dass die Deutsche Palliativstiftung, deren Vorsitzender der Autor ist, im Buch wiederholt Erwähnung findet, ist vielleicht nicht notwendig – ein Hinweis am Ende des Buches hätte aus meiner Sicht genügt.

Für die Folgeauflagen bleibt ein Re-Lektorat zu wünschen, um die vorhandenen kleinen Fehler zu entfernen.

Miriam Ahlborn, Braunschweig