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Original Article

Do we need a neurosurgical frailty index?

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ABSTRACT

Background: An increasing number of elderly patients now require neurosurgical intervention, and it is sometimes unclear if the benefits of surgery outweigh the risks, especially considering the confounding factor of numerous comorbidities and often poor functional states. Historically, many patients were denied surgery on the basis of age alone. This paper examines the current selection criteria being used to determine which patients get offered neurosurgical management and attempts to show if these patients have a good outcome. Particular focus is given to the increasing insight into the need to develop a neurosurgical frailty index.

Methods: Using a prospective cohort study, this study observed 324 consecutive patients (*n*) over a 3-month period who were ≥65 years of age at the time of referral or admission to the neurosurgical department of the Royal Hallamshire Hospital. It highlights the selection model used to determine if surgical intervention was in the patient's best interest and explores the reasons why some patients did not need to have surgery or were considered unsuitable for surgery. Strengths and weaknesses of different frailty indices and indicators of functional status currently in use are discussed, and how they differ between the patients who had surgery and those who did not.

Results: Sixty-one (18.83%) of *n* were operated on in the timeframe studied. Compared to patients not operated, they were younger, less frail, and more functionally independent. The 30-day mortality of patients who had surgery was 3.28%, and despite the stringent definition of poor outcomes, 65.57% of patients had good postoperative results overall, suggesting that the present selection model for surgery produces good outcomes. The independent variables that showed the greatest correlation with outcome were emergency surgery, the American Society of Anesthesiology grade, the Glasgow Coma Scale, and modified frailty index-5.

Conclusion: It would be ideal to carry out future studies of similar designs with a much larger sample size with the goal of improving existing selection criteria and possibly developing a neurosurgical frailty index.

Keywords: Neurosurgical frailty index, Frailty, Neurosurgery in elderly, Neurosurgery in frail patients

INTRODUCTION

Background

Current data suggest that about 11% of the world's population is at least 60 years of age with this figure expected to rise to 22% by 2050.[15] It has also been estimated that by 2050 there will be over 3.4 million centenarians worldwide.[10] It is therefore, unsurprising that an increasing number of elderly patients require neurosurgical intervention when these demographic changes are coupled with the increased incidence of chronic subdural hematomas, metastatic and primary brain tumors, and degenerative spine diseases in older patients.[24] Historically, many surgeons have shown reluctance in accepting elderly patients to receive neurosurgical care, and age has been shown to be an independent risk factor for perioperative complications in spinal surgery, for example;[29] however, it is ultimately a subjective task to determine the exact cutoff age at which a particular surgical procedure is considered too dangerous. There has been a paradigm shift in the past 20 years, as many studies have shown that age as an independent risk factor should not be used as a contraindication to neurosurgical procedures. This realization is buttressed by the data which show similarity in outcomes between both older and younger patients when controlled for other contributing factors.[25] There is nonetheless a gaping dearth in the literature of robust selection criteria for neurosurgery in the elderly, particularly in the presence of varying degrees of frailty.

Frailty

Frailty has been progressively shown to be a very important index for predicting postoperative complications and thus weighing up the risk of surgery against the likely benefit. Clegg *et al*.[8] defined frailty as "A state of increased vulnerability to poor resolution of homeostasis after a stressor event, which increases the risk of adverse outcomes, including falls, delirium, and disability." Frail individuals are generally older, have a greater number of comorbidities, and have a higher incidence of physical and cognitive impairment.[5] Some instances in neurosurgical literature where the correlation of frailty with postoperative outcomes was shown include the work of Youngerman *et al*.,[32] where they demonstrated that morbidity, mortality, and prolonged admissions increased with increasing levels of frailty as calculated using the Modified frailty index[30] (MFI) [Appendix A] and Cloney *et al*.[9] who published data that suggested that frailer patients with glioblastoma received less aggressive intervention, had longer hospital admissions, and suffered more complications. There are at least 31 different frailty indices, but a lack of consensus exists on which index is most practical to assess and yet, is clinically relevant in predicting outcomes.[26] A standardized and thoroughly validated neurosurgical frailty index would be very beneficial in the development of scientific and universal selection criteria for neurosurgery in the elderly.

What is the best frailty index and determinant of functional status?

Some of the commoner indices currently in use have undergone different degrees of validation and modification, but it appears that it is still quite elusive to get robust indices which are easy to administer or derive in the clinical setting, capture the imperative information, and yet have high predictive values.

The MFI-5 used in this paper was derived from MFI-11 which has 11 factors made of 16 variables. One criticism of the MFI-5 noted while carrying out this research work is that it appears to categorize certain patients erroneously. A patient who is frail from any other combination of morbidities apart from congestive heart failure, hypertension, diabetes, or chronic obstructive pulmonary disease and is not currently functionally dependent will be assigned a score of 0 even though such a patient may have glioblastoma multiforme with just a few months to live and have other comorbidities not recognized by the MFI-5. The Clinical frailty scale [Appendix B] is probably better in this regard as it takes into cognizance patients who are terminally ill and yet not otherwise evidently frail (CFS-9).

The Glasgow Coma scale (GCS)[27] [Appendix C] was primarily designed to provide a practical way to assess the impairment of consciousness after acute brain injury at the bedside. It is, therefore, an ideal tool for predicting patient outcomes after traumatic brain injuries but might not be an ideal tool for predicting outcomes in patients who have been admitted for elective spinal degenerative surgeries. That is why some authors caution that in predicting outcomes, it should only be used in combination with other variables in a multivariate model.[27]

The Eastern Cooperative Oncology Group/World health organization performance status[31] [Appendix D] focuses primarily on the subject's physical status. A cursory look at the derivation of respective scores in this index gives the impression that this index ignores the place cognitive function plays in frailty.

The modified Rankin scale (MRS) [Appendix E] might not fully interpret outcomes in patients in whom physical disability or its resolution is not the primary outcome of interest. Another recognized weakness, which is also present in many of the frailty indices above – is the subjective determination between categories and reproducibility of the score between examiners and the patients (Broderick, 2017).[4]

It is, therefore, apparent that more work needs to be done in the creation of a frailty index, perhaps primarily created for neurosurgical patients, that will be reproducible, easy, and convenient to determine and have a well-validated predictive value of neurosurgical outcomes of interest.

The status quo

At present, the majority of works in the literature that have studied the impact the age of patients has on their outcomes after neurosurgical intervention are retrospective and single-center studies. These include the works of Chen *et al*.[7] and Heiland *et al*. (Heiland, 2018),[12] who both concluded that preoperative functional status and the presence or absence of neurological deficits are more important indices that help predict outcomes compared to biological age. Data obtained from a prospective study by the Global Spine Tumor Study

Group involving 1266 patients showed that survival rates and neurological improvements were lower postoperatively in older patients when compared to their younger counterparts. The authors observed that these results were compounded by the higher occurrence of emergency and palliative surgeries in the older population and maintained that age, nonetheless was not a contraindication to surgery (Hussain, 2023).[14] Sarnthein *et al.*[24] prospectively looked at the outcome of surgery in patients 80 years and above compared to patients between 55 and 75 years of age over three years and matched for an indication for surgery. They observed that while the octogenarians had a higher incidence of Clavien-Dindo grading 2 (CDG) [Appendix F] complications, the overall rate of severe complications, morbidity, and mortality was similar to the matched controls.

An ideal study would be prospective, multicenter, involve a large study number of patients, and take into cognizance pre-and post-operative functional status, presence of neurologic deficits, and the impact of frailty. It is nonetheless understandable that such a project would require significant resources and commitment.

Bligh *et al*[2] retrospectively looked at every patient over the age of 70 years who had a neurosurgical procedure over two years at Royal Hallamshire Hospital. The study showed an overall 30-day mortality of 5.6%, while it was 8% in patients older than 80 years of age.

Plan of investigation

Research objective

This project aims to evaluate if elderly patients undergoing neurosurgery have a good outcome based on current selection criteria. The objective is to explore the criteria currently employed in determining which elderly patients will be operated on and the impact pre-operative functional status and frailty, in particular, have on determining outcomes following neurosurgical intervention. The hypothesis is that the patient's outcome postoperatively will be better predicted by the patient's pre-morbid functional status and/or presence of frailty rather than the patient's age alone.

MATERIALS AND METHODS

Consecutive patients referred or admitted to the neurosurgery department of Royal Hallamshire Hospital were recruited to the study over three months from April to June 2019. Elderly patients were defined as patients who were 65 years and above at the time of referral or admission for elective and emergency procedures.[13]

Patient demographics, medical history, functional status, indication for surgery or reason for referral, surgery performed, and 30-day outcomes were collected prospectively in a patient registry. Functional status was assessed using the Karnofsky performance scale[6] [Appendix G], World Health Organization (WHO) performance scale, clinical frailty scale[23], MFI, American Society of Anesthesiologists (ASA) score, and postoperative mRS with a goal to compare and determine which index was best predictive of poor outcomes.

Statistics

Outcomes were assessed using postoperative functional status as determined by the mRS, and also the 30-day morbidity and mortality.[22] Unfavorable outcomes were defined as detailed in Figure 1. If the patient did not attend follow-up, their clinical status on discharge was ascribed as their outcome.[24]

For this study, $P < 0.05$ has been employed to show statistical significance. Statistical analysis was performed using RStudio version 1.2.1335 (RStudio, Boston, Massachusetts, USA) and GraphPad Prism 8 (2365 Northside Dr., Suite 560, San Diego, California).

RESULTS

A total number of 324 patients above 65 years of age were either referred or admitted to the neurosurgery department of Sheffield Teaching Hospital during the period under review. This includes patients who were admitted for elective procedures and patients with non-urgent, urgent, or emergency referrals for neurosurgical input.

The youngest patient was 65 years, and the oldest patient was 97 years, while the mean age of the study was 78 years. Of this, 49.07% were male and 50.93% were female. Eighty-one of these patients had suffered a cerebrovascular accident; 51 patients had spinal pathologies such as lumbar canal stenosis or suspected cauda equina syndromes; 53 patients had brain or spinal tumors – This includes many incidental meningiomas and malignant gliomas. Thirty-four patients had chronic subdural hematomas, while 25 patients were referred with acute subdural hematomas.

Only 61 (18.83%) out of the 324 patients who met the selection criteria for this study had an operation. About 18.83% of the 324 patients in total (*n*) died within one month of referral or admission, while the 30-day mortality rate of the operated patients was 3.28%.

Operated patients

Of all the patients who had surgery, 27 were elective admissions, 14 were emergency referrals/admissions, 19 were urgent referrals, and one was a non-urgent referral. Ten of these patients (16.39%) had been previously admitted to the neurosurgery department in the preceding 12 months. Sixteen (26.23%) of the patients operated had varying degrees of postoperative complications. The postoperative mortality rate for patients who underwent surgery was 3.28%.

Operated versus not-operated comparisons

Patients who were operated on (Group A) were relatively younger, with a mean age of 75.5 (P = 0.00243). They had a lower mean WHO performance status of 2.42 compared to 3.14 in Group B, who did not have surgery (P = 0). They had a lower mean American Society of Anesthesiology (ASA) of 2.80 compared to 3.54 in Group B (P < 0.05). The mean pre-morbid karnofsky performance status (KPS) [Appendix G] for Group A was 77.54, while it was 68.72 in Group B (P = 0.00026), and the mean clinical frailty index was 3.13 in Group A and 4.11 in Group B (P = 0.00061).

Good outcome versus poor outcome

The second objective of this paper is to find out if patients have a good outcome based on the current selection criteria used. Poor outcomes include characteristics already defined, and it should be noted that patients with a CDG of 1–3 have been included in this list.

DISCUSSION

Historical background

Munro *et al*[19] carried out a prospective observational national study in Scotland to determine the effect of patients' ages on the management of acute intracranial hematoma. The study found that patients who were 65 years or older had greater mortality compared to patients who were <65 years of age, with survival rates of 83% and 99%, respectively, for extradural hematomas and 66% compared to 92%, respectively, for acute subdural hematomas. Logistic regression showed that age had an independent effect on transfer and survival with a seeming bias against the older population.

Brandes *et al*. (Brandes, 2003)[3] carried out a prospective trial on consecutive elderly patients (age >65 years) who had surgery for glioblastoma multiforme. They found out that the time to disease progression and overall survival was significantly better for the group of patients who had more aggressive treatment. The study concluded that the practice of excluding elderly patients from clinical trials or state-of-the-art treatment on the basis of age alone was not ideal. They admonished that the patient's performance status was a better predictor of outcome rather than age in isolation.

Present work

Only 61 (18.83%) out of the 324 patients included in this work actually had surgery during the timeframe examined. This is understandably so considering that a sizeable number of patients who did not need neurosurgery. For example, 81 of the patients referred to the department (25% of n) had suffered a cerebrovascular accident, and as mirrored in many previous publications such as Rabinstein *et al*. (Rabinstein, 2002),[21] many of these patients were not deemed to be candidates for surgery.

Sixteen (5.99%) of the patients who did not merit neurosurgical intervention in this current work were recommended for best supportive care or commenced on devastating brain injury protocol. One hundred and fifteen patients were recommended for conservative care. Many of these patients had pathologies for which urgent neurosurgical care was not deemed necessary based on universal brain trauma guidelines.

Lewis *et al*.[16] conducted a retrospective cohort study on 500 consecutive blunt traumatic brain injury patients above 15 years of age with a GCS of 13 and above and intracranial hemorrhage on the preliminary head computed tomography (CT) scan who were admitted to a level 1 trauma center over 28 months. Surprisingly, patients who were managed surgically had a higher mortality of 8.2% as against 2.0% in patients managed conservatively (P = 0.010). The paper, however, did not categorize outcomes based on age or comorbidities so it might be difficult to extrapolate their findings in a distinctly elderly population subset. The paper agreed with brain injury guidelines that patients with mild traumatic brain injuries who are not on anticoagulant therapy and have no evidence of inebriation could be managed successfully without neurosurgical consultation or repeat head CT scans.

Five patients in this study were refused initial neurosurgical intervention with a plan for possible future surgery. This was the case in patients with acute subdural hematomas (aSDH). Many studies have shown that surgery for acute subdural hematomas are usually associated with high mortality rates. One such work is by Benedetto *et al*.,[1] where the authors retrospectively analyzed the records of patients above 70 years who had undergone surgery for evacuation of traumatic aSDH over three years. The mortality rate at one month and six months after surgery was 55.1% and 67.2%, while functional recovery was discovered to be 10.4% and 13.4%.

Comparison of operated versus not-operated patients

This paper has categorized every patient who did not have surgery in the period studied as "Not-Operated." This group includes patients who were deliberately managed conservatively, patients who were deemed inappropriate referrals to neurosurgery, patients who needed further work-up before a decision on surgery could be made, and patients who might have benefited from surgery but were considered too frail.

Patients who were managed surgically were younger than patients who were not with mean ages of 75.51 and 78.91, respectively (P = 0.002). They also had better indices of frailty

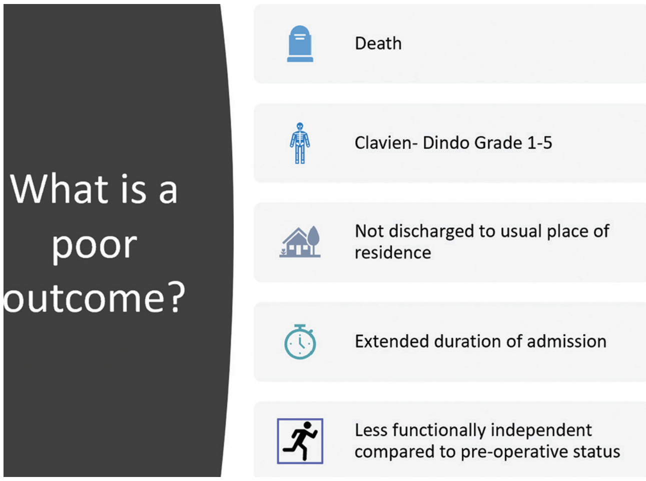

Figure 1: Poor outcomes were defined to be any of the following outcomes: Death; CDG 1-5; Not discharged to usual place of residence; Extended duration of admission and being less functionally independent compared to pre-operative status.

including ASA, WHO performance status[31], KPS, and clinical frailty scale. This suggests that patients who got operated were generally younger and fitter compared to patients who did not get surgical management in the time frame studied. These results align with current best practices to consider the patient's pre-morbid functional status when deciding on operative care.

The mortality rate in the patients who were not operated on was significantly higher than the rate in patients who were managed surgically, with values of 23.04% and 3.28%, respectively. It is understandable why this is the case as while the operated group included many elective procedures, such as spinal procedures for lumbar decompression, which have a relatively low mortality rate[11], the not-operated group included patients who were usually too ill to have surgery such as patients for whom best supportive care or devastating brain injury protocol was advised. An alternative explanation that might be worthwhile to pursue is that some of the patients who did not have surgery died for this reason and might have fared better if managed operatively. They would, therefore, have become casualties of stringent selection criteria for surgery. This is potentially a controversial issue and might be difficult to ascertain. It is nonetheless reasonable to challenge previously held notions, especially in the face of constantly improving neuroanesthesia and technologically advanced tools now used in neurosurgery, such as tools for neuronavigation.

Table 1: Reason for "refusal."

	Frequency
Conservative care	43%
Location of bleed and neurology	0.75%
The patient's neurology, frailty, and family wishes	0.38%
Outpatient referral	14.98%
Explore the non-neurosurgical cause of the patient's symptoms	5.62%
Further investigation	9.74%
Refer to different specialty	3.37%
Best supportive care/devastating brain injury protocol	5.99%
Not for neurosurgery	11.98%
For surgery at a future date (e.g., when acute subdural hematoma becomes chronic)	1.87%
Patient's comorbidities/frailty	2.25%

The Table 1 captures some of the reasons why a patient referred for neurosurgical care could not be immediately accepted for admission/surgery. There are currently no standardized responses in use, so some of the reasons above might be subject to the same interpretation and are phrased based on the preferences of the neurosurgical doctor who received the referral as well as the decision made during the morning neurosurgery multidisciplinary team meetings. Some of the patients above later went on to have surgery, for example, patients with acute subdural hematoma who presented with increasing or sustained confusion and in whom repeat scans showed chronic subdural hematomas.

Table 2: CDG postoperatively.

CDG	Frequency
1	9
2	5
3	1
4	1

CDG: Clavien-Dindo grading, Nine patients had a CDG of one, and one patient had a CDG of four. The CDG system grades postoperative complications based on the therapy used to correct the complication and is increasingly being used in neurosurgery to help assess the severity of postoperative complications. A score of 1 denotes any deviation from the normal postoperative course without the need for pharmacological, surgical, radiologic, or endoscopic intervention. Permitted medications exempted from pharmacological treatment include antiemetics, antipyretics, analgesics, diuretics, and electrolytes. This also includes wound infections managed by the bedside [Table 2]. A score of 2 involves the use of medications not covered above. A score of 3 requires radiologic, endoscopic, or surgical intervention and is further subdivided into (a) or (b) for interventions not requiring or requiring general anesthesia, respectively. A score of 4 involves life-threatening complications, and a score of 5 denotes death [Table 2].

Good versus poor outcome

The second part of the objective of this paper was to try to determine if patients who were selected for surgery based on present selection criteria went on to have good outcomes. We were also interested in knowing how patients who had good outcomes differed from patients who had bad or poor outcomes. Forty of the 61 patients operated on (65.57%) had good outcomes, while 21 patients (34.43%) had poor outcomes. The 30-day mortality rate of patients who had surgery is considered reasonably low at 3.28%. Bligh *et al.*[2] reported a 30-day mortality rate of 5.6% in patients

Table 3: One-*way* ANOVA between operated and not-operated patients.

Group	*n*	Mean Age	Standard Deviation	Standard Error
Operated (A)	61	75.5082	7.4646	0.9557
Not operated (B)	263	78.9087	7.9107	0.4878

ANOVA: Analysis of Variance, One-way analysis of variance comparison shows that patients who were operated on were slightly younger, with a mean age of 75.5 years, while patients who were not operated on had a mean age of 78.9 years. The f-statistic value was 9.34, while P-value was 0.00243 [Table 3].

Table 4: GCS of operated versus not operated.

Group	*n*	Mean GCS	Standard Deviation	Standard Error
Operated (A)	61	14.5246	1.577	0.2019
Not operated (B)	260	13.1423	3.1166	0.1933

GCS: Glasgow Coma Scale, There was no statistical significance between the two groups of patients (P = 0.75). Data for one of the patients in Group B were unavailable. This was factored into the analysis [Table 4].

Table 5: MFI-5-good versus poor outcome.

Group	*n* (Sample size)	Mean MFI-5	Standard Deviation	Standard Error
Good outcome (A)	39	1.0513	0.8568	0.1372
Poor outcome (B)	21	0.4286	0.6761	0.1475

MFI-5: Modified frailty index 5, The MFI-5 was lesser in patients who had a poor outcome suggesting a lower burden of comorbidities. The P-value was 0.006, suggesting statistical significance [Table 5].

Table 6: Predictors of poor outcome.

Predictive Variable	R	*P*-value (two-tailed)	Significant
Age	−0.1687	0.1976	No
Gender	0.000	>0.9999	No
Emergency surgery	0.3622	0.0045	Yes
WHO performance status	0.2302	0.0768	No
ASA	0.3636	0.0043	Yes
KPS	0.1700	0.1941	No
Clinical frailty scale	−0.1945	0.1364	No
GCS	−0.2615	0.0436	Yes
MFI-5	−0.3847	0.0024	Yes

ASA: American Society of Anesthesiologists, GCS: Glasgow Coma Scale, MFI: Modified frailty index-5, KPS: Karnofsky performance status, WHO: World Health Organization, Emergency surgery, ASA score, GCS, and MFI-5 were all found to have the highest correlation with poor outcomes (morbidity and mortality), with the greatest statistical significance found in MFI-5 with P = 0.0024 and r = −0.3847 [Table 6].

<80 years and 8% in patients > 80 years (n = 798),[28] in a similar fashion, reported a 30-day mortality rate of 3.9% (n = 27,098). However, one major weakness of this thesis is the relatively small sample size of just 61 operated patients, so its findings must be interpreted carefully in relation to previously described studies.

We included CDG of 1 and 2 in poor outcomes due to the stringent criteria used in this study. This is similar to the criteria used by Maldaner *et al.*[18] Other authors sometimes only include CDG-3 (Postoperative complications requiring surgical, endoscopic, or radiological treatment) or CDG-4 (Life-threatening complications requiring intensive care/intensive care unit management) in defining poor outcomes, for example, as used by Macki *et al.*[17] (Macki, 2019). If this study defined morbidity only as CDG ≥3, the number of patients who had good outcomes would rise from 40 (65.57%) to 46 (75.41%) of all patients who had surgery.

With a *P*-value of 0.78, it is assumed that there was no statistically significant difference between the ages of patients who had good outcomes (Group A) compared to those who did not (Group B). Surprisingly also, comparison in GCS and majority of the frailty indices between Group A and B patients did not reveal any statistically substantial difference. The GCS was marginally higher in Group A with a value of 14.85 compared to 13.91 in

Group B; however, the *P*-value was 0.76 so we cannot reject the null hypothesis. Focal deficits were equally present in both groups of patients. This is contrary to expectations, where it would have been anticipated that patients with a greater degree of preoperative focal deficits would have a greater burden of postoperative complications. In the same vein, the MFI-5 was observed to be slightly lesser in patients with poor outcomes (0.43 as against 1.05 in Group A) with a *P*-value of 0.0056. This would suggest a lesser burden of comorbidities in the patients who had poor outcomes and would be against the run of play. It would be interesting to observe what the findings will show if a much larger sample size is used.

ASA in Group B was marginally higher, with a value of 3.33 as against 2.53 in Group A, but with a *P*-value of 0.75. *P*-values of variations between the KPS and Clinical Frailty Index of Group A and Group B patients were 0.77 and 0.09, respectively, which would suggest that the observed numerical values between the two groups are statistically negligible.

Predictors of poor outcomes

Finally, an attempt was made to show what patient factors were the greatest predictors of poor outcomes. Pearson's correlation revealed that emergency surgery, ASA score, GCS, and MFI-5 all showed a statistically significant correlation with poor outcomes. The greatest significance was observed in MFI-5 with $P = 0.0024$ and $r = -0.3847$. These findings support the hypothesis that a patient's premorbid functional status and degree of frailty rather than age in isolation may be used to deduce the possibility of poor postoperative outcomes reasonably.

Ideally, logistic regression analysis may best serve to find out the predictors of mortality as employed by Bligh *et al.*[2] and Maldaner *et al.*[18] (Maldaner, 2018). It, however, could not be calculated based on the relatively small sample size of patients who had surgery following the guidelines by Peduzzi et al. (Peduzzi, 1996):[20]

$$n = 10\,k/\mathrm{p}$$

Limitations

The major challenge in writing this paper was its relatively small sample size. This was due to a combination of the prospective nature of the research work and the short time frame under which it had to be done. This probably impacted the ability to show statistical significance and, as demonstrated above, the derivation of logistic regression between postoperative outcomes and the multiple predictive variables of interest. Furthermore, the follow-up postoperatively for many of this subsection of patients was set at 6–8 weeks after surgery. As discussed earlier, for these patients and those lost to follow-up for any reason, functional outcomes were judged based on the patient's performance at the time of discharge. It is, however, reasonable to expect that with physiotherapy and pain resolution, many of these patients will have developed greater functional independence 2–3 months after surgery, further increasing the percentage of good outcomes observed.

Finally, the majority of patients included in this study were referred from trusts other than Sheffield Teaching Hospitals National Health Service Foundation Trust and not admitted to Royal Hallamshire Hospital. Some of them did not have their medical records linked to the Personal Demographics Service leading to gaps in data on past medical records, place of residence, and adequate records of 30-day functional status.

CONCLUSION

The existing selection criteria for neurosurgery in the elderly are associated with a good overall outcome. Frailty and preoperative functional status correlate more with good outcomes rather than age as a stand-alone consideration. Therefore, it is increasingly important that this is factored in when making a clinical decision on who is expected to benefit reasonably from neurosurgical procedures.

Neurosurgical frailty index

There appears to be a need to develop a neurosurgical frailty index whose design will better incorporate the characteristics necessary in the context of an elderly patient in need of neurosurgical care. Current models in use are mostly borrowed from sister specialties and might not adequately identify the cognitive and functional subtleties needed to categorize postoperative neurosurgical outcomes. It will also be ideal to carry out the research work just completed prospectively over a longer duration and across multiple centers.

Hopefully, this work will set the pace for future researchers to carry out more studies in comparing which frailty indices best predict good outcomes in elderly patients who have neurosurgery. The results of this may go on to form the basis for a neurosurgical frailty index and help improve the selection criteria currently in use.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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APPENDIX

A: Modified frailty index-5.

Value	Morbidity
+1	Diabetes mellitus
+1	Hypertension requiring medication
+1	COPD or pneumonia
+1	Congestive cardiac failure
+1	Non-independent functional status

Adapted from Weaver *et al.* COPD: Chronic obstructive pulmonary disease

B: Clinical frailty scale.

Category	Description
1. Very fit	People who are robust, active, energetic, and motivated. These people commonly exercise regularly. They are among the fittest for their age.
2. Well	People who have no active disease symptoms but are less fit than category 1. Often, they exercise or are very active occasionally, for example, seasonally.
3. Managing well	People whose medical problems are well controlled but are not regularly active beyond routine walking.
4. Vulnerable	While not dependent on others for daily help, symptoms often limit activities. A common complaint is "being slowed up" and/or being tired during the day.
5. Mildly frail	These people often have more evident slowing and need help in high-order IADLs (finances, transportation, heavy housework, and medications). Typically, mild frailty progressively impairs shopping and walking outside alone, meal preparation, and housework.
6. Moderately frail	People need help with all outside activities and with keeping house. Inside, they often have problems with stairs, need help with bathing, and might need minimal assistance with dressing.
7. Severely frail	Completely dependent on personal care, from whatever cause (physical or cognitive). Even so, they seem stable and not at risk of dying (within – 6 months)
8. Very Severely frail	Completely dependent, approaching the end of life. Typically, they could not recover from even a minor illness.
9. Terminally ill	Approaching the end of life. This category applies to people with a life expectancy<6 months who are not otherwise evidently frail

Source: Rockwood *et al.*

C: Glasgow coma score.

Eye opening	Best verbal response	Best motor response
Spontaneous 4	Oriented 5	Obeys command 6
To sound 3	Confused 4	Localize 5
To pain 2	Inappropriate 3	Normal flexion 4
Never 1	Incomprehensible 2	Abnormal flexion 3
	None 1	Extension 2
		Nil 1

Source: Teasdale *et al.*

D: Eastern Cooperative Oncology Group/World Health Organization performance status.	
Grade	**Description**
0	Fully active; able to carry on all pre-disease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature, for example, light housework, office work
2	Ambulatory and capable of all self-care but unable to carry out any work activities; up and about more than 50% of waking hours
3	Capable of only limited self-care, confined to bed or chair for more than 50% of waking hours
4	Completely disabled. Cannot carry out any self-care. Totally confined to bed or chair.
5	Dead

Source: Young *et al*.

E: Modified Rankin score.	
Level	**Description**
0	No symptoms
1	No significant disability despite symptoms, able to perform all usual duties and activities
2	Slight disability; unable to perform all previous activities but able to look after own affairs without assistance
3	Moderate disability: Requires some help but is able to walk without assistance
4	Moderately severe disability: Unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe disability: bedridden, incontinent, and requires nursing care and attention

Source: Broderick *et al*.[4]

F: Clavien-Dindo classification.		
Grades	**Definition**	**Modes of Therapy**
1	Any deviation from the normal postoperative course	No pharmacological, surgical, endoscopic, or radiological treatments were required. Accepted therapeutic regimens are drugs such as anti-emetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. Wound infections or small abscesses requiring incision at the bedside are within this category
2	Normal course altered	Pharmacological management other than in grade 1. Blood transfusion and total parenteral transfusion are also included
3	Complications that require interventions of various degrees	Subclassified into: 3a- Intervention performed under local anesthesia 3b- Interventions that require epidural or general anesthesia
4	Complications threatening the life of patients (including CNS complications) requiring ITU support	Subclassified into: 4a- Single organ dysfunction (including dialysis) 4b- Multi-organ dysfunction
5	Death of a patient	

Source: Maldaner *et al*. (Maldaner, 2018), ITU: Intensive therapy unit

G: Karnofsky performance status.

Investigator assigned percentage	Features
100%	Normal: no complaints and no evidence of disease
90%	Able to carry on normal activities; minor signs or symptoms of disease
80%	Normal activities but with effort; some signs or symptoms of disease
70%	Cares for self but is unable to carry on normal activities or to do active work
60%	Requires occasional assistance but is able to care for most needs
50%	Requires considerable assistance and frequent medical care
40%	Disabled; requires special care and assistance.
30%	Severely disabled; hospitalization is indicated, but death is not imminent
20%	Hospitalization is necessary; very sick, active, supportive treatment is necessary.
10%	Moribund: fatal processes progressing rapidly

Source: Chambless *et al*.