Non-technical skills in Neurosurgery : a systematic review of the literature

Pierre-Louis Hénaux[1,2], MD, PhD; Pierre Jannin[2], PhD ; Laurent Riffaud[1,2], MD, PhD

[1]Department of Neurosurgery, Rennes University Hospital, 2, rue Henri Le Guilloux 35033 Rennes, Cedex 9, France

[2]INSERM MediCIS, Unit U1099 LTSI, Rennes 1 University, Faculty of Medicine, 2 Avenue du Professeur Léon Bernard, 35043 Rennes Cedex, France

Authors' e-mail adress : pierre-louis.henaux@etudiant.univ-rennes1.fr; pierre.jannin@univ-rennes1.fr; laurent.riffaud@chu-rennes.fr

Corresponding author : Dr. Pierre-Louis Henaux

Department of Neurosurgery, Pontchaillou University Hospital,

2, rue Henri Le Guilloux 35033 Rennes Cedex 9, France

Phone Number: + 33 2 99 28 42 77

Fax: + 33 2 99 28 41 80

Email: pierre-louis.henaux@etudiant.univ-rennes1.fr

Key-Words

Non-Technical Skills; Neurosurgery; Interpersonal Skills; Cognitive Skills; Patient Safety

Abbreviations list

ACGME: Accreditation Council for Graduate Medical Education

CPD: continuing professional development

NOTECHS: NonTECHnical Skills

NOTSS: Non Technical Skills for Surgeons

NTS: non-technical skills

OTAS: Observational Teamwork Assessment for Surgery

TS: technical skills

UE: undesirable events

ABSTRACT

Background

Undesirable events in the neurosurgery operating theatre are surprisingly less often the result of a technical error than of a dysfunction linked to non-technical skills (NTS). The essential aim of our study was a systematic literature study published on NTS in neurosurgery. The secondary objective was identification of a list of NTS more specific to neurosurgery in order to define on that basis the training needs of neurosurgery trainees.

Methods

MEDLINE and The Cochrane Database of Systematic Reviews were searched according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement. Research initially identified 2132 articles. 21 were eligible for systematic study. Data were extracted from the articles regarding study design, sample size, NTS assessed, assessment tools and the key results were collected.

Results

Interpersonal skills (communication, teamwork), cognitive skills (decision making, situation awareness) and personal resource factors (coping with stress or fatigue) were specifically identified. No article used assessment tools such as NOTECHS, NOTSS or OTAS. They were carried out in a real environment in 11 cases, in a simulated environment in 9 cases and during theoretical teaching in 1 case.

Conclusions

Very few studies have been carried out concerning neurosurgical NTS, despite increasing numbers of articles over the last few years on NTS in other domains of surgery. Society today is concentrating more and more on the quality and safety of medical care. The development and

application of NTS assessment tools is therefore essential in order to provide assistance in the training of future neurosurgeons.

INTRODUCTION

Neurosurgery is a discipline requiring knowledge of numerous hyperspecialist domains such as vascular, tumoral, malformation, degenerative and spinal pathologies. As well as this declarative knowledge of neurosurgical pathologies and their associated indications for operation , the surgeon has to acquire technical skills both in accordance with good practice and under ongoing development, for example microsurgery, computer-assisted surgery[1–7] and robotics[8]. Even with perfect mastery of this knowledge and of the technical skills (TS) involved, a certain number of undesirable events (UE) are to be observed in the neurosurgery operating theatre[9–16] . These events may have irreversible consequences involving serious functional deficits or even life-threatening situations[17,18]. Surprisingly, they are less often the result of a technical error than of a dysfunction linked to non-technical skills (NTS)[19]. This relationship between NTS and UE has led the surgical community to explore in greater depth safety and quality issues with increasing numbers of publications on NTS over the last few years. NTS can be divided into two groups according to the taxonomy developed by Yule et al.[20]. The first includes interpersonal skills : communication, leadership, teamwork, briefing, planning and preparation, resource management, requests for advice and feedback, attitudes to pressure, stress and fatigue. The second group covers cognitive skills including awareness of the situation, mental disposition, risk assessment, anticipation of problems, decision-making, adaptation strategies, flexibility or workload. In real conditions, interpersonal skills and cognitive skills may be involved simultaneously. For example, poor communication between the surgeon and the anesthesiologist during an unexpected haemorrhage in the operating theatre (NTS involved: communication and situational awareness) may have life-threatening consequences. Publications on this subject still rely for the moment on non-standardized methods. NTS assessment is rendered problematical by a methodology difficult to put into practice (necessitating robust psychometric testing) involving multiple variables which are themselves not easily controlled[21–30]. However, it is certain that NTS exercise a positive or negative influence on TS depending on whether or not they are applied[19]. The safety and quality of care is a universal and increasing preoccupation among the population[9,17,31–34]: surgeons have taken this into account and, as in other sensitive domains such as the army[35] or navy, they are beginning to develop "firewall" tools such as checklists[9,36–40]. These NTS, still ill-defined, are only just beginning to emerge in surgeon training objectives and are even less present in the confidential world of neurosurgery[25,41–54].

The essential aim of our study was a systematic study of the literature published on NTS in the neurosurgical domain. The secondary objective was identification, from the existing literature, of a list of NTS more specific to neurosurgery in order to define on that basis the training needs of neurosurgery trainees.

MATERIAL AND METHODS

We conducted a systematic review following the PRISMA statement[55]. Ethics committee approval was not required for our research protocol. We did not register our review protocol in the PROS-PERO database.

Using the databases PubMed-MEDLINE and The Cochrane Database of Systematic Reviews, we combined two A and B categories using the Boolean operator "AND", Category A was the following : Adaptation, Psychologic OR Adjustment, Psychological OR Behavior, Adaptive OR Coping Behavior OR Coping Skills OR Psychological Adaptation OR Psychological Adjustment OR skills, Category B was: neurosurgery OR neurosurgical procedures. We defined the following limits: publication date between January 1980 and December 2018 ; articles concerning studies on humans, excluding those on animals ; publications in English and French. The final research was carried out on 2nd January 2019. The lists of article references included were also researched to find other references such as grey literature (unpublished studies with limited distribution, for example conference abstracts) and published studies not identified using our initial search strategy. This led us to add 2 articles for which we made a complete assessment of the text. We assessed the collected quotations, sifting through the titles and abstracts to identify the pertinent articles on the basis of the following predefined inclusion criteria :

1) Data concerning NTS OR interpersonal behaviour OR leadership OR teamwork OR planning and preparation OR feedback OR stress and pressure OR fatigue OR cognitive skills OR anticipation of problems OR decision-making OR flexibility OR adaptation strategies

AND

2) Data concerning the neurosurgical domain

AND

3) Data on training needs OR teaching OR simulation systems including robotics. These criteria were chosen to identify the articles specifically examining NTS in neurosurgery, the resulting training needs and the integration of these skills to simulation systems.

The data was extracted from the articles concerned using a structured data résumé (Figure 1), to ensure coherent assessment of each article. Using this method, details of the study design, the size of the sample, the NTS assessed, the assessment tools and the key results were collected.

RESULTS

Selection of articles

The diagram summarizing the research strategy is shown in Figure 2.

Research initially identified 2132 articles. In all, 21 articles were eligible for systematic study.

Populations studied

12 articles concerned analysis of neurosurgery residents[43,44,54,56–64]. 12 others studied senior neurosurgeons[33,35,58,62,64–71] and 3 others directors of training (also senior neurosurgeons)[44,58,61]. Six others dealt with the whole team of a neurosurgery operating theatre[35,65,66,68–70] and one article studied the whole team of a neurosurgery department[33].

Study designs

7 were experimental studies[56,57,59,60,63,64,71], 7 were surveys[43,44,54,58,61,62,66], 5 were interventional studies[33,35,65,67,69], and 2 were observational studies[68,70].

Environment

These studies were carried out :

- in a real environment in 11 cases : 10 in the operating theatre[33,35,44,58,61,65,66,68–70], 1 in a neurosurgery department[33], and 4 in consultation[44,58,61,67],
- in a simulated environment in 9 cases[54,56,57,59,60,62–64,71],
- during theoretical teaching in 1 case[43].

Non-technical surgical skills assessed

Interpersonal NTS were specifically assessed in 9 studies[33,43,44,59,60,63,67,68,71].

Cognitive NTS were specifically evaluated in 9 studies[44,56,57,62,64–66,69,70]. Finally, neurosurgery NTS were assessed overall in 6 studies without differentiation between the two types[35,54,57,58,61,69].

Assessment tools and key results of each study

None of the articles selected used assessment tools such as NOTECHS, NOTSS or OTAS, all of which have all been established as valid in the literature concerning assessment of NTS in surgery.

Studies in a real environment

Neurosurgery interns complained of lack of teaching on behaviour and interpersonal relations in a questionnaire designed by Cusimano *et al.*[44] given to a population of 30 interns. Open questions with content analysis and double-scale quantification were carried out both among neurosurgery interns and among heads of teaching programmes. These revealed a positive correlation between excessive workload and voluntary withdrawal, and between dismissal and interpersonal skills during the neurosurgery internship. According to Pathak *et al.*[67] Senior neurosurgeons demonstrated good productivity and flexibility, but appeared to have difficulty in remaining objective and making themselves understood in consultation. This study was carried out during neurosurgery consultations, and the sample included 12 senior neurosurgeons with at least 10 years' experience. The surgeon was assessed by an outside observer using an assessment scale including : productivity, flexibility, objectivity and comprehensibility. Fargen *et al.*[69] studied the effect of the introduction of a checklist for neurointerventional procedures in neurovascular pathology. 71 procedures were carried out 4 weeks before the introduction of the checklist and 60 others 4 weeks after it. The checklist brought about a significant improvement in communication within the team and a significant reduction in the number of undesirable events. Ferroli *et al.*[35] assessed a notification system inspired by aviation and applied to the neurosurgical domain. The entire team of a neurosurgery department participated in the study and reported incidents occurring in the service. 14 incidents were reported and analyzed. 9 were due to human factors and 3 to questions of organization. Lau *et al*.[33] assessed and installed a safety education video in a neurosurgery department. It had been made over several months by a multidisciplinary team including neurosurgeons, anaesthetists, nurses and professionals from the quality and video domains. This team ensured that all the safety parameters involved in a neurosurgical procedure were collected and formalized in video format. McLaughlin *et al*.[66] examined the interest of establishing a checklist before the beginning of an operation. 98,9% of those questioned judged this to be in the interest of the patient's safety, and 97,8% thought it increased team spirit. All members of the team judged that the surgeon should be present at the time of the checklist and according 76,3% thought that the surgeon should carry it out in person. Osvald *et al*.[65] studied the impact of the introduction of a checklist in a neurosurgery operating theatre. 8795 surgical procedures were carried out without checklist between January 2007 and December 2010, with two error reports : one procedure on the wrong side of the skull and one at the wrong level on the lumbar verterbrae. Between January 2011 and June 2012 no errors of side or level were reported. Couat *et al*.[68] through an observational study of the operating theatre using video analysis and ethographical methods, demonstrated that 33% of errors committed in the operating theatre were at least partly caused by poor communication or organisation management. Michinov *et al*.[70] in an operating theatre observational study of deep brain stimulation showed that explicit coordination, awareness of the situation and leadership are the NTS most involved in deep brain stimulation by the neurosurgeon. What is more, these aspects of behaviour differ according to the time of operation and the other members of the theatre team with whom the surgeon is communicating. Brandman *et al.*[61] also used a survey which underlined the fact that heads of programmes considered NTS more important than did the interns, with an emphasis on the disclosure of bad news. Interns focussed more on obtaining the patients' consent. Both heads of programmes and interns considered the communication of red flags as critical. The survey carried out by Khan *et al.*[58] made it clear that according to interns the current environment does not leave enough place for the teaching of NTS. For them NTS appears more important than it does for their tutors, both quantitatively and qualitatively. Teachers judge that too much teaching time is spent on NTS, and students think the contrary.

Studies in a simulated environment

Sakamoto *et al*.[71] carried out an experimental study on 5th-year medical students which showed that expert feedback improved technical performance in surgical anastomosis, without lengthening operating time. Trainees with feedback achieved higher scores than neurosurgeons. Tanweer *et* al.[62] demonstrated through a survey that neurosurgical decision-making is essentially similar from both the patient's and the neurosurgeon's point of view. Morineau *et al*.[64] showed a significant association between expert decision-making and conflict reduction and management of conflict control based on knowledge essentially contributed by experts. Harnof *et al*.[63] in an experimental study of neurosurgical interns in simulated interviews with patients and their families showed the realistic qualities of the actors and their efficiency in NTS communication training. Haji *et al*.[59] showed the importance of simulation in the teaching of teamwork, communication, dealing with pressure, stress and fatigue to first-year neurosurgery interns. Hunt *et al*.[60], also using simulation, demonstrated that leadership and teamwork are essential for a successful career in neurosurgery. Training camps improved the trainee's awareness of his own behaviour and motivation. Three-quarters of participants understood how to apply this in daily life. Ganju *et al.* specifically studied the effects of fatigue on neurosurgery interns[56]. They subjected 7 neurosurgery interns to 4 sessions of 6 pre- and post-duty surgical exercises in a simulated environment. Fatigue appeared to reduce performance to a certain extent, particularly in “day after duty” interns. Memory and attention were the functions most impaired. Fluidity of gesture and operation duration were also affected by fatigue. Selden *et al.*[54] carried out an opinion poll on 186 neurosurgery interns following practical and theoretical teaching of multiple NTS, in a simulated environment. The teaching of NTS received 100% approval from trainee neurosurgeons, particularly the sections on leadership. Finally, Ciporen *et al*.[57] in an experimental study on interns in neurosurgery and anaesthetics showed no significant difference in NTS between the two groups. Understanding information and dealing with pressure were important elements. Leadership was more obvious among the neurosurgical interns, but not significantly so. The anaesthetist interns were better at collecting information and considering different options.

Study during theoretical teaching

Pettit *et al*.[43] used an opinion poll on theoretical teaching of one hour per month given to 11 neurosurgery interns. Pre-tests and post-tests revealed both quantitative and qualitative improvements in knowledge concerning leadership.

DISCUSSION

This systematic review of the literature on NTS is to our knowledge the first which specifically concerns neurosurgery. Analysis of these skills is scattered through the literature, and they are frequently assessed individually without use of an up-to-date unified domain taxonomy. Articles reporting on the assessment of one or several NTS appear very limited in number (21). Specific training needs are difficult to define for the moment since these NTS have not yet been properly formalized. However, the much more abundant literature on the subject in other surgical disciplines offers the possibility of interpolation with the neurosurgical domain.

Methodological limits of existing studies in neurosurgery

The methodology of the studies selected after our research did not offer a high standard of proof. Few of them used specific statistical tests. We found no articles using specific surgery NTS assessment methods whose robustness and validity had been demonstrated in the literature. The 3 principal scales currently used for objective assessment of NTS are the OTAS (Observational Teamwork Assessment for Surgery)[72], the NOTECHS (NonTECHnical Skills)[21] and the NOTSS (Non Technical Skills for Surgeons)[73]. The OTAS[72] essentially assesses the work of the team on the basis of 5 criteria : communication, leadership, cooperation, coordination and surveillance. The NOTECHS[21] classifies NTS in 4 categories : leadership and management, teamwork and cooperation, problem-solving, and decision-making and awareness of the situation. A score of 5 points is given for each category with a scale from 1 (very low) to 5 (very high). The NOTSS corresponds to interviews with consultant surgeons who show five main categories of NTS (awareness of the situation, decision-making, management tasks, leadership, communication and team spirit). Within each category there are 2 or 3 NTS elements depending on the surgical speciality, leading to a score covering 14 separate elements of skill. In some studies all the NTS are assessed together and in others only one or a few of the skills are examined. These factors make it difficult to interpret the results of all these studies. The ideal solution would be an overarching assessment scale with proportionally divided sub-sections to allow all the parameters of the NTS to be taken into account. Ten of these studies were carried out in a simulated environment or during teaching. The 11 others were done in a simulated environment, in the operating theatre or in consultation. There exist no studies comparing neurosurgery NTS in a simulated environment with a real environment such as the operating theatre. The scope of the evaluation of these NTS proposed here focused on the healthcare activity in real or simulated environment but does not include all the NTS required in this profession.

The methodological heterogeneity of the studies included in our work made it impossible to assess risk of bias in individual studies, summary measures, synthesis of results, risk of bias across studies and additional analysis as suggested in the PRISMA statement.

Literature on surgical NTS

Although there are numerous synonyms in the literature describing surgical NTS, the 4 essential domains most often described are communication, decision-making, leadership and teamwork[19–21,73–80]. There also exists a subdivision of surgical NTS into two major groups : cognitive skills and interpersonal skills[20].

Several specific skills among the interpersonal NTS have been studied separately, in particular stress[18]. Stress can apparently have both positive and negative effects. A moderate level of stress[24] results in improved performance through increase in concentration. It can however endanger levels of performance when it becomes overwhelming. Pressure gives similar results to stress in a majority of cases. Surprisingly, fatigue (through sleep loss particularly post-duty)[56] can bring about contradictory results. Some studies clearly show a slowdown in task performance, clumsiness and even numbers of supplementary errors, and difficulty in concentrating. Other studies highlight contrary conclusions, with more rapid procedure time, better gesture ergonomy and fewer errors. An element of disinhibition is probably the reason for this, with fewer conflicts in a fatigue situation, and more pragmatic attitudes. Therefore, assessment in stress or fatigue conditions is very important in order to have objective data on this topic. There is a major issue in the context of the respect of the weekly working hours imposed by the European directives, while at the same time neurosurgery is impaired by an insufficient surgical demography in France.

Interpersonal communication[69] and communication with the patient are among the least studied areas in the literature. Most articles highlight the beneficial effects of feedback from a more experienced surgeon in terms of quality, gesture ergonomy, operation time and numbers of errors. In the rest of the literature NTS are analysed as a whole[17,19–24,29,72,73,75–77,79,81–83], using scales to examine the different skills. Overall, a close link is shown to exist between teamwork and the number of undesirable events occurring in the operating theatre. These articles underline the necessity for maximum communication among the whole team before, during and after a surgical procedure in order to reduce the risk of errors[17,28,32–35,69,78].

Repercussions and prospects

The utility of a good knowledge of NTS and of their assessment was demonstrated in the work of Hull *et al* in 2012[19]. NTS appear to have a positive influence on TS : they apparently improve the quality of care and patient outcome by improving safety and efficiency in the operating theatre. This study was carried out on a panel of several different types of specialist surgery.

Good mastery of NTS in neurosurgery has obvious pedagogical implications. A better understanding and definition of these skills in each specialist surgical domain, particularly in neurosurgery, would enable those responsible for teaching to identify more clearly the training needs for surgeons in that domain. The next step would be inclusion of NTS as specific subjects in educational programmes[25,41,50–52,54,64]. This is beginning to be done in the United States by the Accreditation Council for Graduate Medical Education (ACGME)[53]. The ACGME indicated for each of the specialties the "milestones" to be achieved by residents in training in each of the six "core competencies" required in the training course. Those dedicated to neurosurgery are particularly detailed in the March 2018 version of these recommendations[84]. Including NTS learning in neurosurgery can be envisaged at two points in the training period : during internship (initial training) and/or as ongoing education in the context of continuing professional development (CPD). Confining learning of these skills exclusively to one or another particular stage of the learning process seems unduly simplistic. Placing the acquisition of these skills at the beginning of internship training would be more valuable, since these are general skills which can be applied from the outset of daily surgical activity. They do not necessarily require previous specific declarative knowledge such as complex anatomical elements, which could represent a technical obstacle for a young resident operating, for example, on a brain tumour in a difficult location. It also appears more logical for students to acquire these skills as early as possible to optimize patient safety, for the same reason as they learn basic technical skills (for example, how to hold an instrument properly). It is also essential to include NTS in CPD, since acquisition of these skills is not yet systematic in early training. Surgery, and neurosurgery in particular, is often taught by mentoring, the main teaching tool being the role model. In spite of many hours spent in the operating theatre or with patients, a neurosurgery intern may at times find it difficult to understand the difficulties facing the surgeon and the cognitive conflicts he experiences[64]. On the other hand, the surgeon may have difficulty in transmitting the skills he has learnt by experience, which seem natural to him since he cannot formalize them and make them explicit. Understanding NTS more clearly, formalizing them and rendering them explicit, will greatly improve the training of young neurosurgeons by helping them to identify problems at an early stage, so as to optimize patient safety[85] and accelerate their learning curve.

NTS are also an important subject in the research domain. Initially, applying recognised measuring scales (NOTECHS, NOTSS, OTAS) to neurosurgery could render it possible to pursue the study of their feasability and assess their reliability and variability in a specific context. Neurosurgery is a complex and specific surgical discipline which nonetheless shares similar difficulties and NTS with other surgical specialties, while retaining its own particular aspects. Studying NTS in neurosurgery opens the possibility of enriching the taxonomy in this domain. The concepts of morbidity and mortality within neurosurgical procedures are of extreme importance. Many operations may carry a risk of life-threatening consequences or of life-changing functional handicaps. They involve cognitive conflicts which are difficult for the surgeon to manage, the more so as the procedure often takes place in the context of an emergency. One example is a patient's recovery from anaesthesia after an operation for cranio-cerebral pathology. Several different scenarios are possible : 1) A patient without preoperative neurological signs may on recovery present new disabilities which may or may not disappear (induced handicap) ; 2) A patient with no preoperative vigilance disorders may not recover consciousness after anaesthesia and risks falling into a chronic coma state ; 3) Fortunately in the majority of cases the patient recovers consciousness without new disabilities, or with an improvement compared to preoperative neurological signs. It can easily be understood that in these different situations stress management, risk assessment and pressure are not the same. Stress management continues until the patient's recovery from anaesthesia ; it does not end when the surgical procedure is finished.

Different methods of intervention to improve safety in operating theatres have been appearing over the last few years, particularly since 2009 with the Surgical Safety Checklist[36]. Other specific checklists have been developed in neurosurgical specialist areas such as vascular neurosurgery or deep brain stimulation[40]. In terms of public health, surgical errors are responsible for a significant increase in morbidity, a deterioration in the quality of life and increased expenditure[10,12–17,28,33,34,36,38,86]. These checklists have been developed[36–40] in order to reduce the number of avoidable errors, with the constant purpose of improving the quality of care and the safety of patients.

CONCLUSIONS

After this systematic review of the literature, it appears that very few studies have been carried out concerning neurosurgical NTS, in spite of increasing numbers of articles over the last few years on NTS in other domains of surgery. Moreover, this literature is very diverse in comparison with studies on TS. The complexity of the methodology required to ensure robust assessment tools is probably the reason for this disparity. Society today is concentrating more and more on the quality and safety of medical care, particularly in the domain of neurosurgery. The development and application of these assessment tools is therefore essential. They will also provide important and still underestimated assistance in the training of future neurosurgeons, thus ensuring that all the skills necessary to the profession are effectively transmitted.

Disclosure

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Figure Legends

Figure 1 Résumé of structured data for article analysis

Figure 2 Diagram of analysis of articles

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Table 1. Characteristics of the studies assessing non-technical skills in neurosurgery

First author	Year of publication	Population	Type of study	Environment	Non-technical skills assessed	Tools for assessment	Key results
Cusimano[44]	1999	Teaching hospital neurosurgeons and interns in neurosurgery	Qualitative	Real	Interpersonal skills and workload	Qualitative analysis of questionnaires Double scale content analysis	Positive correlation between excess workload and voluntary withdrawal and between dismissal and interpersonal skills during the neurosurgery internship
Pathak[67]	2000	Professors of neurosurgery	Interventional study	Real environment and consultations	Leadership	External observation scale for patterns of leadership and language	Good productivity and flexibility, moderate objectivity and comprehensibility
Morineau[64]	2009	Neurosurgery interns, registrars and professors	Experimental study	Simulation	Decision-making	Number of conflicts and checks reported by each neurosurgeon Skills /Rule / Knowledge approach	Significant link between the expert undertaking tasks and checking of conflicts, Regulation of conflict control essentially based on experts' knowledge
Pettit[43]	2011	Neurosurgery interns	Survey	Theoretical teaching	Leadership	Opinion poll	Training in the importance of leadership and the means to develop it.
Ganju[56]	2012	Neurosurgery inters	Semi-experimental study	Simulation	Dealing with fatigue, cognitive skills	Fluidity of gestures, time taken and cognitive errors	No significant reduction in skills during simulated surgical procedures after on-call service.
Selden[54]	2012	Professors of neurosurgery and first-year neurosurgery interns	Survey	Simulation	Multiple non-technical skills	Opinion poll	Teaching appreciated by interns for the improvement of their knowledge and their technical and non-technical skills .

Ferroli[35]	2012	Neurosurgery operating theatre team	Interventional study	Real environment – operating theatre	Multiple non-technical skills	Incidence of undesirable events and analysis of their causes by methods originating in aviation	The majority of incidents were linked to human or organisational factors
Lau[33]	2012	Duty neurosurgery team	Interventional study	Real environment	Communication and teamwork	Analysis of perioperative safety video	The perioperative safety video improves safety in the operating theatre and raises the team's awareness of safety issues
Oszvald[65]	2012	Neurosurgery operating theatre team	Interventional study	Real event – operating theatre	Communication,teamwork preparation, risk assessment, anticipation of problems	Number of undesirable events	The surgical safety checklist improves communication within the team and reduces the number of undesirable events
Harnof[63]	2013	Neurosurgery interns	Experimental study	Simulation – interviews with patients and their families	Communication	Feedback questionnaires (Likert scale)	Realistic actors, effficient training in interpersonal communication skills
Couat[68]	2013	Neurosurgery operating theatre team	Observational study	Real environment - operating theatre	Communication, resource management	Analysis of videos and direct observation using ethnographical methods (notes taken from observation on site)	33% of errors in the operating theatre are at least partly due to poor communication or organisational management
Fargen[69]	2013	Neurosurgery operating theatre team	Interventional study	Real environment - operating theatre	Communication,teamwork preparation, risk assessment, anticipation of problems	Communication and number of undesirable events	The surgical safety checklist improves communication within the team and reduces the number of undesirable events
McLaughlin[66]	2013	Neurosurgery operating theatre team	Survey	Real environment - operating	Communication,teamwork preparation, risk	Opinion poll	The surgical safety checklist improves communication within the team and reduces the number of undesirable events

				theatre	assessment, anticipation of problems		
Michinov[70]	2014	Neurosurgery operating theatre team and patient	Observational study	Real environment - operating theatre	Cooperation and teamwork, awareness of the situation, explicit coordination, decision-making and leadership	Behavioural marker system for assessing neurosurgeons' non-technical skills (BMS - NNTS)	Explicit coordination, awareness of the situation and leadership are the non-technical skills most implicated in deep brain stimulation surgery by the neurosurgeon. Moreover these behaviours vary with the time of the operation and the other member of the surgical team with whom he is communicating.
Tanweer[62]	2015	Neurosurgery interns, registrars and professors	Survey	Simulation	Decision-making	Questionnaire	In neurosurgical decision-making the point of view of the patient and of the neurosurgeon are essentially equivalent.
Brandman[61]	2015		Survey	Real environment – common practice	All non-technical skills	Online questionnaire, Likert scale, open-ended questions	Programme directors placed non-technical communication skills at a higher level than interns, with emphasis on announcing bad news. Interns focussed more on obtaining patients' consent. Both programme directors and interns considered red-flag communication as criticallly important
Haji[59]	2015	First-year neurosurgery interns	Pre- and post-test model	Simulation	Teamwork, communication, dealing with pressure, stress and fatigue	Multiple-choice questionnaire	Significant differences between pre- and post-test but not on the retention test
Hunt[60]		Neurosurgery interns	Pre- and post-test model	Simulation	Leadership	Questionnaire and personality assessment (Hogan Personality Inventory)	Leadership and teamwork are essential for success in a neurosurgeon's career, This training session improves interns'

							awareness of their own behaviour and motivation. ¾ of trainees understood how to apply this in daily practice.
Khan[58]	2018	Neurosurgery interns and teaching neurosurgeons	Survey	Real environment: teaching/ curriculum	All non-technical skills	Questionnaire with quantitative and qualitative analysis	Interns feel that the current environment leaves little place for the acquisition of non-technical skills. They give greater importance to the learning of non-technical skills than their teachers do, both quantitatively and qualitatively.Teachers feel that too much time is given to non-technical skills, and the trainees believe the contrary.
Sakamoto[71]	2018	5th-year medical students and neurosurgeons	Experimental study	Simulation	Feedback	Comparison of a surgical act of vascular anastomosis with and without feedback	Expert feedback improves the technical performance of anastomosis without prolonging operation time. Trainees with feedback had higher scores than the neurosurgeons.
Ciporen[57]	2018	Neurosurgery and anaesthetic interns	Experimental study	Simulation	Awareness of the situation, decision-making, communication, teamwork, leadership, dealing with pressure	Non-technical skills observation scale	No significant difference in non-technical skills between interns in neurosurgery and anaesthetics. Understanding information and dealing with pressure were important. Leadership was more important for neurosurgery interns, but not significantly. Anaesthetics interns performed better in collecting information and considering different options,

Name of first author

Year of publication

Population

Study design

Environment

Non-technical skills assessed

- *Interpersonal skills*
  - Communication
  - Leadership
  - Teamwork
  - Briefing/Planning/Preparation
  - Resource management
  - Seeking advice and feedback
  - Coping with pressure/stress/fatigue
- *Cognitive skills*
  - Situation awareness
  - Mental readiness
  - Risk assessment
  - Anticipation of problems
  - Decision-making
  - Adaptation strategies and flexibility
  - Workload distribution

Assessment tools for NTS

- NOTSS
- NOTECHS
- OTAS
- Others

Key results


Research strategy
Total = 2132
Limits applied
Articles excluded after limits applied
Total = 739
Selection of titles
Articles kept for title assessment
Total = 1393
Articles excluded by title
Total = 1232
Selection of abstracts
Articles kept for abstract assessment
Total = 161
Articles excluded by abstract assessment
Total = 109
Selection of whole texts
Articles kept for whole text assessment
Total = 52
Articles excluded after text assessment
Total exclus = 33
TS or NTS not assessed
Manual research
Total included = 2
Articles eligible for systematic study
Total = 21

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	7
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NC
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	NC
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NC

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NC
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NC
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-13
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	NC
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	10-13
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NC
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NC
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NC
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	114
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14-15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	20
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	21

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

NC: non considered

Disclosure-Conflict of Interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.