Accuracy of operating neurosurgeons' prediction of functional levels after intracranial tumor surgery

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OBJECTIVE In the absence of practical and reliable prognostic tools in intracranial tumor surgery, decisions regarding patient selection, patient information, and surgical management are usually based on neurosurgeons' clinical judgment, which may be influenced by personal experience and knowledge. The objective of this study was to assess the accuracy of the operating neurosurgeons' predictions about patients' functional levels after intracranial tumor surgery.

METHODS In a prospective single-center study, the authors included 299 patients who underwent intracranial tumor surgery between 2011 and 2015. The operating neurosurgeons scored their patients' expected functional level at 30 days after surgery using the Karnofsky Performance Scale (KPS). The expected KPS score was compared with the observed KPS score at 30 days.

RESULTS The operating neurosurgeons underestimated their patients' future functional level in 15% of the cases, accurately estimated their functional levels in 23%, and overestimated their functional levels in 62%. When dichotomizing functional levels at 30 days into dependent or independent functional level categories (i.e., KPS score < 70 or ≥ 70), the predictive accuracy was 80%, and the surgeons underestimated and overestimated in 5% and 15% of the cases, respectively. In a dichotomization based on the patients' ability to perform normal activities (i.e., KPS score < 80 or ≥ 80), the predictive accuracy was 57%, and the surgeons underestimated and overestimated in 3% and 40% of cases, respectively. In a binary regression model, the authors found no predictors of underestimation, whereas postoperative complications were an independent predictor of overestimation ($p = 0.01$).

CONCLUSIONS Operating neurosurgeons often overestimate their patients' postoperative functional level, especially when it comes to the ability to perform normal activities at 30 days. This tendency to overestimate surgical outcomes may have implications for clinical decision making and for the accuracy of patient information.

<https://thejns.org/doi/abs/10.3171/2016.3.JNS152927>

KEY WORDS brain neoplasms; decision making; Karnofsky Performance Scale; prognosis; surgery; oncology

IN intracranial tumor surgery, patient selection in terms of surgical strategy, which tools to use, how much tissue to remove, and when to abstain from surgery is particularly important because the margins between good outcome and devastating deficits can be small. However, in the absence of practical and reliable prognostic tools, surgical management strategies continue to be based mainly on neurosurgeons' clinical judgment, which may be influenced by personal experience, knowledge, and per-

haps even personality. Inaccurate predictions concerning the results may lead to incorrect patient information and nonbeneficial management strategies. Thus, it is important to be aware of the reliability of the clinical judgment. In other clinical disciplines, a tendency toward overoptimism has been demonstrated, both for predicting life expectancy and for other surgical results.^{5,11,12,17}

In this prospective study, we aimed to assess the accuracy of the operating neurosurgeons' prediction of

ABBREVIATIONS KPS = Karnofsky Performance Scale.

SUBMITTED December 15, 2015. **ACCEPTED** March 9, 2016.

INCLUDE WHEN CITING Published online June 17, 2016; DOI: 10.3171/2016.3.JNS152927.

functional levels 30 days after intracranial tumor surgery by comparing expected and observed Karnofsky Performance Scale (KPS) scores.¹⁸

Methods

Study Design and Study Population

We prospectively included 299 unselected patients $\geq$ 18 years of age who underwent elective craniotomy for an intracranial tumor at St. Olavs University Hospital in Trondheim, Norway. Our department serves a population of approximately 750,000 as the single neurosurgical department in 1 of Norway's 4 geographical health regions. The inclusion period was from September 2011 through March 2015.

All operations were performed after induction of general anesthesia, and a neuronavigation system with 3D preoperative MRI and updated intraoperative 3D ultrasound volumes was used as needed.¹⁴ Preoperative functional MRI and MRI tractography were performed if preferred by the operating surgeon.⁶ Direct cortical and subcortical stimulation for motor functions and neurophysiological stimulation for preservation of cranial nerves were used in selected cases. In total, 13 different neurosurgeons performed the procedures in the study period; these were both consultants and residents. Surgical strategies were discussed in clinical meetings before surgery, and the operating surgeons performed a clinical examination and informed the patients about the potential risks and benefits of surgery in preoperative consultations.

Data Collection and Variables

Right after having finished surgery, while the patient still had not emerged from general anesthesia, the operating surgeon rated the patient's expected functional level at 30 days after surgery by using KPS scores. The same surgeon had also rated the patient's preoperative KPS score, and was thus aware of the baseline functional level. The KPS is a widely used measure in oncological and neurosurgical research. It consists of a 10-level scale, with scores ranging from 100 (normal function, no complaints or evidence of disease) to 0 (death). The scale has shown good validity and excellent interrater reliability.^{25,31}

The observed KPS score at 30 days was calculated by a trained study nurse based on answers from a comprehensive telephone interview as part of a related project. The questions included in this interview addressed health-related quality of life, postoperative neurological deficits, and need for assistance. In 15 cases in which the patients were unable to answer for themselves (e.g., due to severe dysphasia), proxy ratings were used. The study nurses did not account for the surgeons' expected KPS score when rating; hence their ratings were independent.

Baseline and treatment data were collected from electronic medical records. The histopathological finding was confirmed by a neuropathologist according to the WHO classification.²² The MR images were assessed by a neurosurgeon, and an ellipsoid volume formula ($4\pi \times r^3/3$) based on the maximal tumor diameters in the perpendicular dimensions was used to calculate tumor volumes.

Eloquence was graded as suggested by Sawaya et al.³⁰ Complications were registered according to the classification system introduced by Landriel Ibañez et al.²¹ Using this classification system, the complications that occurred within 30 days were divided into surgical and medical, and into grades of severity (Grade 1–4). Grade 1 complications were those not requiring invasive treatment; Grade 2 complications required invasive treatment (with or without general anesthesia); Grade 3 complications were life-threatening complications requiring management in an ICU; and Grade 4 complications led to death. If the patient was suffering several complications, the most severe was registered. By definition, surgical complications were directly related to the surgery or surgical technique (e.g., hematoma, hydrocephalus, CSF leak), whereas medical complications were not directly related to the surgery or surgical technique (e.g., urinary tract infection, pneumonia, pulmonary embolism).

Ethics and Approvals

All included patients gave their written and informed consent at admission. Data collection was approved by the Regional Committee for Medical and Health Research Ethics in Mid-Norway and adhered to the guidelines of the Helsinki Declaration.

Statistical Analyses

All analyses were done using SPSS statistics software, version 22.0. We used Q-Q plots to test for normal distribution of data. The mean $\pm$ SD was presented if data were normally distributed, whereas medians and interquartile range were presented in skewed data. Expected and observed KPS scores were compared in contingency tables. In a binary regression model, we tested possible predictors of under- and overestimation ($p < 0.10$ as univariables). The statistical significance level was set to $p < 0.05$.

Results

Study Population

Of 466 consecutive patients who were surgically treated for intracranial tumors, 299 (64%) were included and analyzed in the study. A flow chart of the inclusion process is presented in Fig. 1. As shown, 23 patients were lost to follow-up. Among these, we found 5 patients who were "too ill to answer" (e.g., terminal phase of disease, severe psychiatric symptoms) after review of their hospital records.

Baseline and treatment characteristics are presented in Table 1. The mean patient age was 55 years, and 47% were female. The majority of patients were functionally independent, with a KPS score of ≥ 70 prior to surgery ($n = 267$, 89%). The most frequent histopathological results were high-grade glioma ($n = 94$, 31%), meningioma ($n = 87$, 29%), low-grade glioma ($n = 45$, 15%), and metastasis ($n = 50$, 17%). As seen in Table 1, 108 (36%) of the tumors were located in eloquent areas. Postoperative complications occurred in 90 patients (30%); of these, 79 patients (88%) had minor complications (Landriel Ibañez Grade 1–2).

FIG. 1. Flow chart of the inclusion process used for this study.

Prediction of Postoperative Functional Level

In a contingency table, the expected KPS score is compared with the observed KPS score after 1 month (Table 2). Accurate predictions are shown in the diagonal gray-shaded cells ($n = 69$, 23%). In cases to the left of the shaded cells the surgeons overestimated the postoperative functional level ($n = 184$, 62%), whereas functional levels in cases to the right of the shaded cells were underestimated by the surgeons ($n = 46$, 15%).

When dichotomizing KPS scores into functional independence (≥ 70) and functional dependence (< 70) categories, the surgeons made accurate estimations in 80%, underestimated in 5%, and overestimated in 15% of the cases (Table 3). The positive predictive value of the surgeons' expected functional level was 58% for functional dependence and 83% for functional independence.

We also dichotomized the KPS variable dependent on the patient's ability to perform normal activities (i.e., KPS score < 80 and ≥ 80). Based on this, the operating neurosurgeons made accurate estimations in 57%, underestimated in 3%, and overestimated in 40% of the cases (Table 4). The positive predictive value of the operating surgeons' expected functional level was 41% for normal function and 90% for impaired function.

When comparing residents and consultants, we found that the residents underestimated in 20% of the cases, accurately estimated in 30%, and overestimated in 50%, whereas the consultants underestimated in 14% of the cases, accurately estimated in 21%, and overestimated in 64%. The senior consultants with more than 20 years of experience who had performed more than 10 operations in the present study, underestimated in 0%–18% of the cases, accurately estimated in 12%–28%, and overestimated in 54%–88%.

Using binary regression, we sought to explore possible predictors for over- and underestimation. Age in years, high-grade glioma, meningioma, metastasis, American Society of Anesthesiologists score ≥ 3 , and eloquent tumor location were not associated with overestimation in univariable analyses ($p > 0.10$). In a multivariable model (Table 5) we included low-grade glioma (yes/no), consultant as operating surgeon (yes/no), postoperative deficits (yes/no), and complications (yes/no), but only postoperative complications were found to be an independent predictor of overestimation ($p = 0.01$). Using the same variables, we identified no predictors of underestimation.

In total, 55% of the complications that were associated with overestimation were directly related to surgery or

surgical technique (Table 6). As shown, the majority of these complications were mild (57%) or moderate (30%).

Discussion

Main Findings

In this prospective study, we explored the operating neurosurgeons' ability to predict functional levels at 30 days after intracranial tumor surgery. In 6 of 10 cases, the surgeons tended to overestimate functional levels at 30 days. This was found to be associated with postoperative complications in a multivariable model. The surgeons were often accurate in predicting dependence or independence, but were often overly optimistic concerning the patients' ability to perform normal activities at 30 days. Consultants did not predict more accurately than residents. This overoptimism in prediction may possibly imply that many patients with brain tumors suffer from unintended surgical effects that are not expected by the operating surgeons. This may potentially affect clinical decision making and the accuracy of patient information.

Clinical Prediction

The neurosurgeon's clinical judgment is based on knowledge of both prognostic factors and the natural history of disease, personal experience, level of critical thinking, and perhaps also personality. Indications for intracranial surgery, surgical strategies, and even operability are often relative and influenced by clinical judgment, and it is thus of importance to be aware of the reliability. Unfortunately, we found our neurosurgeons to be overly optimistic, at least when predicting short-term functional level at 30 days. Because consultants did not predict more correctly than residents, one may postulate that experience has a limited impact on prediction ability. However, the results may also be affected by selection bias—consultants and residents perform different operations.

In a study from 2014, Kondziolka et al. assessed the accuracy of neurosurgeons, radiation oncologists, and medical/neurooncologists in the prediction of survival in 150 patients with brain metastasis undergoing radiosurgery.¹⁹ These investigators found all clinicians to be relatively poor at predicting survival, and that neurosurgeons as a group were more optimistic than medical/neurooncologists. Clinicians' prediction of postoperative morbidity and survival have also been examined in a few nonneurosurgical studies, with inconsistent findings depending on both methods and discipline.^{11,12,16,17,24,35} In accordance with our findings, most studies found the clinicians to be overoptimistic. This may be explained by overconfidence, which is a common phenomenon in decision making processes.^{4,13} Overconfidence, in turn, seems to depend on confirmation bias,²⁰ where the decision maker is favoring information that confirms previously existing beliefs. Thus, it is also related to the amount and strength of supporting evidence in published literature. Unfortunately, publication bias is common in surgical research.³⁴ Furthermore, retrospective studies using unstandardized outcome measures are overrepresented in intracranial tumor surgery, and often contain both selection bias and assessment bias.³² As we have demonstrated in a recent study, underreporting of

TABLE 1. Baseline and treatment characteristics in 299 patients with intracranial tumors

Characteristic	Value (%) [*]
No. of patients	299
Age in yrs, mean $\pm$ SD	55 $\pm$ 14
Female sex	140 (47)
Preop KPS score	
≥ 80	218 (73)
70	49 (16)
≤ 60	32 (11)
ASA score	
1–2	218 (73)
≥ 3	81 (27)
Histopathological finding	
High-grade glioma	94 (31)
Diffuse low-grade glioma	45 (15)
Meningioma	87 (29)
Metastasis	50 (17)
Other tumor†	23 (8)
Primary op	205 (69)
Multifocal	30 (10)
Median preop tumor vol in cm ³ , IQR	16, 5–32
Eloquent tumor—Sawaya Grade 3	108 (36)
Operating surgeon	
Consultant	239 (80)
Resident	60 (20)
Postop complications‡	90 (30)
Surgical	48 (16)
Medical	42 (14)
Mild; Grade 1	56 (19)
Moderate; Grade 2	23 (8)
Severe; Grade 3	7 (2)
Death; Grade 4§	3 (1)
New or worsened motor or language deficits¶	24 (8)
Initiation of postop radiotherapy before 30 days	62 (21)
Initiation of postop chemotherapy before 30 days	66 (22)

ASA = American Society of Anesthesiologists; IQR = interquartile range.

^{*} Except for age and tumor volume, values are presented as the number of patients (%).

† Ependymoma (n = 2), subependymoma (n = 3), pilocytic astrocytoma (n = 2), primitive neuroectodermal tumor (n = 1), ganglioglioma (n = 2), schwannoma (n = 1), neurocytoma (n = 2), hemangioblastoma (n = 5), hemangioma (n = 2), osteosarcoma (n = 1), lymphoma (n = 1), choroid plexus papilloma (n = 1).

‡ Any complication registered within 30 days. If suffering several complications the most severe was registered (graded 1–4 according to Landriel Ibañez et al.).

§ In total 4 patients died within 30 days, but cause of death in 1 patient with brain metastasis was the underlying cancer disease (no complication).

¶ Postoperative new or worsened motor or language deficits from medical records, reported by patients as "permanent" after 30 days.

postoperative morbidity may be substantial.⁹ With this taken into account, neurosurgeons' overoptimism regarding their surgical results is not very surprising.

Although most studies found clinicians to be overoptimistic, 2 studies predicting complications after gas-

TABLE 2. Contingency table comparing expected versus observed KPS score after 1 month*

Expected KPS Score	Observed KPS Score											Total
	0	10	20	30	40	50	60	70	80	90	100	
50	2			1	1		4			1		9
60	1				1	3	8	11	2		1	27
70	1		1		3	1	16	32	1	4	1	60
80					1	1	12	32	9	10	4	69
90							5	44	14	15	7	85
100							3	22	9	10	5	49
Total	4	0	1	1	6	5	48	141	35	40	18	299

* Overestimation in 62% (values to the left of shaded cells), accurate estimation in 23% (values in shaded cells), underestimation in 15% (values to the right of shaded cells).

trointestinal surgery nevertheless found that the clinical prediction was better than a scoring system.^{16,24} Another study found clinical prediction to be valuable when incorporating it into a multifactorial prediction model in the same field.³⁵ Prognostic tools based on multiple factors can be useful in decision making, and several grading systems have also been proposed for various types of intracranial tumors.^{1,7,8,10,23,26,27,33} These are usually based on independent prognostic factors such as age, functional status, comorbidity, preoperative symptoms, histopathology, and tumor characteristics. However, because most available grading systems attempt to predict duration of survival, they do not take postoperative morbidity into account, even though preservation of functions and quality of life is the main therapeutic goal in many cases. Intracranial tumor surgery is a tremendously complex and demanding field, and disease courses are heterogeneous. A reliable prognostic tool for neurological deficits, complications, and disease course for a given patient, with a particular tumor, in a specific location of the brain is possibly utopian. Thus, neurosurgeons' clinical judgment is still the most decisive factor in many cases.

Prediction of Functional Level

The KPS score reflects the total burden of disease and comorbidity on the patients' functional status. It is a well-known prognostic factor for survival in patients with brain tumors. In addition, the score correlates to patient-reported quality of life.²⁸ Prediction of the KPS score is thereby useful for both patient selection and for assessing the risks and benefits of surgery, but we must acknowledge that an accurate prediction is difficult because the score is based on a rather gross general impression of the patient. When scoring the patients' functional state, both objective

and subjective variables affecting daily activities must be considered. The latter is a particular challenge, because subjective issues like fatigue, pain, dizziness, nausea, or depression may be undetected if not asked about explicitly. Also, even though the scale has shown good validity and interrater reliability, it is not easy to differentiate between some of the levels. This was our reason for dichotomization into a dependent or independent functional level (i.e., < 70 or ≥ 70) and whether the patients had the ability to perform normal activities (i.e., < 80 or ≥ 80). Nevertheless, we found our neurosurgeons to be overoptimistic, especially when it comes to the patients' ability to perform normal activities.

Neurosurgeons have, by tradition, had a special respect for eloquent regions in the brain and are perhaps unaware of or even ignore complaints unrelated to these regions when making prognoses. Cognitive problems are largely underestimated by neurosurgeons compared with the patients' perspective,⁹ and we assume that other subtle and/or subjective symptoms are also underestimated, although they may have a major impact on the patients' working ability and functional level. We would especially like to highlight the neurosurgeons' optimism regarding completely normal function (i.e., KPS Score 100) at 30 days. As demonstrated in Table 2, only 18 of 299 patients had completely normal function without symptoms or complaints, and we believe this finding is important to bear in mind when informing patients prior to surgery.

Not surprisingly, postoperative complications were found to be an independent predictor of overestimation in the present study. The majority of these complications were minor, which may imply that seemingly mild complications such as urinary tract infections may also significantly affect the patients' ability to perform daily activities at 30 days postoperatively. Even though we did

TABLE 3. Neurosurgeons' prediction of functional dependence or independence in 299 patients with intracranial tumors

Expected KPS Score	No. w/ Observed KPS Score (%)		
	Underestimation	Accurate Estimation	Overestimation
<70	15	21	NA
≥70	NA	219	44
Total	15 (5)	240 (80)	44 (15)

NA = not applicable.

TABLE 4. Neurosurgeons' prediction of normal function in 299 patients with intracranial tumors

Expected KPS Score	No. w/ Observed KPS Score (%)		
	Underestimation	Accurate Estimation	Overestimation
<80	10	86	NA
≥80	NA	83	120
Total	10 (3)	169 (57)	120 (40)

TABLE 5. Predictors of overestimation in 184 of 299 patients with intracranial tumors

Predictor	No. of Patients	Univariable Analyses		Multivariable Analysis	
		OR (95% CI)	p Value	OR (95% CI)	p Value
Diffuse low-grade glioma	45	0.80 (0.50–1.28)	0.08	1.68 (0.82–3.47)	0.16
Consultant—operating surgeon	239	1.81 (1.02–3.21)	0.04	1.72 (0.95–3.10)	0.07
Postop motor or language deficits*	24	2.91 (1.13–7.51)	0.03	2.31 (0.90–5.94)	0.08
Postop complications†	90	2.29 (1.33–3.96)	0.003	2.03 (1.16–3.55)	0.01

* Postoperative new or worsened motor or language deficits from medical records, reported as permanent after 30 days (patient-reported outcomes).

† Any complication registered within 30 days. If patient was suffering several complications, the most severe is registered.

not reach the same statistical conclusion for surgically acquired neurological deficits, there was a trend ($p < 0.1$), and we believe that surgical risks are generally underestimated, partly due to the aforementioned underreporting in published literature. This means that some patients in hindsight may regret their choice of treatment, and patients with malignant tumors may waste precious time at the end of their life with reduced quality of life and in need of assistance, or even hospitalization.² Furthermore, in patients with high-grade gliomas, a postoperative reduction of functional level decreases the likelihood of receiving life-extending adjuvant treatment in the form of radio- and chemotherapy.¹⁵

Strengths and Limitations

The generalizability of our findings will depend on the case mix, but external validity is presumably good, given the large sample size and the population-based referral. Our findings may also be influenced by the experience and knowledge of the participating neurosurgeons. Theoretically, their clinical judgment may be better or worse than average. In our department, the KPS score is used in daily clinical decision making, and the surgeons have routinely assigned the preoperative KPS score in all patients since 2007. The scoring is based on a preoperative consultation and a clinical examination by the same surgeon. Thus, we believe the surgeons are well versed in scoring using the KPS. Local follow-up routines have an impact on the surgeons' experience with the normal postoperative course and may affect the surgeons' predictions. In our center, patients with high-grade gliomas and metastases are usually not followed by operating surgeons after discharge, whereas patients with other tumors are seen by their surgeons approximately 4 weeks after surgery, as outpatients.

Using telephone interviews for rating the KPS score was

done for practical reasons. Because this study was part of a larger related project, the interviews contained approximately 75 questions, and lasted 15–45 minutes. During the conversation, the study nurses gained a detailed impression of the patient's functional level, and asked explicitly when in doubt. Thus, we truly believe that the scores are reliable.

An ideal time point for assessing outcomes is difficult to find for any condition, especially for heterogeneous brain tumors. A surgery-related outcome measure should ideally and primarily reflect the effects of surgery, and not capture the impact of disease progression or subsequent therapy such as specialized rehabilitation or cancer treatment. In the present study, approximately 1 in 5 patients had started radiotherapy and/or chemotherapy at follow-up. However, in patients with high-grade glioma, radiotherapy and temozolomide are usually not associated with many adverse effects early after surgery, and patient-reported quality of life is quite stable from 1 month after surgery to tumor progression.²⁹ Follow-up at 30 days was chosen because by tradition this has been regarded as the postoperative period, and both postoperative mortality and postoperative complications are often reported using this criterion. Although such short-term results are especially important for patients with malignant tumors, we believe that knowledge of the postoperative course is also important for benign and low-grade tumors. Surgeons inform their patients regarding what to expect after surgery and make judgments concerning benefits and risks. Thus, they should ideally be able to present a realistic prognosis to the patient. We do not know if surgeons would be better at guessing outcomes at 3 months, 6 months, or 1 year. However, long-term predictions are usually less accurate than short-term ones.¹¹ Even so, predictions of long-term results may perhaps be less affected by surgery and more influenced by the neurosurgeons' knowledge of the disease.

Implications for Future Research

To calibrate neurosurgeons' clinical prediction accuracy to get a less optimistic and more realistic picture of surgical implications, there is a need for high-quality studies in brain tumor surgery research. Validated outcome measures for postoperative morbidity and patient-reported outcomes can be important contributions in this matter.³ Additionally, development of reliable prognostic tools for postoperative morbidity is highly desired. In the meantime, raising awareness of the issue may help to correct neurosurgeons' overoptimistic attitudes.

TABLE 6. Postoperative complications associated with overestimation in 67 of 299 patients with intracranial tumors

Complication	No. (%)
Surgical	37 (55)
Medical	30 (45)
Mild; Grade 1	38 (57)
Moderate; Grade 2	20 (30)
Severe; Grade 3	6 (9)
Death; Grade 4	3 (4)

Conclusions

In this prospective study, we found that neurosurgeons often overestimate the patients' postoperative functional levels, especially when it comes to the ability to perform normal activities. The tendency to overestimate surgical outcomes may have implications for clinical decision making and for the accuracy of patient information.

Acknowledgments

We thank Linda M. Nordtvedt and Even Hovig Fyllingen, together with participating neurosurgeons at St. Olavs University Hospital, for assisting in data collection.

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Disclosures

The authors report no conflict of interest concerning the materi-

als or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Sagberg, Jakola, Solheim. Acquisition of data: Sagberg, Jakola. Analysis and interpretation of data: Sagberg, Solheim. Drafting the article: Sagberg. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Sagberg. Statistical analysis: Sagberg, Solheim. Study supervision: Jakola, Solheim.

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