Patient-reported experience measures in patients undergoing navigated transcranial magnetic stimulation (nTMS): the introduction of nTMS-PREMs

Sabina Patel, Prajwal Ghimire, José Pedro Lavrador, Josephine Jung, Richard Gullan, Keyoumars Ashkan, Ranjeev Bhangoo, Francesco Vergani

Received: 31 October 2019 / Accepted: 17 February 2020 / Published online: 25 February 2020
© The Author(s) 2020

Abstract
Background Patient-reported experience measures (PREMs) are a unique measure of experience of patients which can help address the quality of care of the patients.

Objective Our aim of the study is to collect quality of care outcomes with our newly navigated transcranial magnetic stimulation patient-reported experience measure (nTMS-PREMs) questionnaire among neurosurgical patients undergoing nTMS.

Methods A single-centre prospective nTMS-PREMs 19-item questionnaire study was performed between February 2018 and December 2018 on patient referred for nTMS at our hospital. The Data was analysed using Likert scale, linear and logistic regression using statistical software (STATA 13.0®).

Results Fifty patient questionnaires were collected (30 males, 20 females, mean age of 47.6 ± 2.1 years) among which 74% of patients underwent both motor and language mapping with a mean duration of 103.3 ± 5.1 min. An overall positive response was noted from the results of the questionnaire, tiredness and anxiety being the common effects noted. Patients with the left-sided disease appreciated more the conditions provided in our laboratory (Q4, \( p = 0.040 \)) and increasing age was related to less confidence and trust (Q6, \( p = 0.038 \)) in the staff performing the exam. Younger patients tolerated nTMS better than older patients (\( > 65 \) years). PubMed literature search resulted in no relevant articles on the use of PREMs in nTMS patients.

Conclusion nTMS is a well-tolerated non-invasive tool and nTMS-PREMS provides a promising role in identifying the unmet needs of the patients and improving the quality of their care.

Keywords PREMs · nTMS · Unmet needs · Quality of care

Introduction

Navigated transcranial magnetic stimulation (nTMS) has become in recent years a commonly used tool in the preoperative planning for neurosurgical patients [8]. nTMS is now being widely used as an important pre-operative tool for motor and speech mapping in eloquent glioma surgery (awake/asleep), brain metastasis, cavernoma, and vascular malformations [5, 7, 14, 15, 17, 20, 23, 25] and is a useful adjunct to impact the surgical indications, guide the surgical approach, and estimate and reduce the risk of inducing postsurgical deficits [26, 27]. It has further been highlighted in recent studies that the preoperative nTMS motor mapping/speech mapping provides improved outcome in patients with glioblastoma [24] and is also useful in language-eloquent tumour surgery in awake-ineligible patients [25]. While a safe and non-invasive way to map the cerebral cortex, nTMS can...
be associated with anxiety or unpleasant experience [14] or discomfort [28] and can be time-consuming, with motor mapping requiring up to 90 min and language mapping requiring up to 120 min [8]. To date, little is known about the overall patients’ experience during nTMS, with particular regard to how well the procedure is tolerated and what additional information it gives to patients in their overall healthcare experience. This is of particular relevance, since patients’ collaboration and understanding of nTMS are crucial for the success of the examination.

Patient-reported experience measures (PREMs) are increasingly used to assess the effectiveness of clinical care on a particular patient population (for example, Picker Patient Experience Questionnaire (PPE-15), Patient Experience Questionnaire (PEQ), Scottish Inpatient Patient Experience Survey (SIPES), Norwegian Patient Experience Questionnaire (NORPEQ), In-Patient Experiences of Health Care (I-PAHIC)) [1–4, 11]. In neurosurgery, studies to evaluate patients’ experience and satisfaction have been performed, for example, in patients undergoing awake craniotomy [10, 18, 30]. However, no specific PREMs have been reported for the use of nTMS. In the present paper, we aim to document the first patient-reported experience measure for nTMS in neurosurgery (nTMS-PREMs).

Material and methods

A prospective study was carried out between January and December 2018 at our hospital. All patients (age ≥ 18 years old) who were referred for TMS at our Institution were involved. Patients were referred for TMS after multidisciplinary team (MDT) discussions when a lesion in a presumed eloquent brain was identified. All patients were instructed about TMS in person at the time of the first outpatient meeting in the neuro-oncology clinic and again on the day of the exam. In addition, patients and their families were supplied with a booklet explaining the details of the exam. TMS was performed as an outpatient procedure. A T1 post-contrast MRI for navigation purposes was acquired before or on the day of the exam. Patients who had the MRI on the same day of TMS had only a T1 post-gadolinium MRI sequence for navigation purposes and were given a break of approximately 1 h before proceeding to TMS. All patients underwent either motor mapping alone or a combination of motor and language mapping. In the latter case, motor and language mapping were performed on the same day as a continuous exam. Motor mapping was performed with single pulse stimulation at 105% of the resting motor threshold (RMT) while language mapping was performed with repetitive stimulation at 100% of the RMT. Two authors (S.P. and J.P.L.) performed all the mappings. After the mapping, the results were explained and discussed with patients, with particular regard to the relationship between positive responses and tumour location. Details of the nTMS protocol at our institution have been previously reported [8].

After the exam, all patients were invited to anonymously fill an ad hoc nTMS-PREMs questionnaire (Supplementary Material 1). The questionnaire was designed with reference to the Royal College of Surgeons (RCS) of England survey/audit indications with domains covering quality of the information provided, facilities of the laboratory, the test/examination, staff evaluation, and discharge information [19]. The questionnaire evaluated the following domains of the TMS experience: background (the quality of the information provided before the exam, 3 questions); laboratory (the facilities of the TMS laboratory, 2 questions); staff (evaluating the examiners performing the procedure, 3 questions); exam (the experience during the exam itself, 5 questions); discharge information (the quality and accuracy of the information provided at discharge, 4 questions); and the overall rating of the nTMS experience (2 questions). One question within the “exam” section was aimed only at patients who had language mapping alongside the motor mapping. Each question was rated as a scale from 1 (very poor experience) to 5 (excellent experience). Each question was addressed individually as well as part of the 6 domains where the combined score (combined results of all questions within that domain) was determined. In order to provide a better global evaluation of each question and domain, the responses were also combined as follows: poor, ratings 1 and 2; neutral, rating 3; and good, ratings 4 and 5.

The following variables were analysed against each question and domain: age, gender, duration of the exam, and type of mapping (motor versus motor and language), The laterality of the disease, location of the disease, and RMT ratio (RMT disease side/RMT healthy side)—pathological (90% < RMT < 110%) versus non-pathological (all other values)—were assessed against each question in the “exam” domain. Linear regression was used for age and duration of the exam. Logistic regression was used for gender, laterality of the disease, RMT ratio, and type of mapping. Multinomial logistic regression was used for location. The combined score analysis was performed using ordered logistic regression analysis. A multivariate analysis was performed for the 6 domains. An adjustment for age, gender, duration, and type of monitoring was used for every domain and laterality and RMT ratio for the “exam” domain. A subgroup analysis for the older population was performed. p values < 0.05 were considered significant for all the performed analysis. Statistical software (STATA 13.0®) was used for all the performed analysis. All the analyses were performed after the study was completed.

In addition, a literature search was performed in PubMed to look for previous papers reporting PREMs related to TMS. We used MeSH terms related to nTMS and PREMS. There were no articles in the search that was dedicated to specific
experience measures in nTMS. The study was registered in the local audit registry as a service improvement project approved by the Neurosurgical Department. Informed consent was taken with all the patients in the study for nTMS mapping. The pre-operative mapping was applied following the standard nTMS mapping protocol published previously [8].

Results

Patients were referred from both the neuro-oncology and neurovascular services with a total of 50 questionnaires completed (30 males, 20 females, mean age of 47.6 ± 2.1 years)—2 patients did not return the questionnaires. The vast majority had an underlying brain tumour—46 (92.0%). The preferential location was on the left side (29 patients, 60.4%) with the frontal (22 cases, 48.9%) and temporal (13 cases, 28.9%) lobes being more commonly affected. Twenty-one patients (46.67%) had a pathological RMT ratio (mean RMT ratio, 1.0 ± 0.02). Seventy-four percent of patients underwent both motor and language mapping with a mean duration of 103.3 ± 5.1 min (motor only, 85.8 ± 6.1 min; motor and speech, 106.9 ± 5.9 min; p = 0.02, t test) (Table 1).

A breakdown of responses to the questionnaire is reported in Table 2. In general, patients reported a positive experience with nTMS, with 94% positive responses for the overall nTMS experience. Seven hundred ninety-two (85%) of the responses provided about our service were rated as good, and 648 (69%) rated with the maximum score. Taking into account the individual domains of the questionnaire, 89% of patients reported a positive score for the “background” domain, with a good understanding of TMS and availability of information prior to TMS taking place with only 7% rating this section poorly. The combined score for the “laboratory” domain was good in 85% of responses with 75% reporting no technical problems during the exam. The “staff” section had the highest positive rating, with 95% good responses, indicating confidence in the staff performing the investigation (95%), presence of knowledge (92%), and support from staff (96%). The “exam” domain had the lowest positive rating (70% as good) with a poor experience due to anxiety and pain reported by 26% and 24% of patients, respectively. In addition, 16% of patients reported tiredness during/after the exam and difficulties in concentration. Reassuringly, 94% of patients felt the exam duration met their expectations and was acceptable. The quality of the “discharge information” provided was well rated by the patients (84% rated as good) with 88% of patients feeling they had a better understanding of the relationship between their lesion and the eloquent areas of the brain and 70% of patients clearly understood the importance of nTMS in the context of the surgical treatment they were about to receive.

The significant results from the univariate statistical analysis are reported in Table 3 (the complete table of results is provided in Supplementary Table 2). An increased duration of the exam was related to increased pain felt during the exam (Q13, p = 0.004) and a poorer understanding of the significance of the results for the surgical treatment (Q14, p = 0.031). Increasing age was related to less confidence and trust (Q6, p = 0.038) and less ability to recognize knowledge and experience (Q7, p = 0.003) in the staff performing the exam (Table 3).

The univariate analysis was also repeated against each domain of the questionnaire. This revealed that longer exams were related to a poorer rate of the laboratory conditions (p = 0.017). Increasing age was related to a poorer rate of staff performance (p = 0.001). Concerning the exam, the patients who had only motor mapping had a better experience than the ones who had both motor and language mapping (p = 0.020). Patients who had frontal lesions and longer mapping reported worse experiences (p = 0.028 and p = 0.003). The quality of the information provided at discharge was better in patients who had motor mapping only (p = 0.001) and

| Table 1 Demographic characteristics of the study population |
|----------------------------------------------------------|
| nTMS (n = 50)                                            |
| Age                                                      | 47.6 ± 2.1 |
| Gender                                                   |            |
| Male                                                     | 30 (60.0%) |
| Female                                                   | 20 (40.0%) |
| Pathology                                                |            |
| Oncology                                                 | 46 (92.0%) |
| Vascular                                                 | 4 (8.0%)   |
| Type of mapping                                          |            |
| Motor only                                               | 13 (26.0%) |
| Speech and motor                                         | 37 (74.0%) |
| Laterality                                               |            |
| Right                                                    | 19 (39.6%) |
| Left                                                     | 29 (60.4%) |
| Location (lobe)                                          |            |
| Insula                                                   | 3 (6.7%)   |
| Frontal                                                  | 22 (48.9%) |
| Parietal                                                 | 7 (15.6%)  |
| Temporal                                                 | 13 (28.9%) |
| RMT                                                      |            |
| Ipsilateral to the disease (%)                           | 41.1 ± 1.7 |
| Contralateral to the disease (%)                         | 40.5 ± 1.5 |
| RMT ratio                                                | 1.0 ± 0.02 |
| Pathological RMT (patients)                              | 21 (46.64%)|
| Duration (min)                                           | 103.3 ± 5.1|
| Motor only                                               | 85.8 ± 6.1 |
| Speech and motor                                         | 106.9 ± 5.9|

Laterality

| Location (lobe)                                          |
|----------------------------------------------------------|
| Insula                                                   | 3 (6.7%) |
| Frontal                                                  | 22 (48.9%) |
| Parietal                                                 | 7 (15.6%) |
| Temporal                                                 | 13 (28.9%) |
| RMT                                                      |            |
| Ipsilateral to the disease (%)                           | 41.1 ± 1.7 |
| Contralateral to the disease (%)                         | 40.5 ± 1.5 |
| RMT ratio                                                | 1.0 ± 0.02 |
| Pathological RMT (patients)                              | 21 (46.64%)|
| Duration (min)                                           | 103.3 ± 5.1|
| Motor only                                               | 85.8 ± 6.1 |
| Speech and motor                                         | 106.9 ± 5.9|
Table 2  Results of the nTMS-PREMs questionnaire

| Questions                                                                 | Rating | Classification | Overall |
|--------------------------------------------------------------------------|--------|----------------|---------|
| **Intro**                                                                |        |                |         |
| 1. How much information has been given to you about TMS?                 | 2 (4%) | Poor (6%)      | 11 (7%) |
| 2. How much understanding you had about the importance and role of TMS in | 1 (2%) | Poor (8%)      | 4 (8%)  |
| the treatment of your disease?                                            | 4 (8%) |               | 44 (88%)|
| 3. Have you been given enough time and privacy to discuss TMS?           | 2 (4%) | Poor (8%)      | 44 (88%)|
| **Lab**                                                                 |        |                |         |
| 4. Was the laboratory quiet so you could concentrate and collaborate during the exam? | 1 (2%) | Poor (2%)      | 7 (7%)  |
| 5. Was there any technical problem during the course of the exam?        | 5 (10%)| Poor (12%)     | 38 (76%)|
| 6. Did you have confidence and trust in the staff performing the exam?   | 1 (2%) | Neutral (45%)  | 143 (95%)|
| 7. Did you recognize knowledge and experience about your condition in the members of the staff? | 2 (4%) | Neutral (45%)  | 143 (95%)|
| 8. Did the members of staff provide you support during the exam?         | 2 (4%) | Neutral (45%)  | 143 (95%)|
| 9. Do you think the exam duration was in line with your expectations and acceptable? | 1 (2%) | Good (47%)     | 165 (70%)|
| 10. Did you feel tired during the exam? (1 very tired, 5 not tired at all) | 3 (6%) | Neutral (33%)  | 165 (70%)|
| 11. Were you able to concentrate during the exam? (Speech mapping only)? | 4 (11%)| Neutral (33%)  | 165 (70%)|
| 12. Were you anxious during the exam? (1 very anxious, 5 not anxious at all) | 12 (24%)| Neutral (33%)  | 165 (70%)|
| 13. Did you feel pain during the exam? (1 very painful, 5 not painful at all) | 6 (12%)| Neutral (33%)  | 165 (70%)|
| **Discharge**                                                            |        |                |         |
| 14. Were the explanations of the results important for your understanding of the operation? | 2 (4%) | Neutral (33%)  | 165 (70%)|
| 15. Did TMS help you to understand the relationship between the lesion and the brain areas that control function? | 3 (6%) | Neutral (33%)  | 165 (70%)|
| 16. Have your concerns been supported and answered by the team staff?    | 2 (4%) | Neutral (33%)  | 165 (70%)|
| 17. Has the post-exam instructions / follow-up plan been explained to you satisfactorily at the end of the exam? | 3 (6%) | Neutral (33%)  | 165 (70%)|
worse in patients who had longer mappings ($p = 0.002$). None of the studied variables seemed to influence the way patients rated their overall experience of nTMS (all $p > 0.05$) (Table 4).

The multivariate analysis confirmed age ($p = 0.01$) and duration of the exam ($p = 0.05$) as two major factors influencing the rating of the TMS exam. Increasing age was related to a poorer rating in almost all domains with the exception of the laboratory conditions and increased duration of the exam was related to the poor rating of laboratory conditions ($p = 0.03$) and worse discharge information ($p = 0.003$) (Table 5 and Supplemental Table 3).

**Discussion**

PREMs play an important role in evaluating the experience of patients to an intervention that leads to the evaluation of patients’ satisfaction and is useful for research, quality improvement projects, clinician performance evaluation, audit, and economic evaluation [1, 11]. In recent years, generic- and intervention-specific PREMs have been developed and used in different areas of clinical medicine and surgical practice, stressing the relevance of patient satisfaction to a patient-centred approach in modern medicine [1, 3, 4, 11]. Well-established surgical PREMs have already been developed for specific surgical interventions, like hernia repair or hip replacement and these have been approved for use in the UK and worldwide [2]. In neurosurgery, intervention-specific PREMs will act as an important indicator of the quality of care of neurosurgical patients and enhance research, quality governance, and economic evaluation/cost-effectiveness of the overall treatment/surgical decision-making and execution.

Over the last decade, nTMS has been used by neurosurgeons to map functional areas of the brain for surgical planning in neuro-oncology [5, 22], AVM resection [7, 9, 16], and epilepsy [13]. A successful nTMS depends largely on patient cooperation, with a long duration of the exam and fatigue or discomfort potentially affecting the results of the mapping. PREMs specifically designed to assess the nTMS experience can give a valuable insight into patient counselling, experience during the procedure, side effects, duration of the test, and how the results of the mapping are understood and perceived by patients. The information provided can in turn be used as a feedback for the nTMS team to allow self-assessment and service improvement. Our literature search through PubMed showed that there are currently no PREMs specifically designed for TMS. Previous papers looked at patient experience during repetitive TMS for therapeutic application [12]. Singh et al. [28] looked at experience and attitudes in patients undergoing repetitive TMS for psychiatric conditions in North India over a 3-month period. They noted an overall positive experience in the context of repetitive TMS for treatment of depression, with a majority agreeing they
Q14. Were the explanations of the results important for your understanding of the operation?
Q13. Did you feel pain during the exam? (1 very painful, 5 not painful at all)
Q7. Did you recognize knowledge and experience about your condition in the members of the staff?
Q6. Did you have confidence and trust in the staff performing the exam?
Q4. Was the laboratory quiet so you could concentrate and collaborate during the exam?

| Summary of the positive findings in the univariate analysis for nTMS-PREMs questionnaire |
|---------------------------------------------|
| Coef. | 95% confidence interval | p value |
|-----------------------------|-----------------------------|---------|
| Laterality (left side) | 1.400 | [0.064–2.737] | 0.040 |
| Q6. Did you have confidence and trust in the staff performing the exam? | Age | −7.055 | [−13.708 to −0.408] | 0.038 |
| Q7. Did you recognize knowledge and experience about your condition in the members of the staff? | Age | −6.313 | [−10.411 to −2.214] | 0.003 |
| Q13. Did you feel pain during the exam? (1 very painful, 5 not painful at all) | Duration | −9.501 | [−15.793 to −3.209] | 0.004 |
| Q14. Were the explanations of the results important for your understanding of the operation? | Duration | −9.023 | [−17.189 to −0.857] | 0.031 |

would recommend TMS to others. A similar result was reported by an earlier study carried out in Tasmania in 2001, again in the context of rTMS for depression [6]. In neurosurgery, recent studies [14, 23, 28, 29] focused on the occurrence of pain, discomfort, and seizures during pre-surgical brain mapping. The authors concluded that nTMS is safe and generally well tolerated. Despite giving useful information on the safety and tolerability of nTMS, this study did not report PREMs addressing the whole patient experience.

In the present paper, we report the first specific nTMS-PREMs. To this effect, we designed a patient questionnaire following the indications of the Royal College of Surgeon in auditing patient experience and satisfaction and the published literature review on commonly developed PREMs [1, 19]. As a result, six domains were identified and evaluated: background information, laboratory, staff, exam experience, discharge information, and overall rating of the nTMS experience. Our results show that nTMS is largely well-tolerated and patients have an overall good experience with nTMS at different time points of the mapping. In all domains, there was a majority of positive responses, with 94% of positive responses for the overall nTMS assessment. However, approximately one in four patients reported the occurrence of anxiety and pain during the exam. Both univariate analysis and multivariate analysis confirmed the age and duration of exam as two major factors that influence patients’ experience during the TMS procedure. The univariate analysis clarified that longer duration of mapping and language mapping are related to a poorer experience. The poorer experience with language mapping can be explained on the basis of the longer duration of the test and on the discomfort/pain induced by repetitive stimulation involving the temporalis muscle [27–29]. Similarly, an increased duration of the exam was related to a poorer understanding of the discharge information, with particular regard to the role of TMS in planning the surgical treatment. We speculate that this is due to the difficulty of patients to maintain attention and retain information due to fatigue after a long mapping session. Elderly patients tended to give a poorer assessment of the staff performing nTMS. This result may be explained on the basis that only very few negative responses were reported concerning the staff (with a possible influence on the statistical result). However, we acknowledge that nTMS was performed by relatively junior members within the neuro-oncology team and therefore, we cannot exclude that a perceived “generational gap” between patients and healthcare professionals may have played a role [21, 31].

The information gathered from the PREMs recorded in this study can be used to improve clinical practice. The poor experience reported with long duration of mapping can be mitigated by ensuring patients can take appropriate rest. It has now become customary at our institution to offer patients a break in between motor and language mapping, so that they can be more relaxed and focused during the language testing. In addition, on top of providing patients with a booklet containing all the information about nTMS before the testing, we make sure to spend enough time to explain the results of mapping, showing patients their nTMS-generated maps. After nTMS, the majority of patients reported a good understanding of the relationship between the tumour and functional areas of the brain. This is relevant, as nTMS results can be used for better patient counselling at the time of consenting for an operation. It is now a routine at our institution to include nTMS-generated maps, when available, as part of the information presented to patients and relatives when describing the challenges and risks of a specific neurosurgical intervention in a highly functional area.

**Limitations**

This is a single-centre pilot study in a limited number of patients. Further multicentric, international studies are warranted.
Table 4 Univariate analysis for the 6 domains of the nTMS-PREMs questionnaire

|                        | Coef.  | 95% Confidence Interval | p value |
|------------------------|--------|-------------------------|---------|
| **Introduction**       |        |                         |         |
| Age                    | -0.015 | [-0.037 to -0.014]      | 0.378   |
| Gender                 | -0.324 | [-1.042 to -0.394]      | 0.377   |
| Laterality             | 0.424  | [-0.288 to 1.135]       | 0.244   |
| Location               |        |                         |         |
| Frontal                | 0.589  | [0.070 to 1.108]        | 0.026   |
| Parietal               | 0.611  | [-0.048 to 1.271]       | 0.069   |
| Temporal               | 0.438  | [-0.091 to 0.966]       | 0.104   |
| RMT ratio              | 0.240  | [-0.479 to 0.960]       | 0.512   |
| Duration               | -0.011 | [-0.024 to 0.003]       | 0.121   |
| Type of mapping        | 0.901  | [-0.003 to 1.802]       | 0.050   |
| **Laboratory**         |        |                         |         |
| Age                    | 0.003  | [-0.027 to 0.032]       | 0.866   |
| Gender                 | -0.832 | [-1.730 to -0.066]      | 0.069   |
| Laterality             | 1.308  | [0.428 to 2.188]        | 0.004   |
| Location               |        |                         |         |
| Frontal                | 0.074  | [-0.600 to 0.748]       | 0.830   |
| Parietal               | 0.459  | [-0.472 to -1.390]      | 0.334   |
| Temporal               | 0.190  | [-0.537 to 0.916]       | 0.609   |
| RMT ratio              | -0.045 | [-0.900 to 0.810]       | 0.917   |
| Duration               | -0.019 | [-0.035 to -0.003]      | 0.017   |
| Type of mapping        | -0.390 | [-1.304 to -0.524]      | 0.402   |
| **Staff**              |        |                         |         |
| Age                    | -0.076 | [-1.22 to -0.030]       | 0.001   |
| Gender                 | -0.806 | [-1.875 to -0.262]      | 0.139   |
| Laterality             | 0.074  | [-0.889 to 1.037]       | 0.880   |
| Location               |        |                         |         |
| Frontal                | -13.414| [-1510.328 to 1483.499] | 0.986   |
| Parietal               | -13.303| [-1510.218 to 1483.61]  | 0.986   |
| Temporal               | -13.037| [-1509.95 to 1483.877]  | 0.986   |
| RMT ratio              | 0.351  | [-0.612 to 1.315]       | 0.475   |
| Duration               | -0.012 | [-0.028 to 0.004]       | 0.155   |
| Type of mapping        | 1.259  | [-0.251 to 2.768]       | 0.102   |
| **Exam**               |        |                         |         |
| Age                    | -0.008 | [-0.025 to 0.009]       | 0.331   |
| Gender                 | -0.428 | [-0.929 to 0.073]       | 0.094   |
| Laterality             | 0.166  | [-0.333 to 0.665]       | 0.513   |
| Location               |        |                         |         |
| Frontal                | -1.375 | [-2.602 to -1.047]      | 0.028   |
| Parietal               | -0.985 | [-2.211 to -0.295]      | 0.134   |
| Temporal               | -1.162 | [-2.395 to -0.207]      | 0.065   |
| RMT ratio              | -0.027 | [-0.530 to 0.476]       | 0.916   |
| Duration               | -0.014 | [-0.023 to -0.005]      | 0.003   |
| Type of mapping        | 0.748  | [0.118 to 1.378]        | 0.020   |
| **Discharge information** |    |                         |         |
| Age                    | -0.17  | [-0.040 to 0.006]       | 0.139   |
| Gender                 | -0.423 | [-1.067 to -0.221]      | 0.198   |
| Laterality             | 0.407  | [-0.231 to 1.044]       | 0.212   |

Table 4 (continued)

|                        | Coef.  | 95% Confidence Interval | p value |
|------------------------|--------|-------------------------|---------|
| **Location**           |        |                         |         |
| Frontal                | -0.302 | [-1.060 to -0.457]      | 0.436   |
| Parietal               | 0.201  | [-0.741 to 1.143]       | 0.676   |
| Temporal               | -0.189 | [-0.971 to -0.592]      | 0.635   |
| RMT ratio              | -0.080 | [-0.718 to -0.557]      | 0.804   |
| Duration               | -0.020 | [-0.033 to -0.008]      | 0.002   |
| Type of mapping        | 2.037  | [0.819 to 3.254]        | 0.001   |
| **Overall**            |        |                         |         |
| Age                    | -0.013 | [-0.057 to -0.030]      | 0.542   |
| Gender                 | -0.674 | [-1.908 to -0.560]      | 0.285   |
| Laterality             | 0.185  | [-0.960 to 1.331]       | 0.751   |
| Location               |        |                         |         |
| Frontal                | 0.216  | [-0.583 to 1.015]       | 0.597   |
| Parietal               | 0.230  | [-0.733 to 1.193]       | 0.639   |
| Temporal               | 0.392  | [-0.551 to 1.335]       | 0.415   |
| RMT ratio              | -0.083 | [-1.221 to -1.054]      | 0.886   |
| Duration               | -0.010 | [-0.033 to -0.012]      | 0.372   |
| Type of mapping        | 1.708  | [-0.3780 to 3.794]      | 0.109   |

to further validate our questionnaire and confirm the generalisability of our results across different countries and patient populations. Our pilot, single-centre experience will serve as the necessary basis for such studies.

Conclusion

nTMS is an overall well-tolerated procedure, with positive feedback reported by the vast majority of patients. Poorer experience has been identified in elderly patients and in patients undergoing long mapping, with particular regard to pain

Table 5 Positive findings of multivariate analysis for the 6 domains of the nTMS-PREMs questionnaire

|                        | Coef.  | 95% Confidence interval | p value |
|------------------------|--------|-------------------------|---------|
| **Introduction**       |        |                         |         |
| Age                    | -0.034 | [-0.064 to -0.003]      | 0.030   |
| Laboratory             |        |                         |         |
| Duration               | -0.0181| [-0.04 to -0.0014]      | 0.034   |
| **Staff**              |        |                         |         |
| Age                    | -0.351 | [-0.669 to -0.0329]     | 0.031   |
| **Exam**               |        |                         |         |
| Age                    |        |                         |         |
| **Discharge information** |    |                         |         |
| Age                    | -0.028 | [-0.050 to -0.007]      | 0.01    |
| **Overall**            |        |                         |         |
| Age                    | -0.089 | [-0.159 to -0.019]      | 0.013   |
and understanding of nTMS results. This information can help in tailoring the nTMS experience to individual patients’ needs.

Acknowledgements The authors would like to acknowledge the Department of Neurosurgery at King’s College Hospital, London, for support during the study.

Authors’ contributions PG, SP, and JPL drafted the manuscript. SP carried out the collection of the data. PG, JPL and FV participated in the design of the study. SP, JJ, and JPL contributed in drafting discussion. FV, RB, RG, and KA conceived of the study and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent All patients involved in the study voluntarily completed the questionnaire after informed consent regarding the study.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Beattie M, Murphy DJ, Atherton I, Lauder W (2015) Instruments to measure patient experience of healthcare quality in hospitals: a systematic review. Syst Rev 23(4):97
2. Black N, Varaganum M, Hutchings A (2014) Relationship between patient reported experience (PREMs) and patient reported outcomes (PROMs) in elective surgery. BMJ Qual Saf 23(7):534–542
3. Christalle E, Zeh S, Hahlweg P et al (2018) Assessment of patient centredness through patient-reported experience measures (ASPIRED): protocol of a mixed-methods study. BMJ Open 8: e025896
4. Fernandes S, Fond G, Zendjidian X, Michel P, Baumstarck K, Lancon C et al (2019) The patient-reported experience measure for improving quality of care in mental health (PREMIUM) project in France: study protocol for the development and implementation strategy. Patient Prefer Adherence 13:165–177
5. Frey D, Schilt S, Strack V, Zdunczyk A, Rösler J, Niraula B et al (2014) Navigated transcranial magnetic stimulation improves the treatment outcome in patients with brain tumors in motor eloquent locations. Neuro-Oncology 16(10):1365–1372
6. Garry W, Martin J, Kirkby K, Pridmore S (2000) Transcranial magnetic stimulation: experience, knowledge and attitudes of recipients. Aust N Z J Psychiatry 35:58–61
7. Ille S, Picht T, Shiban E, Meyer B, Vajkoczy P, Krieg SM (2018) The impact of nTMS mapping on treatment of brain AVMs. Acta Neurochir 160(3):567–578
8. Jung J, Lavrador JP, Patel S, Giamoussiadis A, Lam J, Bhangoo et al (2019) First UK experience of navigated Transcranial magnetic stimulation in pre-surgical mapping of brain tumours. World Neurosurg 122:e1578–e1587
9. Kato N, Schilt S, Schneider H, Frey D, Kufeld M, Vajkoczy P, Picht T (2014) Functional brain mapping of patients with arteriovenous malformations using navigated transcranial magnetic stimulation: first experience in ten patients. Acta Neurochir 156(5):885–895
10. Khu KJ, Doglietto F, Radovanovic I, Taleb F, Mendelsohn D, Zadeh G, Bernstein M (2010) Patients’ perceptions of awake and outpatient craniotomy for brain tumor: a qualitative study. J Neurosurg 112(5):1056–1060
11. Kingsley C, Patel S (2017) Patient-reported outcome measures and patient-reported experience measures. BJU Educ 17(4):137–144
12. Klomjai W, Katz R, Lackmy-Vallee A (2015) Basic principles of transcranial magnetic stimulation (TMS) and repetitive TMS (rTMS). Ann Phys Rehabil Med 58
13. Koudijs SM, Leijten FS, Ramsey NF, van Nieuwenhuiizen O, Braun KP (2010) Lateralization of motor innervation in children with intractable focal epilepsy—a TMS and fMRI study. Epilepsy Res 90: 140–150
14. Krieg SM, Shiban E, Buchmann N, Gempf J, Foerschler A, Meyer B, Ringel F (2012) Utility of presurgical navigated transcranial magnetic brain stimulation for the resection of tumors in eloquent motor areas. J Neurosurg 116(5):994–1001
15. Krieg SM, Liounis P, Mákelä JP, Wilenius J, Karhu J, Hannula H, Savolainen P, Lucas CW, Seidel K, Laakso A, Islam M, Valtio S, Lehtinen H, Vitikainen AM, Tarapore PE, Picht T (2017) Protocol for motor and language mapping by navigated TMS in patients and healthy volunteers; workshop report. Acta Neurochir 159(7):1187–1195
16. Kronenburg A, van Doormaal T, van Eijssden P, van der Zwan A, Leijten F, Han K (2014) Surgery for a giant arteriovenous malformation without motor deterioration: preoperative transcranial magnetic stimulation in a non-cooperative patient. J Neurosurg Pediatr 14(1):38–42
17. Lefaucheur JP, Picht T (2016) The value of preoperative functional cortical mapping using navigated TMS. Neurophysiol Clin 46(2):125–133
18. Manninen PH, Baliki M, Lukitto K, Bernstein M (2006) Patient satisfaction with awake craniotomy for tumor surgery: a comparison of remifentanil and fentanyl in conjunction with propofol. Anesth Analg 102(1):237–242
19. Meredith P, Wood C (1995) The development of the Royal College of Surgeons of England’s patient satisfaction audit service. J Qual Clin Pract 15(2):67–74
20. Paiva WS, Fonoff ET, Marcolin MA, Bor-Seng-Shu E, Figueiredo EG, Teixeira MJ (2013) Navigated transcranial magnetic stimulation in preoperative planning for the treatment of motor area cavernous angiomas. Neuropsychiatr Dis Treat 9:1885–1888
21. Peck BM (2011) Age-related differences in doctor-patient interaction and patient satisfaction. Current gerontology and geriatrics research, article ID 137492
22. Picht T, Schmidt S, Brandt S, Frey D, Hannula H, Neuvonen T et al (2011) Preoperative functional mapping for rolandic brain tumor surgery: comparison of navigated transcranial magnetic stimulation to direct cortical stimulation. Neurosurgery 69(3):581–589
23. Picht T, Krieg SM, Sollmann N, Rösler J, Niraula B, Neuvonen T, Savolainen P, Liounis P, Mákelä JP, Deletis V, Meyer B, Vajkoczy P, Ringel F (2013) A comparison of language mapping by preoperative navigated transcranial magnetic stimulation and direct cortical stimulation during awake surgery. Neurosurgery 72(5):808–819
24. Picht T, Frey D, Thieme S, Kliesch S, Vajkoczy P (2016) Presurgical navigated TMS motor cortex mapping improves outcome in glioblastoma surgery: a controlled observational study. J Neuro-Oncol 126(3):535–543

25. Raffa G, Quattropani MC, Scibilia A, Conti A, Angileri FF, Esposito F, Sindorio C, Cardali SM, Germanò A, Tomasello F (2018) Surgery of language-eloquent tumors in patients not eligible for awake surgery: the impact of a protocol based on navigated transcranial magnetic stimulation on presurgical planning and language outcome, with evidence of tumor-induced intra-hemispheric plasticity. Clin Neurol Neurosurg 168:127–139

26. Rosenstock T, Picht T, Schneider H, Koch A, Thomale UW (2019) Left perisylvian tumor surgery aided by TMS language mapping in a 6-year-old boy: case report. Childs Nerv Syst 35(1):175–181

27. Schwarzer V, Bährrend I, Rosenstock T, Dreyer FR, Vajkoczy P, Picht T (2018) Aphasia and cognitive impairment decrease the reliability of nTMS language mapping. Acta Neurochir 160(2):343–356

28. Singh S, Sharma M, Aggarwal A, Avasthi A (2018) The knowledge, experience and attitudes of recipients of repetitive transcranial magnetic stimulation: a study from North India. Asian J Psychiatr 31:102–106

29. Tarapore PE, Picht T, Bulubas L, Shin Y, Kulchynska N, Meyer B, Berger MS, Nagarajan SS, Krieg SM (2016) Safety and tolerability of navigated TMS for preoperative mapping in neurosurgical patients. Clin Neurophysiol 127(3):1895–1900

30. Wahab SS, Grundy PL, Weidmann C (2011) Patient experience and satisfaction with awake craniotomy for brain tumours. Br J Neurosurg 25(5):606–613

31. Williams SL, Haskard KB, DiMatteo MR (2007) The therapeutic effects of the physician-older patient relationship: effective communication with vulnerable older patients. Clin Interv Aging 2(3):453–467

Comments

The authors report on patient reported experience measures (PREMs) for navigated transcranial magnetic stimulation (nTMS). They argue that while nTMS provides safe and non-invasive cortical mapping the examination is often long and associated with anxiety and discomfort. Although patient collaboration is essential for a successful examination, PREMs specific to nTMS have not been reported before. The authors use a new questionnaire designed in house, on guidelines from the Royal College of Surgeons, and review outcomes on 50 adult patients with eloquent brain lesions (tumours in 92%), recruited between January and December 2018, who go on to have surgery. The examination is carried out as an out-patient procedure; patients are given an explanatory booklet before the test and a discussion on the results is carried out on completion. Patients were then given the questionnaire to complete; only two out of 50 were not returned. Responses were overall good, but anxiety and pain were identified frequently in the Exam domain of the questionnaire. This is an interesting study that addresses the impact and patient perception of nTMS. The authors acknowledge a major limitation related to the single-centre nature of this study - its use in other centres and its external validation is an important subsequent step to this work.

Kristian Aquilina
London, UK

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.