International Journal of Physical Medicine & Rehabilitation
ISSN: 2329-9096

Krug J and Litofsky NS, Int J Phys Med Rehabil 2014, 2:3
DOI: 10.4172/2329-9096.1000196

Research Article | Open Access

Relationship of Balance and Mobility Status to Quality of Life in Patients with Primary Brain Tumors: A Pilot Study

Jeffrey Krug[1] **and N. Scott Litofsky**[2*]

[1]*Instructor- Program in Physical Therapy, 108 Lewis Hall, University of Missouri-Columbia, Columbia, MO 65211, USA*

[2]*Division of Neurological Surgery, Director of Neuro-Oncology and Radiosurgery, University of Missouri- School of Medicine, One Hospital Drive, MC321, Columbia, MO 65212, USA*

[*]**Corresponding author:** N. Scott Litofsky, Professor and Chief, Division of Neurological Surgery, Director of Neuro-Oncology and Radiosurgery, University of Missouri-School of Medicine, One Hospital Drive, MC321, Columbia, MO 65212, USA, Tel: (573)882-4909, (573)884-5184; E-mail: litofskyn@health.missouri.edu

Received date: 09 Feb 2014; **Accepted date:** 20 May 2014; **Published date:** 23 May 2014

Abstract

Objective: Most research regarding the effectiveness of brain tumor treatments measure survival time, recurrence rate, and extent of surgical resection. Objective measurements of functional abilities and self-perceived quality of life (QoL) are important aspects of treatment response, yet these are not commonly assessed. This study was designed to determine the relationship between balance and mobility status and self-perceived QoL for patients before and after surgical excision of primary brain tumors.

Methods: Nine adults who underwent surgical excision of presumed primary brain tumor were assessed prior to, immediately following, and 3 months post-surgery utilizing the Timed Up-and-Go (TUG), Tinetti Performance-Oriented Mobility Assessment (Tinetti) and Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36). ANOVA with repeated measures over time was performed on the data across the three time points. Outcome measures were correlated using Spearman's correlations. Statistical significance for all tests was accepted at $p < 0.05$.

Results: Balance, mobility and QoL measures changed significantly from pre-surgery to immediately post-surgery and from immediately post-surgery to 3 months later. However, neither QoL nor balance or mobility demonstrated significant change from pre-surgery to 3 months post-surgery. These results reflect clinically-noted changes in physical abilities the 3 time points. All measures significantly correlated at the two post-surgery measurements, indicating a close link between balance and mobility and QoL.

Conclusion: The TUG and Tinetti can be used in brain tumor patients to quantify clinical changes in balance and mobility. These changes correlate with QoL over time.

Keywords: TUG; Tinetti; SF-36; Brain Tumor; Quality of life

Introduction

Impairments standing balance and limitations with ambulation and transfers are common in patients with brain tumors [1]. Deficits in performing ambulation and balance skills reduce overall functional abilities and independence with daily activities. One goal of surgical excision of brain tumor is to improve brain function, including motor skills, mobility, balance, and overall quality of life [1].

Multiple studies have assessed the effectiveness of surgery in minimizing tumor volume, reducing recurrence rates, or increasing survival time following diagnosis [2-7]. However, very few studies specifically measure functional outcomes using reliable and valid instruments despite clinical tools to quantify this domain [8-10]. These studies refer to neurological deficits or physical function deficits, but fail to quantify these deficits or to objectively measure change over time [11].

The degree of physical dysfunction varies depending on tumor location, size and its invasive properties [12-13]. Clinical signs may be similar to those seen following stroke or traumatic brain injury [1,11,14-16 . While not every person with a brain tumor presents with physical deficits, impairments such as altered strength, muscle tone, coordination, and sensation often occur [13,17,18]. The common impairment of hemiparesis frequently results in decreased functional mobility limitations.

Researchers have examined physical impairments in patients with brain tumors, but the data is sporadic and not well quantified. Many of these studies fail to measure physical impairments or functional status objectively [2-5,7,19-21]. For instance, Qureshi et al. [6] incorporated two functional outcome scales – Rankin score and Barthel Index (BI)- into a study assessing the physical effects of supratentorial mass lesions. However, these measures were determined by phone interview with the patient's caregivers and did not involve direct patient examination [6]. The 6 Minute Walk Test has also been used to assess physical functioning in gliomas, but its value in neurologically impaired patients is unknown [22].

Gait and balance are important components of physical functioning. The Timed-Up-and-Go (TUG) and Tinetti Performance-Oriented Mobility Assessment (Tinetti) are excellent assessments of balance and mobility for several reasons. Both tests are easy to administer. Both tests have a history of use in patients with neurological disorders.

The TUG correlates well with the Berg Balance Scale (BBS) (often used to assess patients with stroke), which in turn correlates well with the Tinetti [23-28]. Because neurological and mobility deficits and pattern of recovery of brain tumor patients is similar to that observed after stroke [14-16,29-31], and the TUG and Tinetti have been reliably validated for use in the stroke population [32,33], both the TUG and Tinetti are appropriate for use in brain tumor patients, too. The TUG and Tinetti have been shown to be valid in monitoring change in performance over time [23,34-36]. Finally, because "mobility, ambulation, and balance are not mutually exclusive constructs," [26] use of the TUG and Tinetti together a more complete picture of physical functioning in patients.

Physical functioning is a component of patient self-perceived quality of life (QoL). In patients with brain tumors, correlation between physical functioning and QoL has been mixed. In one study, functional measures did not correlate well with a QoL measure during rehabilitation of 10 patients with brain tumor [8], but another study of brain tumor subjects found functional status correlated well with QoL [37]. The TUG and Tinetti were not used in those studies.

The primary objective of this pilot study is to determine whether the (TUG) [23] and (Tinetti) [24] would be sensitive and appropriate outcome measures of balance and mobility status pre-operatively and post-operatively in patient with primary brain tumors. The secondary aim of this project was to determine if balance and mobility as measured by these tools would correlate with QoL. We hypothesize that the TUG and Tinetti would be sensitive and appropriate measures of balance and mobility in patient with primary brain tumors and would correlate with QoL measured by SF-36.

Methods

Patients pre-operatively diagnosed with primary brain tumor were selected as part of a convenience sample and assessed by a single tester. Patients were evaluated the day before surgery, 3 days after surgery, and 3 months after surgical resection to determine 1) balance and mobility using TUG and the Tinetti instruments and 2) self-perceived QoL using the Medical Outcome Study (MOS) 36-Item Short Form Health Survey (SF-36).

Patients were included if they had surgical resection of presumed primary brain tumor and intact lower body structures. Exclusion criteria included age < 18 years old, preexisting neurological disorders, history of dementia or cognitive impairment with inability follow directions on standardized measures, or preexisting balance conditions. The study was approved by the Health Sciences Institutional Review Board at University of Missouri-Columbia (IRB #1091137).

In the TUG, test subjects are started in a comfortable seated position in a standard arm chair (seat height 46 cm, arm height 65 cm). On command, subjects arose from the chair, walked 3 meters to a marker on the floor, turned around, walked back to the chair, and sat down again. The test is scored by the time required to accomplish the sequence. Community-dwelling elderly should perform the test in < 12 seconds. Subjects taking less than 10 seconds function independently; those requiring > 15 seconds had fall risk, and those requiring > 30 seconds need assistance with transfers and stair ambulation [23].

The Tinetti is a standardized test which measures a person's ability to balance while performing activities, including walking, in two components: a 9-item balance portion and a 7-item gait section. The nine balance maneuvers include the following: sitting, arising, attempting to arise, immediate standing (first 5 seconds), standing, sternal nudge, eyes closed standing, turning 360o while standing, and sitting.

Each item is scored as 0 (abnormal response), 1 (adaptive response), or 2 (normal response) with the exception of sitting balance and eyes-closed standing balance, in which abnormal scores 0 and normal scores 1; therefore, the maximum score for the balance component is 16. The gait portion includes 7 items: gait initiation, step symmetry, step continuity, path, trunk, walking time, and step length and height (right swing foot and left swing foot scored separately for both length and height). Each portion is scores as 0 for abnormal and 1 for normal, with the exception of path, which is scored 2 for normal; maximum score on the gait portion is 12, for a total maximum score of 28. Patients who score < 19 have a high fall risk.

The SF-36 contains 36 questions which cover 8 functional domains: physical functioning (10 items), role limitations due to physical health problems (4 items), bodily pain (2 items), role limitations due to emotional problems (3 items), vitality (4 items), social functioning (2 items), mental health (5 items), and general health perceptions (5 items). Each item has 5 levels of response. Scores for each domain range from 0 to 100 once scaled to the test manual. Higher scores indicate better health status for the domain. Two component summary scores – physical health component and mental health component – are also derived from the SF-36 manual. Scores can be compared to age-appropriate United States norms.

Prior to surgery, patients were assessed by the tester. Each patient completed 2 trials of the TUG; scores were averaged and recorded. Each patient then completed the SF-36 independently; on occasionally a caregiver or the tester who read the questions and indicated the answers provided by the patient. Finally, the patient completed the Tinetti balance and gait assessments, which were scored. Following surgery, once the patient was determined to be medically stable and often on the day prior to discharge from the hospital, the testing procedure was repeated. The measures were completed a third time as part of the patient's 3 month physician follow-up appointment; the tests were administered in the same sequence by the original tester; again, a caregiver or the tester could assist the patient in completing the SF-36 form by marking the patient's answers to the questions. For the TUG and the Tinetti, participants were allowed to use assistive devices or wear orthotics but no physical assistance was provided.

TUG, Tinetti, and SF-36 scores analyzed statistically with ANOVA with repeated measures over time across the three time points. Outcome measures were correlated with Spearman's correlations. Statistical significance for all tests was accepted at $p < 0.05$.

Results

Demographics

Nine patients were studied, 3 men and 6 women, aged 40 to 71 (mean 49.2 +/1 10.1 years). Three patients had a diagnosis of meningioma and five had a glial neoplasm, and 1, presumed to have a hemorrhagic glial neoplasm prior to surgery had no evidence on tumor on final pathology. Table 1 describes each patient's clinical findings at presentation and at follow-up.

Patient #	Age	Diagnosis	Tumor Location	Pre-Op Neurological Symptoms/Deficts	3 Month Post-Op Neurological Deficits	Post-Op Treatment	Survival
1	54	Hemorrhage (no evidence of tumor)	Temporal, right	Seizure; dysdiadokinesis, left	Anxiety, depression	none	84 months
2	64	Glioblastoma (Grade IV)	Front-parietal, left	Hemiparesis, right	Hemiparesis, right	XRT, chemotherapy	11 months (died)
3	51	Glioblastoma (Grade IV)	Parietal, right	Hemiparesis, left	No deficits	XRT, chemotherapy	(died)
4	71	Meningioma (atypical)	Frontal	Seizure; monoparesis,,left leg	No deficits	None	72 months
5	70	Meningioma	Temporal, left	None	No deficits	None	74 months
6	56	Anaplastic astrocytoma (Grade III)	Parietal, left	Seizure	Unsteady gait	XRT, chemotherapy	9 months (died)
7	43	Oligodendroglioma (Grade II)	Fronto-parietal, right	Seizure; pronator drift, left	Dysdiadokinesis, left	none	74 months
8	40	Anaplastic astrocytoma (Grade III)	Frontal (posterior), right	Seizure; hemiparesis, left	Hemiparesis, left	XRT, chemotherapy	19 months (LTF)
9	45	Meningioma	Foramen magnum, right	Neck pain; no deficits	CN X1 paresis, right	Radiosurgery	85 months

Table 1: Patient's clinical findings.

Outcome Measures over time

SF-36: Mean SF-36 pre-surgery score was 57.3 +/16.9. Immediately following surgery, mean SF-36 score was 48.9+/-17.4. Three months following surgery, mean SF-36 score was 69.2+/-21.2. Changes in SF-36 score were significantly different between the pre-surgery and immediately after surgery time periods ($p < 0.05$), and between the immediately after surgery and 3 months after surgery time periods ($p < 0.01$). Pre-surgery to 3 months following surgery, SF-36 scores were not significantly different ($p = 0.11$). Like the TUG and Tinetti, SF-36 scores worsened immediately following surgery, and subsequently improved to near pre-surgery levels by 3 months following surgery. SF-36 scores are shown in Figure 1.

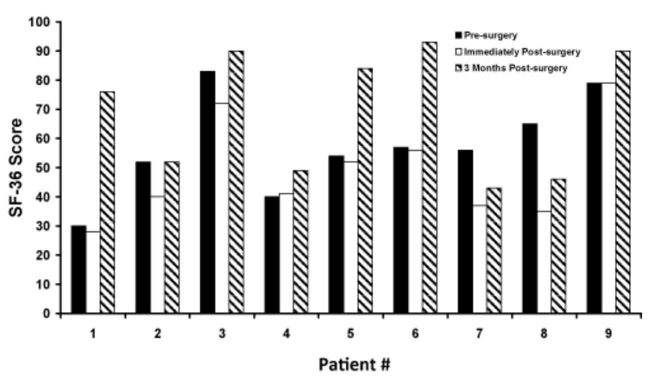

Figure 1: SF-36 Scores for all patients at each measurement point.

TUG: Mean TUG pre-surgery was 13.9 +/- 4.2 seconds. Immediately following surgery, TUG mean time deteriorated to 18.8 +/-7.1 seconds. At three months following surgery, mean TUG improved to 13.0+/-5.7 seconds. Changes in TUG time were significantly different between pre-surgery and immediately after surgery time periods ($p < 0.05$), and between immediately after surgery and 3 months after surgery time periods ($p < 0.005$). Pre-surgery to 3 months following surgery TUG times were not significantly different ($p = 0.86$). Figure 2 illustrates TUG times for each patient at each time point.

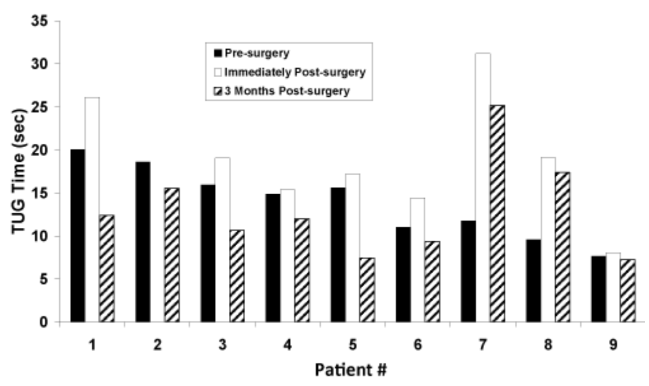

Figure 2: TUG scores for all patients at each measurement point.

TINETTI: Mean Tinetti pre-surgery score was 20.4 +/-5.7. Immediately following surgery, mean Tinetti score was 14.4 +/-8.2. Three months following surgery, mean Tinetti score was 23.6+/-4.6.

Changes in Tinetti score were also significantly different between the pre-surgery and immediately after surgery time periods ($p < 0.05$), and between the immediately after surgery and 3 months after surgery time periods ($p < 0.001$). Comparing pre-surgery to 3 months following surgery, Tinetti scores were not significantly different ($p = 0.11$). Like the TUG, Tinetti scores worsened immediately following surgery, and subsequently improved to near pre-surgery levels by 3 months following surgery. Tinetti results are depicted in Figure 3.

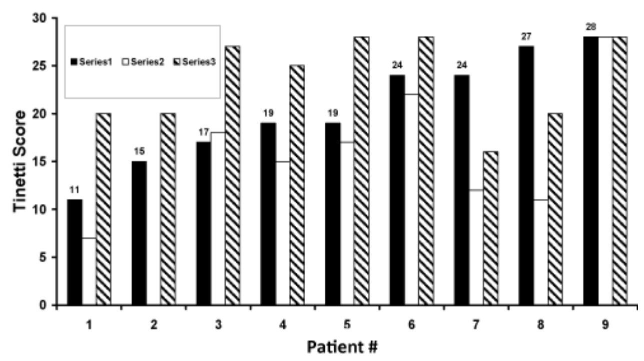

Figure 3: Tinetti scores for all patients at each measurement point.

Due to small sample size, no covariates were included in any ANOVA models.

Correlation of Outcome Measures

Pre-surgery, the TUG and Tinetti significantly correlated with each other. (r=0.992, p<0.05). SF-36 did not correlate with either balance and gait test prior to surgery. However, all scores significantly correlated with each other at the two time points following surgery. TUG and Tinetti correlated immediately post-surgery (r=-0.833, p<0.01) and 3 months post-surgery (r=-0.966, p<0.05. SF-36 and TUG (r=-0.762, p<0.05) and SF-36 and Tinetti (r=0.883, p<0.005) correlated immediately post-surgery. Lastly, balance and gait measures and QoL correlated at 3 months post-surgery (SF-36 and TUG: r=-0.845, p<0.005; SF-36 and Tinetti: r=0.849, p<0.005) (Figure 4).

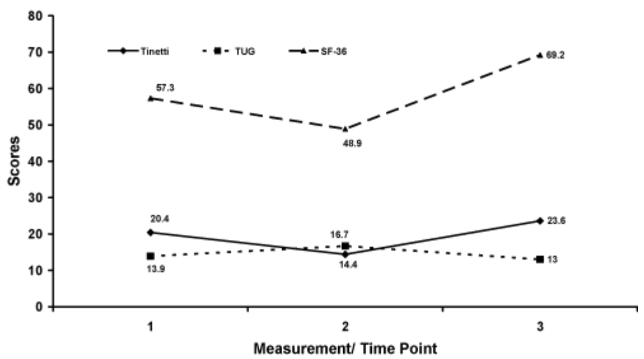

Figure 4: Mean scores for outcome measures at each measurement point.

Discussion

While survival remains an important endpoint, other endpoints warrant assessment in patients with cancer or other neoplasms [25]. Two domains not routinely measured in patients with brain tumors include physical function and QoL. Therefore, the goals of this study were to examine the utility of the TUG and Tinetti assessments of gait and balance in patients with primary brain tumors to determine whether such measures of physical function would also correlate with QoL We found that the TUG and Tinetti were appropriate and sensitive measures in patients with primary brain tumors. Furthermore, and the tests correlated well with each other and with SF-36 QoL tool.

The TUG data in this study is comparable to values calculated by Mayo et al. [38] in recovery of 111 patients in first three months following stroke. At three months, the TUG scores between Mayo et al. and our patients were virtually the same (post-stroke TUG was 15.2+/-11.2 seconds and brain tumor patients were 13.0+/-5.7 seconds), reinforcing similarities between stroke and brain tumor populations with regard to gait and balance.

In patients with brain tumors, the greatest impairment and loss of function typically occurs immediately after surgery [1]. Patients then improve over time. Therefore, physical functioning and QoL should not only be assessed shortly after surgery, but also after a period of time during which recovery can occur. Such trends were noted in this study, in which TUG, Tinetti, and SF-36 measures worsened initially after surgery, but improved to near pre-surgery levels at 3 months following surgery. As such, these tests results appropriately reflect patients' status.

Other measures of functional status used in brain tumor studies include the Functional Independence Measure (FIM), the Karnofsky Performance Scale (KPS), the Berg Balance scale (BBS), DGI, gait speed, and the five time sit to stand test. The FIM is a rehabilitation measure and does not specifically measure gait, balance, or the specifics of ambulation [23,39,40]. The KPS measures activities of daily living [2]; gait and balance are not considered in scoring. As such, these measures were not appropriate for assessing patient mobility in terms of gait and balance. The BBS has proven reliable and valid for use in assessing and quantifying balance and fall risk in older community dwelling individuals or with stroke older stroke patients [41]. It also correlates well with the TUG [42]. The BBS is also sensitive to change in stroke patients over time [43-45]. However, the BBS does not include an analysis or measure of ambulation abilities and was therefore excluded. The Dynamic Gait Index (DGI) is another reliable and valid measure used to evaluate and document a patient's ability to modify gait in response to changing task demands in ambulatory patients with balance impairments, specifically older community-dwelling adults and patients with vestibular dysfunction [46]. The DGI has been shown to discriminate between people with balance disorders and those without [47]. The DGI mainly assesses ambulation skills but has a limited number of balance-specific tasks compared to the Tinetti, therefore the Tinetti can offer more specific information on balance impairments. The 10m Walk Test measures how quickly a person can ambulate a distance of ten meters. This time can be compared to norms for functional community ambulators and help determine a person's functional abilities [45]. However, the 10m Walk Test measures only one aspect of ambulation, gait speed, and does not assess balance or quality of movement and does not assess other functional movements. The Five-Times-Sit-to-Stand test (FTSST) has been shown to identify people with balance dysfunction [47] but not as well as the DGI. It also looks only at one domain-sit to stand-whereas the Tinetti assesses multiple aspects of functional balance. Despite the availability of other balance and gait measures shown reliable and valid for neurologically impaired subjects, we chose the Tinetti for its ability to assess both domains as well as for its inclusion of several specific items for balance assessment. The TUG was chosen for its ease of administration and its use of everyday functional mobility: sit to stand, walking short distance, turning around, and moving stand to sit.

To assess QoL in this study, the SF-36, a generic QoL measure, was used. The SF-36 is quick to administer and has been used in more than 4000 publications representing a variety of disease-related studies [48]. Its wide-spread use across populations indicates evidence for its validity [49]. While the FACT-Br has been used more frequently for patients with cancer (including those with brain metastases) [50], the SF-36 has been used reliably and appropriately in neurological and cancer populations [51-56], including those with high-grade glioma [57] and craniopharyngioma [58].“Evidence of content, concurrent, criterion, construct, and predictive validity” has also been documented [48, 59]. Finally, the SF-36 “can also be used in repeated measures of the same patients over time” [48], is sensitive to change and can be used as a pre- and post- test [60] as it was here. Since this study focused on gait and balance as components of physical function, and the SF-36 includes a physical functioning domain [61] use of the SF-36 allowed us to analyze the influence of physical status changes on a person’s overall QoL.

In this study, the SF-36 did not correlate with either the TUG or Tinetti prior to surgery. This finding supports the differences between QoL and balance and gait measures: they are not measuring the same constructs. However, immediately after surgery and at 3 months post-surgery, the SF-36 significantly correlated with the TUG and Tinetti. As physical status changed, so did the patients’ self-perception of their QoL. While mobility is not the equivalent to QoL as measured by SF-36, in this study change in mobility scores did correlate with QoL. The relationship TUG and Tinnetti score to each of the 8 domains of the SF-36 was not assessed in this study because of our small patient population, but physical functioning is an important component of self-perceived QoL. This study suggests that as balance and gait worsen or improve, QoL may follow. Correlation of changes in scores of the TUG, Tinetti, and SF-36 supports use of these measures for research in the brain tumor population.

Both TUG and Tinetti are measures of gait and balance. Despite the Tinetti being more comprehensive and providing specifics regarding gait, the TUG is more practical to administer. Where time is limited, use of the TUG is appropriate and would provide adequate information regarding functional constructs of balance and mobility. However, if time is available, the Tinetti provides more specifics regarding balance and gait especially regarding quality of movement. The Tinetti includes balance activities (sternal nudge, eyes closed standing, turning 360°o while standing) that the TUG does not assess. The Tinetti also assesses quality of gait through items such as gait initiation, step symmetry, step continuity, path, trunk, walking time, and step length and height (right swing foot and left swing foot scored separately for both length and height) whereas the TUG measures only how fast a person performs a specific task.

Clinically relevant observations can be made using the Minimal Detectable Change (MDC) when examining raw scores. MDC is the amount of change on the score of an instrument that indicates a clinically relevant improvement or decline; the MDC is a change that is observable and demonstrates a variation in function. For the TUG, the MDC has not been clearly established; in patients with neurological diagnoses, values ranging from 2 to 11 seconds [49, 51, 52]. In a study of patients following stroke, Flansbjer et al determined MDC for TUG should be 23% times the average baseline score [27]; this translates to 3.1 seconds for our sample of patients with brain tumors. Using a conservative cut-off instead of 5 seconds as a value for MDC 3 of 9 subjects improved their TUG time and 2 subjects had a worse TUG time beyond the MDC comparing pre-surgery to 3 months post-surgery times. The 4 other subjects all improved their TUG scores but not beyond the 5 second MDC threshold.

The MDC for the Tinetti has been established as 5 points [62]. From pre-surgery to 3 months post-surgery, 5 subjects improved while 2 declined beyond this threshold; one subject improved 4 points, from 24 to the maximum possible score of 28 and one subject stayed the same, scoring the maximum of 28 both prior to and at 3 months post-surgery. Having a clinically relevant number upon which to gauge change in a particular patient can be used by health care professionals to proceed with therapeutic interventions.

Examining individual patients’ TUG and Tinetti MDC’s can yield additional insights. Mean values of the study group alone may obscure some observations. The limited number of patients in this study may have allowed extreme scores in one or two patients to skew group outcome data. Ceiling effects may exist, especially with the Tinetti, which limit the amount of improvement which can be demonstrated. For instance, a subject may score from 19 to24 on the Tinetti while demonstrating mild balance impairments. These impairments may resolve at 3 months, but the scores on the Tinetti can only improve several points due to the maximum possible score of 28. Also, several patients had minimal physical deficits. These patients would be completely functional both before and after surgery and therefore demonstrate little overall improvement.

Finally, mean group scores may have been influenced by tumor type. Some patients had aggressive tumors which recurred and progressed following surgery, resulting in decline in function, as evidenced in two subjects with gliobastoma. The scores of these two individuals may well have offset the improvement noted in the other patients, resulting in limited change in the patients as a group from pre- to 3 months post-surgery. This limitation is important to note for future research design.

Our study has a number of limitations. First and foremost, this report is only a pilot study involving a small number of patients. Additionally, the study involves a limited number of tumor types in different brain locations with variable degrees of aggressiveness and growth. Patients had different post-operative treatments. As such, the results may not be generalizable to the entire group of patients with brain tumors. Clearly, a larger follow-up study with a greater number of patients is necessary.

Data analysis should include comparison of age, postoperative complications, surgical management (technique and extent of resection), use of adjuvant therapies, patient participation in rehabilitation therapies, gender, recurrence, and tumor type, size, and location Pain can also affect mobility and QoL, and should be included. Balance and gait deficits present prior to surgery are important to assess. Patients without pre-operative deficits should be grouped separately from those with significant pre-surgery deficits to minimize ceiling effects. Such further evaluation and study should serve to validate our results presented here.

Citation: Krug J, Litofsky NS (2014) Relationship of Balance and Mobility Status to Quality of Life in Patients with Primary Brain Tumors: A Pilot Study. Int J Phys Med Rehabil 2: 196. doi:10.4172/2329-9096.1000196

Conclusions

This study illustrates that an evaluation of balance and gait, and their relationship to QoL is possible in patients with brain tumors. The TUG, Tinetti, and SF-36 are appropriate measures to use in future studies of patients with brain tumor. The strong correlation of the TUG and Tinetti suggest they may measure similar constructs, so the TUG may be favored as it can be carried out quickly in the clinical setting.

Acknowledgements

This research was done in partial fulfillment of the requirements for Mr. Krug's Master of Science degree at the University of Missouri, Columbia, Missouri.

References

1. Ragnarsson KT, Thomas DC (2003) Principles of Cancer Rehabilitation Medicine. (6th Edn.), Holland-Frei Cancer Medicine.
2. Khan RB, Gutin PH, Rai SN, Zhang L, Krol G, et al LM (2006) Of diffusion weighted magnetic resonance imaging in predicting early postoperative outcome of new neurological deficits after brain tumor resection. Neurosurgery 59: 60-66.
3. Kondziolka D, Nathoo N, Flickinger JC, Niranjan A, Maitz AH, et al. (2003) Long-term results after radiosurgery for benign intracranial tumors. Neurosurgery 53: 815-821.
4. Kowalczuk A, Macdonald RL, Amidei C, Dohrmann G 3rd, Erickson RK, et al. (1997) Quantitative imaging study of extent of surgical resection and prognosis of malignant astrocytomas. Neurosurgery 41: 1028-1036.
5. Little KM, Friedman AH, Sampson JH, Wanibuchi M, Fukushima T (2005) Surgical management of petroclival meningiomas: defining resection goals based on risk of neurological morbidity and tumor recurrence rates in 137 patients. Neurosurgery 56: 546-559.
6. Qureshi AI, Geocadin RG, Suarez JI, Ulatowski JA (2000) Long-term outcome after medical reversal of transtentorial herniation in patients with supratentorial mass lesions. Crit Care Med 28: 1556-1564.
7. Stafford SL, Pollock BE, Foote RL, Link MJ, Gorman DA, et al. (2001) Meningioma radiosurgery: tumor control, outcomes, and complications among 190 consecutive patients. Neurosurgery 49: 1029-1037.
8. Huang ME, Wartella JE, Kreutzer JS (2001) Functional outcomes and quality of life in patients with brain tumors: a preliminary report. Arch Phys Med Rehabil 82: 1540-1546.
9. Huang ME, Wartella J, Kreutzer J, Broaddus W, Lyckholm L (2001) Functional outcomes and quality of life in patients with brain tumours: a review of the literature. Brain Inj 15: 843-856.
10. O'Dell MW, Barr K, Spanier D, Warnick RE (1998) Functional outcome of inpatient rehabilitation in persons with brain tumors. Arch Phys Med Rehabil 79: 1530-1534.
11. Greenberg E, Treger I, Ring H (2006) Rehabilitation outcomes in patients with brain tumors and acute stroke: comparative study of inpatient rehabilitation. Am J Phys Med Rehabil 85: 568-573.
12. Giordana MT, Clara E (2006) Functional rehabilitation and brain tumour patients. A review of outcome. Neurol Sci 27: 240-244.
13. Mukand JA, Blackinton DD, Crincoli MG, Lee JJ, Santos BB (2001) Incidence of neurologic deficits and rehabilitation of patients with brain tumors. Am J Phys Med Rehabil 80: 346-350.
14. Bartolo M, Zucchella C, Pace A, Lanzetta G, Vecchione C, et al. (2012) Early rehabilitation after surgery improves functional outcome in inpatients with brain tumours. J Neurooncol 107: 537-544.
15. Bilgin S, Kose N, Karakaya J, Mut M (2013) Traumatic brain injury shows better functional recovery than brain tumor: a rehabilitative perspective. Eur J Phys Rehabil Med 49: 1-7.
16. Khan F, Amatya B (2013) Factors associated with long-term functional outcomes, psychological sequelae and quality of life in persons after primary brain tumour. J Neurooncol 111: 355-366.
17. Brazil L, Thomas R, Laing R, Hines F, Guerrero D, et al (1997) Verbally administered Barthel index as functional assessment in brain tumour patients. J Neurooncol 34: 187-192.
18. Lovely MP (2004) Symptom management of brain tumor patients. Semin Oncol Nurs 20: 273-283.
19. Benesch M, Lackner H, Sovinz P, Suppan E, Schwinger W, et al. (2006) Late sequela after treatment of childhood low-grade gliomas: a retrospective analysis of 69 long-term survivors treated between 1983 and 2003. J Neurooncol 78: 199-205.
20. Claus EB, Bondy ML, Schildkraut JM, Wiemels JL, Wrensch M, et al. (2005) Epidemiology of intracranial meningioma. Neurosurgery 57: 1088-1095.
21. Polin RS, Marko NF, Ammerman MD, Shaffrey ME, Huang W, et al. (2005) Functional outcomes and survival in patients with high-grade gliomas in dominant and nondominant hemispheres. J Neurosurg 102: 276-283.
22. Jones LW, Cohen RR, Mabe SK, West MJ, Desjardins A, et al. (2009) Assessment of physical functioning in recurrent glioma: preliminary comparison of performance status to functional capacity testing. J Neurooncol 94: 79-85.
23. Podsiadlo D, Richardson S (1991) The timed "up and go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 39: 142-148.
24. Tinetti ME, Speechley M, Ginter SF (1988) Risk factors for falls among elderly persons living in the community. N Engl J Med 319: 1701-1707.
25. Weitzner MA, Meyers CA, Gelke CK, Byrne KS, Cella DF, et al. (1995) The Functional Assessment of Cancer Therapy (FACT) scale. Development of a brain subscale and revalidation of the general version (FACT-G) in patients with primary brain tumors. Cancer 75: 1151-1161.
26. Brusse KJ, Zimdars S, Zalewski KR, Steffen TM (2005) Testing functional performance in people with Parkinson disease. Phys Ther 85: 134-141.
27. Flansbjer UB, Holmbäck AM, Downham D, Patten C, Lexell J (2005) Reliability of gait performance tests in men and women with hemiparesis after stroke. J Rehabil Med 37: 75-82.
28. Wall JC, Bell C, Campbell S, Davis J (2000) The Timed Get-up-and-Go test revisited: measurement of the component tasks. J Rehabil Res Dev 37: 109-113.
29. Black PM (1991) Brain tumor. Part 2. N Engl J Med 324: 1555-1564.
30. Haut MW, Haut JS, Bloomfield SS (1991) Family issues in rehabilitation of patients with malignant brain tumors. Neurorehabilitation 1: 39-47.
31. Tang V, Rathbone M, Park Dorsay J, Jiang S, Harvey D (2008) Rehabilitation in primary and metastatic brain tumours: impact of functional outcomes on survival. J Neurol 255: 820-827.
32. Shumway-Cook A, Brauer S, Woollacott M (2000) Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. Phys Ther 80: 896-903.
33. Steffen TM, Hacker TA, Mollinger L (2002) Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther 82: 128-137.
34. Bennie S, Bruner K, Dizon A, Fritz H, Goodman B, et al. (2003) Measurements of balance: comparison of the timed up-and-go test and functional reach test with the berg balance scale. Journal of Physical Therapy Science 15: 93-97.
35. Harada N, Chiu V, Damron-Rodriguez J, Fowler E, Siu A, et al. (1995) Screening for balance and mobility impairment in elderly individuals living in residential care facilities. Phys Ther 75: 462-469.
36. Whitney SL, Poole JL, Cass SP (1998) A review of balance instruments for older adults. Am J Occup Ther 52: 666-671.
37. Osoba D, Aaronson NK, Muller M, Sneeuw K, Hsu MA, et al. (1997) Effect of neurological dysfunction on health-related quality of life in patients with high-grade glioma. J Neurooncol 34: 263-278.

38. Mayo NE, Wood-Dauphinee S, Ahmed S, Gordon C, Higgins J, et al. (1999) Disablement following stroke. Disabil Rehabil 21: 258-268.
39. Geler-Kulcu D, Gulsen G, Buyukbaba E, Ozkan D (2009) Functional recovery of patients with brain tumor or acute stroke after rehabilitation: a comparative study. J Clin Neurosci 16: 74-78.
40. Meyers CA (1994) Neuropsychological aspects of cancer and cancer treatment. Physical Medicine and Rehabilitation: State of the Art Reviews. Hanley & Belfus, Philadelphia 229-241.
41. Berg K, Wood-Dauphinee SL, Williams JI (1995) The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med 27: 27-36.
42. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B (1992) Measuring balance in the elderly: validation of an instrument. Can J Public Health 83 Suppl 2: S7-11.
43. Mao HF, Hsueh IP, Tang PF, Sheu CF, Hsieh CL (2002) Analysis and comparison of the psychometric properties of three balance measures for stroke patients. Stroke 33: 1022-1027.
44. Wood-Dauphinee S, Berg KO, Bravo G, Williams JL (1997) The Balance Scale: responsiveness to clinically meaningful changes. Canadian Journal of Rehabilitation 10: 35-50.
45. Salbach NM, Mayo NE, Higgins J, Ahmed S, Finch LE, et al. (2001) Responsiveness and predictability of gait speed and other disability measures in acute stroke. Arch Phys Med Rehabil 82: 1204-1212.
46. Shumway-Cook A, Woollacott MH (2007) Motor Control: Translating Research into Clinical Practice. (3rd edn), Lippincott Williams & Wilkins, Philadelphia.
47. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, et al. (2005) Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther 85: 1034-1045.
48. Ware JE Jr (2000) SF-36 health survey update. Spine (Phila Pa 1976) 25: 3130-3139.
49. Cusimano MD (1999) Quality-of-Life Assessment in Patients with Lesions of the Cranial Base. Skull Base Surg 9: 259-264.
50. Lien K, Zeng L, Nguyen J, CramarossaG, Della D, et al. (2011) FACT-BR for assessment of quality of life in patients receiving treatment for brain metastases: a literature review. Expert Rev Pharmacoecon Outcomes Res 11: 701-708.
51. Fang FM, Tsai WL, Chien CY, Chiu HC, Wang CJ (2004) Health-related quality of life outcome for oral cancer survivors after surgery and postoperative radiotherapy. Jpn J Clin Oncol 34: 641-646.
52. Garland SJ, Ivanova TD, Mochizuki G (2007) Recovery of standing balance and health-related quality of life after mild or moderately severe stroke. Arch Phys Med Rehabil 88: 218-227.
53. Rogers SN, Humphris G, Lowe D, Brown JS, Vaughan ED (1998) The impact of surgery for oral cancer on quality of life as measured by the Medical Outcomes Short Form 36. Oral Oncol 34: 171-179.
54. Chen JC, Johnstone SA (2002) Quality of life after lung cancer surgery: a forgotten outcome measure. Chest 122: 4-5.
55. Reulen RC, Zeegers MP, Jenkinson C, Lancashire ER, Winter DL, et al. (2006) The use of the SF-36 questionnaire in adult survivors of childhood cancer: evaluation of data quality, score reliability, and scaling assumptions. Health Qual Life Outcomes 4: 77.
56. Wilburn O, Wilburn P, Rockson SG (2006) A pilot, prospective evaluation of a novel alternative for maintenance therapy of breast cancer-associated lymphedema [ISRCTN76522412]. BMC Cancer 6: 84.
57. Litofsky NS, Farace E, Anderson F, Meyers CA, Huang, W, et al. (2004) Depression in patients with high-grade glioma: results of the Glioma Outcomes Project. Neurosurgery 54: 358-367.
58. Dekkers OM, Biermasz NR, Smit JW, Groot LE, Roelfsema F, et al. (2006) Quality of life in treated adult craniopharyngioma patients. Eur J Endocrinol 154: 483-489.
59. Brazier JE, Harper R, Jones NM, O'Cathain A, Thomas KJ, et al. (1992) Validating the SF-36 health survey questionnaire: new outcome measure for primary care. BMJ 305: 160-164.
60. Anderson C, Laubscher S, Burns R (1996) Validation of the Short Form 36 (SF-36) health survey questionnaire among stroke patients. Stroke 27: 1812-1816.
61. Dallmeijer AJ, Dekker J, Knol DL, Kalmijn S, Schepers VP, et al. (2006) Dimensional structure of the SF-36 in neurological patients. J Clin Epidemiol 59: 541-543.
62. Faber MJ, Bosscher RJ, van Wieringen PC (2006) Clinimetric properties of the performance-oriented mobility assessment. Phys Ther 86: 944-954.

This article was originally published in a special issue, entitled: **"Cancer Rehabilitation"**, Edited by J Luo, Temple University School of Medicine, USA