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A Delphi-based needs assessment to identify and prioritise procedural skills through consensus for simulation-based learning in neurosurgery

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Abstract

Background Training of the neurosurgeon today differs greatly from that of the past, with several well-documented challenges contributing to reduced operative time for current cohorts. The Joint Committee on Surgical Training (JCST) in the UK and Ireland have stated that simulation-based education (SBE) is part of the solution to tackle this training crisis. Our objective was to develop a prioritised list of technical skills through consensus with key opinion leaders (KOLs). This approach aimed to enhance understanding of the essential procedures that should shape a technical skills framework for neurosurgical simulation-based learning curricula.

Methods We utilised a modified Delphi process and Copenhagen Academy for Medical Education and Simulation (CAMES) Needs Assessment Formula (NAF) to reach consensus. A total of 71 procedures were included for initial analysis, which were extracted from all phases of the JCST curriculum and subsequent brainstorming with KOLs. A five person steering group oversaw the process, to ensure a robust methodological approach was followed at all stages.

Results For each of the three Delphi rounds, there were 32, 30, and 31 KOL responses, respectively. A prioritised list of 47 procedural skills was generated through consensus. The top three ranking procedures were patient positioning, pinning positions and flap design, intracranial pressure (ICP) probe insertion and external ventricular drain (EVD) insertion. Emphasis was placed on acute cranial trauma, degenerative spine, neuro-oncology and CSF diversion procedures as the categorical themes of highest priority.

Conclusions We describe a multi-jurisdiction general needs assessment for technical skills in neurosurgical simulation training. This study will inform the design of future simulation-based learning curriculum in this sphere of training.

Keywords Neurosurgery, Simulation, Technical skills, Patient safety

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Introduction

Modern neurosurgical trainees face significant challenges in acquiring the necessary technical competencies required at appropriate stages of their training [1, 2]. Factors such as contemporary patient safety expectations and governance [3], the fallout from COVID-19 [4, 5], reduced operative exposure due to working hour restrictions [6], and fewer complex cases due to advances in alternative treatments contribute to this difficulty [7]. As a result, many trainees experience reduced operative autonomy, particularly in the earlier years of training [8], which may delay their seamless progression to independent surgical practice. Given the importance of safe and effective surgery in achieving positive patient outcomes [9], this issue is a cause for concern.

To address these challenges, she Joint Committee on Surgical Training (JCST) has emphasised the role of simulation-based education (SBE) in aiding the recovery of surgical training post COVID-19 [4]. It is a useful tool for learning in neurosurgery, as it is an exceptionally demanding surgical specialty in technical terms, with shallow learning curves [10]. Identifying key procedural skills for SBE—particularly in early to mid-training—can significantly impact surgical performance in the operating room [11–13]. SBE can support the introduction of the competency versus time based neurosurgical curriculum rolled out by the intercollegiate surgical curriculum programme (ISCP) in recent years [14].

Following Kern's Six Step Approach to Curriculum Development, the first step in designing an SBE curriculum is a problem identification and general needs assessment [15]. Other curricula have demonstrated the benefits of SBE, including enhanced understanding of surgical instruments, technology and equipment in a safe learning environment. The selection of skills for inclusion should be guided not only by the quality of simulation modalities [13], but also by their relevance to trainee needs. There are now many affordable, accessible training models [16–18] and modalities (Fig. 1) available for neurosurgical training, including porcine cadavers (Fig. 2). Fresh frozen cadaveric tissue, although significantly more expensive, provide high fidelity. Ethical considerations must be observed to ensure the proper use of biological models, including obtaining review board approval and adhering to laboratory protocols, to guarantee that these modalities are utilised in a respectful and responsible manner during training. The primary focus should be on meeting learning objectives through effective SBE [19].

To date, no consensus-driven assessment specific to neurosurgery has systematically prioritised skills for SBE training. To address this gap, this study aimed to develop a prioritised list of technical skills through multijurisdictional consensus with key opinion leaders (KOL) in Ireland and the United Kingdom (UK). The findings will inform the development of a technical skills

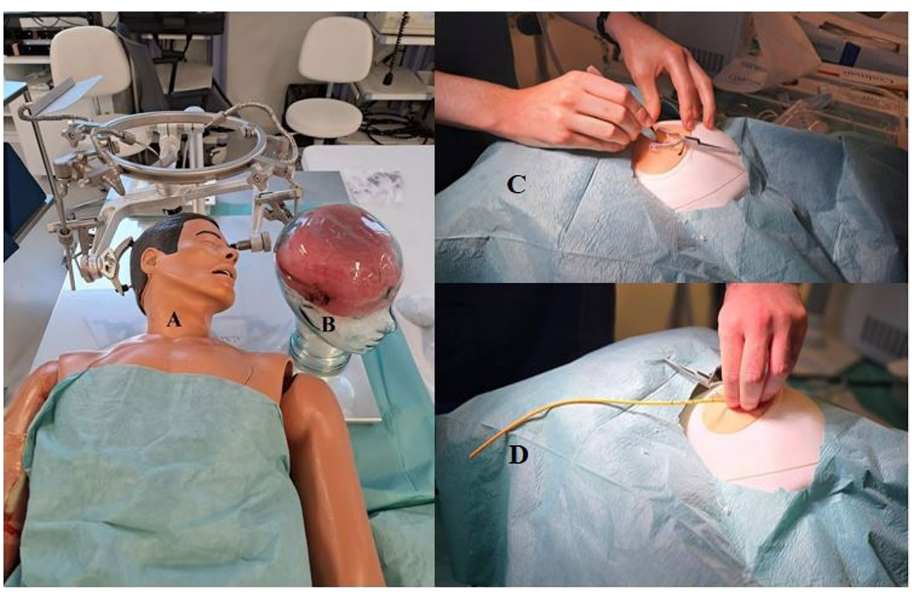

Fig. 1 A full body synthetic manikin to practice patient positioning and three-point rigid fixation using the Mayfield skull clamp (**A**). A glass display head with encompassing silicone-moulded brain for simulating flap designs (**B**). Skin incision prior to burr hole execution for placement of external ventricular drain (EVD) on a locally developed synthetic simulation model (**C**). Successful placement and subsequent drainage of cerebrospinal fluid (CSF) from the lateral ventricle (**D**)

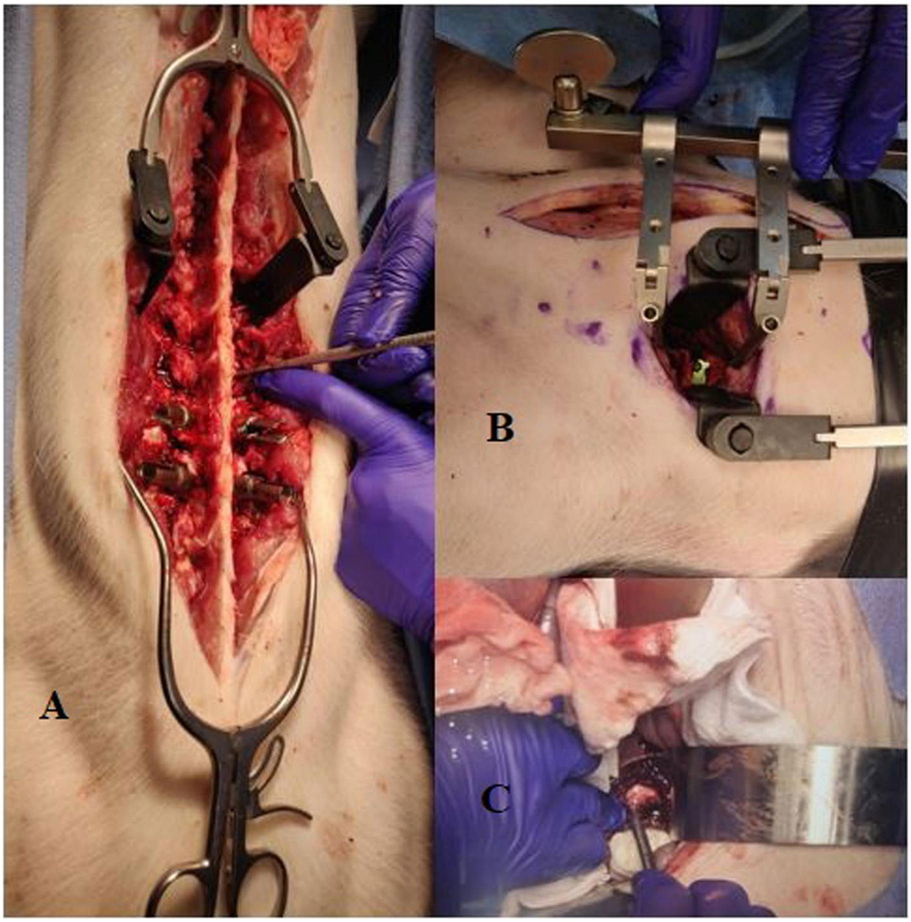

Fig. 2 Utilising a pig cadaver is a cost effective modality to practice spinal procedures through simulation. Pedicle screw insertion posteriorly (**A**). Anterior approach to cervical spine with interbody cage insertion (**B**). Anterior approach to lumbar spine for discectomy (**C**)

framework for a neurosurgical simulation-based learning curriculum.

Methods

This study employed a modified Delphi method employing the Copenhagen Academy for Medical Education and Simulation (CAMES) Needs Assessment Formula (NAF), consisting of three iterative survey rounds, to reach consensus.

This approach is well established and aligns with several comparable studies reported in the literature [20, 21]. The research and data synthesising process was overseen by a steering committee comprising five people: consultant neurosurgeons (DC, GZ), senior neurosurgical trainee (VH), director of simulation education (CC), and a surgical education researcher (AR).

Participants

KOLs in this study were recruited using a convenience and snowball sampling technique. They are defined as senior neurosurgical trainees in years 7 and 8 of an 8-year training programme, those in temporary consultant roles post-Certificate of Completion of Surgical Training (CCST) and full-time consultants in neurosurgery, all of whom are actively working in public practice. KOLs are registered with the following training bodies in the UK and Ireland: Royal College of Surgeons Edinburgh (RCSEd), Royal College of Surgeons England (RCSEng), and Royal College of Surgeons Ireland (RCSI), as having completed or are currently completing Fellowship of Royal College of Surgeons (FRCS) examinations. Multi-jurisdiction consensus was attainable as these training bodies collectively utilise the JCST curriculum [8]. Furthermore, several studies report the management of various neurosurgical conditions in these jurisdictions jointly [22–24], which reinforces the general parallels in patient demographics and clinical practices.

Intervention design

The SurveyMonkey Enterprise version™ (Europe) was used to host the surveys, and information relevant to each survey was collated for distribution via the Quality Enhancement Office in RCSI. Surveys were subsequently distributed to participants via three gatekeepers: RCSI Neurosurgical Programme Administrator, British Neurosurgical Trainees' Association (BNTA) and Society of British Neurological Surgeons (SBNS) relevant mailing lists. Surveys were distributed iteratively using 5-point nominal data scales to calculate responses. Particular questioning criteria applied to each domain. The data collection protocol was followed to ensure that all data was gathered accurately, completely, and systematically, minimizing the risk of errors or inconsistencies.

Round 1: brainstorming and ranking of importance using NAF

Two authors (AR, VH), extracted procedural competencies from all phases of neurosurgical training outlined in the ISCP curriculum. Further procedures were added and existing ones removed through participant brainstorming. In the first round, we utilised component A.1 of the CAMES-NAF formula "Doctors", and requested participants to rank procedures based on the statement, "All neurosurgery trainees at the end of training certification should be competent to perform the following procedures at the level expected of a day-1 consultant," on a 5-point scale (Appendix 1). After thorough deliberation, the steering committee determined that procedures with a mean score of 2.95 or lower in this round would be excluded from subsequent rounds. This decision was made to reduce the burden of lengthy, repetitive surveys on participants and to allow them to focus more effectively on procedures that are critical for newly appointed neurosurgical consultants to demonstrate competence.

Round 2. rating using NAF

Results from the first round were aggregated, with procedures arising from round one redistributed to all participants in round two for the purpose of ranking each procedure's perceived "Frequency" and "Risk" (Appendix 1, components A.2 and A.3). In this case, frequency refers to the procedure's prevalence, while risk refers to the patient's risk if a neurosurgical trainee with insufficient experience performs the procedure.

The steering group was assigned to complete the last section of the CAMES-NAF survey, which sought to quantify the "Feasibility" of training neurosurgical doctors in these procedures in a simulation-based environment (Appendix 1, components B.1, B.2, B.3); specifically, the factors related to cost, availability, and suitability. A total score was obtained by calculating the means for each of the NAF's four domains (Doctors + Frequency + Risk + Feasibility). Each domain was given an equal weighting of 25%. A revised list of procedures was produced as a result, which could be sent to all participants for final prioritisation.

Round 3. feasibility using NAF

In the final round, participants were permitted to remove any procedures that they thought were inappropriate for simulation-based learning, merge and reorder the rankings of the procedures that remained. A 75% majority would determine that the results of this round were the final prioritised ranking list.

In order to evaluate the measure of rank correlation between the NAF score in round two and the final majority decision from KOLs in round three, we performed a Pearson correlation (r) coefficient test. Statistical analysis was performed using Stata Version 17.0 (StataCorp, College Station, TX, USA). In general for absolute for absolute values of r, 0 – 0.19 is regarded as very weak, 0.2 – 0.39 as weak, 0.40 – 0.59 as moderate, 0.6 – 0.79 as strong and 0.8 – 1 as very strong correlation. A high correlation reflects a high degree of consensus.

Results

The first round survey was completed by 32 KOLs and respondents from this round provided baseline demographic data (Table 1). This table reflects the diverse subspecialty interests of multiple participants. This round incurred a KOL response rate of 4% of the total participant population that were invited to respond. A total of 71 surgical procedures were included for analysis, which were categorised into seven domains (Appendix 2).

Thirty KOLs completed the second round survey, which was a response rate of 3.8%. Following the elimination of 17 procedures based on the first round's results, 54 procedures were included in this round (Table 2). The most important procedural skill for SBE in neurosurgery at this stage was patient positioning, pinning positions and flap design, according to the NAF's assessment. There was significant disagreement on the requirement of sub-specialist procedures, such as cerebral arteriovenous malformation (AVM) microsurgery and deep brain stimulation, as well as uncommon procedural skills such as microvascular anastomosis. As a result, these were removed from consideration for selection in this and subsequent rounds.

Thirty-one KOLs completed round three, resulting in a response rate of 3.9%. This round resulted in a final list of 47 procedures, which also highlights the changes in ranking based on analysis from rounds 2 to 3.(Table 3). Two procedures were eliminated, and a further five merged with other procedures as they were deemed inherently similar

Table 1 Demographic data from survey round one respondents

Participant:	**Year 7 Trainee**	**Year 8 Trainee**		**Consultant**
n	3 (9%)	1 (3%)		28 (88%)
Affiliation:	RCSI	RCSEd		RCSEng
n	11 (34%)	11 (34%)		10 (32%)
Sub-specialty interest(s):	Neurovascular	Pituitary	Spinal	Skull-base
n	5 (16%)	5 (16%)	15 (47%)	9 (28%)
Sub-specialty interest(s):	Paediatric neurosurgery	Functional	Pain	Trauma
n:	9 (28%)	4 (13%)	3 (9%)	6 (19%)
Sub-specialty interest(s):	General neurosurgery	Neuro-oncology	Hydrocephalus	Radiosurgery
n:	14 (44%)	6 (19%)	5 (16%)	1 (3%)
Gender M: F	30:: 2			
Age (median & IQR)	51 (42—56)			
Neurosurgical procedures performed (median & IQR)	3,000 (1,500—5,500)			

or used cohesively with other procedural skills. For example, anterior cervical discectomy and fusion (ACDF) are two separate sequential components of the same surgical operation; they were merged here as they address a single operative workflow. Patient positioning, pinning positions and flap design, ICP probe insertion, EVD insertion, burr hole evacuation of chronic subdural haematoma and lumbar puncture and lumbar drain insertion were the highest-ranking prioritised procedures. The excision of convexity meningioma, pterional craniotomy, and elevation of compound depressed skull fracture procedures underwent the most significant shift in rankings due to differing consensus from the steering committee regarding their "feasibility" in round 3. As a result, all procedures were re-ranked based on KOL input during the subjective re-ranking phase at the end. There were no additional unexpected shifts in the rankings; consequently, the consistency across rounds strengthens the collective agreement among the experts on the prioritisation of these neurosurgical procedures. Syringopleural shunt insertion and myelomeningocele repair were the lowest priority procedures, but were nonetheless included in the list. Myelomeningocele, commonly referred to as "spina bifida," is a serious condition involving the spinal cord and its protective coverings. Due to its rarity and association with a niche subspecialty in neurosurgery, KOLs assigned this procedure lower priority. However, it received sufficient support in the first round, to warrant inclusion in subsequent rounds.

As the data was normally distributed, a Pearson correlation coefficient was the appropriate test to evaluate the correlational linkages between the round two NAF and the final KOL opinion in the third round. A Pearson's coefficient of $r=0.97$ (95% confidence interval 0.96, 0.99; $p<0.01$) showed a very strong correlation between both rounds, and adds rigour associated with the NAF analysis (Fig. 3).

Discussion

In this study, we conducted a three-round modified Delphi general needs assessment with KOLs to identify which technical procedural skills in neurosurgery should be prioritised for inclusion into SBE curricula. KOLs in this regard were senior trainees and consultants in neurosurgery. This is the first comprehensive multi-jurisdiction general SBE needs assessment carried out in this domain of surgery. A prioritised list of 47 neurosurgical procedures that should be supported by SBE was produced, with an emphasis placed on acute cranial trauma, degenerative spine, neuro-oncology and CSF diversion procedures as the categorical themes of highest priority.

Patient positioning, pinning positions and flap design, ICP probe insertion and EVD insertion were the top three ranking skills all throughout the Delphi process. This signifies the importance placed on these procedural skills by KOLs, as their top tier status was maintained throughout our objective quantitative analysis in rounds one and two, and in the subjective re-ranking of skills by KOLs after round three. Trainees in neurosurgery are expected to have competence in performing these procedures early in their training, in addition to burr hole evacuation of chronic subdural haematomas (ranked fourth) and lumbar drain insertion (ranked fifth). Currently, these skills are taught through SBE, but there is a notable lack of consistency in how these skills are identified, prioritised and integrated into training programmes. Where possible, considerations should be made to ensure junior neurosurgical trainees are afforded the opportunity to practice these skills in a safe learning simulation environment prior to real patient encounters.

Table 2 Calculation of overall scoring after round two

Procedure / skill	Docs	Freq	Risk	Feas	CAMES-NAF Score	Procedure / skill	Docs	Freq	Risk	Feas	CAMES-NAF Score
Patient positioning, pinning positions and flap design	5.00	4.67	3.77	3.67	**17.10**	Dural repair / cerebrospinal fluid (CSF) leak repair	4.78	2.37	3.97	2.53	**13.65**
Intracranial pressure (ICP) probe insertion	4.84	3.93	2.97	4.07	**15.81**	Intra-axial haematoma evacuation (intraparenchymal haematoma) / supratentorial lobar	4.88	3.13	3.23	2.40	**13.64**
External ventricular drain (EVD) insertion	4.94	3.97	3.00	3.87	**15.77**	Infratentorial intracerebral hemorrhage (ICH) evacuation	4.88	2.70	3.67	2.40	**13.64**
Burr hole evacuation of chronic subdural haematoma	4.97	4.10	2.90	3.73	**15.70**	Interhemispheric approach—craniotomy	4.03	2.10	4.33	3.13	**13.60**
Cervical, thoracic and lumbar laminectomy / laminotomy	4.84	3.73	3.33	3.60	**15.51**	Decompressive bifrontal craniectomy	4.88	2.47	3.43	2.67	**13.44**
Pterional approach—craniotomy	4.88	3.67	3.53	3.33	**15.41**	Resection of parasagittal and falcine meningiomas	4.56	2.67	4.13	2.07	**13.43**
Burr hole brain biopsy including stereotactic	4.91	3.73	3.70	2.87	**15.21**	Endoscopic biopsy of intra- and paraventricular brain tumours	4.13	2.13	4.13	2.87	**13.26**
Lumbar puncture, lumbar drain insertion	4.91	3.83	2.73	3.67	**15.14**	Endoscopic fenestration of cyst / arachnoid cyst	4.16	1.97	4.20	2.93	**13.26**
Endoscopic third ventriculostomy (ETV)	4.41	2.60	4.23	3.67	**14.91**	Principles of infected wound washout	4.94	2.77	2.83	2.67	**13.20**
Trauma flap craniotomy (for subdural, extradural haematoma)	4.88	3.70	3.20	3.07	**14.84**	Ventriculopleural shunt insertion including pleural dissection	3.75	1.80	4.23	3.40	**13.18**
Lumbar microdiscectomy	4.94	3.70	3.50	2.67	**14.80**	Clipping of aneurysm (saccular, complex etc.)	3.09	2.77	4.40	2.80	**13.06**
Ventriculoperitoneal shunt insertion including abdominal dissection	4.88	3.80	3.27	2.80	**14.74**	Elevation of compound depressed skull fracture with dural repair	4.91	2.53	3.20	2.20	**12.84**
Transcortical approach to glioblastoma (GBM) resection / debulking	4.69	3.67	3.77	2.60	**14.72**	Lobectomy for haemorrhagic contusion	4.69	2.27	3.50	2.33	**12.79**
Sylvian fissure splitting and exposure of the middle cerebral artery (MCA) bifurcation	4.50	3.10	4.07	2.93	**14.60**	Middle fossa / extended middle fossa approach—craniotomy	3.31	2.30	4.20	2.87	**12.68**
Anterior cervical discectomy	4.78	3.53	3.83	2.40	**14.55**	Resection of midline ventricular lesion (eg colloid cyst)	3.81	2.17	4.37	2.20	**12.55**
Extra-axial haematoma evacuation (extradural haematoma, subdural haematoma)	4.91	3.37	3.13	2.93	**14.34**	Orbitozygomatic approach—craniotomy	3.31	2.07	4.20	2.87	**12.45**
Retrosigmoid approach—craniotomy	4.63	2.73	3.43	3.53	**14.33**	Resection of sphenoid ridge meningioma	3.78	2.37	4.47	1.73	**12.35**
Decompressive craniectomy	4.88	3.20	3.30	2.93	**14.31**	Intra-operative monitoring (IOM) utilization, e.g. Mapping dorsal columns (asleep)	3.72	2.23	4.00	2.33	**12.29**
Midline suboccipital approach—midline approach to tumour resection	4.72	2.73	4.03	2.80	**14.29**	Resection of 4th ventricular tumours	3.56	2.17	4.57	1.93	**12.23**
Midline suboccipital approach—posterior fossa decompression	4.84	2.73	3.93	2.73	**14.24**	Complex extra-axial lesion resection (intrinsic cerebellar tumour, vestibular schwannoma etc.)	3.16	2.53	4.53	2.00	**12.22**
Pedicle screw insertion: cervical, thoracic, lumbar	3.66	2.97	4.33	3.13	**14.09**	Resection of olfactory groove meningioma	3.81	2.40	4.33	1.67	**12.21**
Transsphenoidal hypophysectomy and biopsy of sellar lesion	3.38	2.97	4.40	3.27	**14.01**	Ventriculoatrial shunt insertion including neck dissection	3.72	2.00	4.20	2.27	**12.19**

Table 2 (continued)

Procedure / skill	Docs	Freq	Risk	Feas	CAMES-NAF Score	Procedure / skill	Docs	Freq	Risk	Feas	CAMES-NAF Score
Midline suboccipital approach—foramen magnum decompression (bone only versus opening dura)	4.84	2.83	3.80	2.47	**13.94**	Resection of petrous ridge meningioma	3.19	2.27	4.50	2.20	**12.15**
Excision of convexity meningioma	4.81	3.20	3.63	2.20	**13.85**	Craniofacial repair of a CSF leak	3.75	2.00	4.27	1.93	**11.95**
Anterior plate systems (fusion)	4.00	2.83	4.20	2.80	**13.83**	Craniocervical junction tumour resection	3.16	2.10	4.60	1.67	**11.52**
Microvascular decompression (facial nerve, trigeminal nerve etc.)	3.5	2.2	4.4	3.73	**13.8333333**	Syringopleural shunt insertion	3.44	1.83	4.17	2	**11.4375**
Cranioplasty using autologous, titanium or acrylic implants	4.875	3.27	3.37	2.27	**13.775**	Myelomeningocele repair	2.97	1.8	4.57	1.93	**11.26875**

Table 3 Final ranking of procedures with the change of ranking arising from analyses from round two and round three outlined

Final ranking	Procedure / skill	Change
1	Patient positioning, pinning positions and flap design	↔
2	Intracranial pressure (ICP) probe insertion	↔
3	External ventricular drain (EVD) insertion	↔
4	Burr hole evacuation of chronic subdural / extradural haematoma	↔
5	Lumbar puncture and lumbar drain insertion	↑3
6	Cervical, thoracic and lumbar laminectomy / laminotomy	↓1
7	Trauma flap craniotomy (for subdural haematoma, extradural haematoma), decompressive craniectomy and decompressive bifrontal craniectomy	↑3, ↑10, ↑21
8	Burr hole brain biopsy including stereotactic	↓1
9	Lumbar microdiscectomy	↑2
10	Ventriculoperitoneal (VP) shunt insertion including abdominal dissection	↑2
11	Excision of convexity meningioma	↑10
12	Pterional approach—craniotomy	↓6
13	Endoscopic third ventriculostomy (ETV)	↓4
14	Transcortical approach to glioblastoma (GBM) resection / debulking	↓1
15	Sylvian fissure splitting and exposure of the middle cerebral artery (MCA) bifurcation	↓1
16	Anterior cervical discectomy and fusion (ACDF)	↓1, ↑6
17	Retrosigmoid approach—craniotomy	↓1
18	Midline suboccipital approach—posterior fossa decompression, foramen magnum decompression (bone only versus opening dura)	↔, ↑3
19	Midline suboccipital approach—midline approach to tumour resection	↓2
20	Elevation of compound depressed skull fracture with dural repair	↑13
21	Transsphenoidal hypophysectomy and biopsy of sellar lesion	↓1
22	Microvascular decompression (facial nerve, trigeminal nerve etc.)	↔
23	Pedicle screw insertion: cervical, thoracic, lumbar	↑4
24	Cranioplasty using autologous, titanium or acrylic implants	↓1
25	Interhemispheric approach—craniotomy	↓2
26	Intra-axial haematoma evacuation (intraparenchymal haematoma) / supratentorial lobar	↓1
27	Dural repair / cerebrospinal fluid (CSF) leak repair	↓3
28	Resection of parasagittal and falcine meningiomas	↔
29	Infratentorial intracerebral hemorrhage (ICH) evacuation	↓3
30	Endoscopic biopsy of intra- and paraventricular brain tumours	↓1
31	Ventriculopleural shunt insertion including pleural dissection	↔
32	Endoscopic fenestration of cyst / arachnoid cyst	↓2
33	Clipping of aneurysm (saccular, complex etc.)	↓1
34	Lobectomy for haemorrhagic contusion	↔
35	Orbitozygomatic approach—craniotomy	↑2
36	Resection of midline ventricular lesion (eg colloid cyst)	↔
37	Middle fossa / extended middle fossa approach—craniotomy	↓2
38	Ventriculoatrial shunt insertion including neck dissection	↑4
39	Resection of 4th ventricular tumours	↔
40	Resection of sphenoid ridge meningioma	↓2
41	Complex extra-axial lesion resection (intrinsic cerebellar tumour, vestibular schwannoma etc.)	↓1
42	Resection of olfactory groove meningioma	↓1
43	Resection of petrous ridge meningioma	↔
44	Craniofacial repair of a CSF leak	↔
45	Craniocervical junction tumour resection	↔
46	Syringopleural shunt insertion	↔
47	Myelomeningocele repair	↔

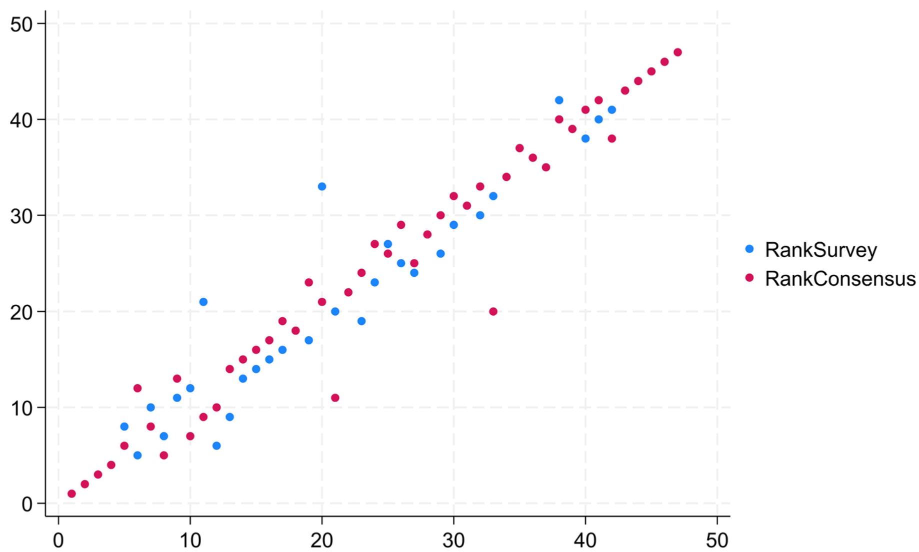

Fig. 3 This plot compares the rankings from the NAF survey analysis (blue) with those derived through KOL consensus (red), highlighting their correlation

For the purpose of immobilisation, the Mayfield skull clamp is utilised in many cases of cranial and cervical spine surgery. Improper application-related adverse effects are uncommon; however, improper fixation can lead to vascular perforation, pin site infection and instances of bone fracture in particularly thin skull areas [25, 26]. After patient immobilisation, flap design—linear, bicoronal, etc.—usually occurs. It is unsurprising that these procedural skills ranked with highest priority in this study given their prevalence in neurosurgery and the potential harm to patients that could result from inadequate pin placement and / or flap design. Incorrect pin placement, even by a few millimetres, can have implications on ergonomics associated with task execution for the neurosurgeon. Furthermore, if due care is taken during initial head fixation, it can reduce unnecessary case time. These clinical presentations can be replicated through SBE, one suggestion is to use a cost effective synthetic-based manikin for patient positioning and pinning practice component. Anonymized magnetic resonance imaging (MRI) or computed tomography (CT) images from real patients with cranial or spinal pathologies can accompany the modalities outlined in Fig. 1 to support practice of flap design and discussion on surface anatomy.

ICP probe insertion and EVD insertion also featured prominently on this list. This is also unsurprising as both these skills are frequently performed life-saving index procedures. In some centres in the UK and Ireland, the two procedures are performed independent of one another; however, other centres combine both approaches by transducing an EVD to obtain an ICP reading [27]. Given both procedures ranked second and third in our study, this suggests there is a degree of generalisability in our list. From a skill execution perspective using SBE, both procedures are typically performed via right frontal burr hole, following identification of Kocher's point. Therefore, a single simulation model perhaps may be used to accommodate practice of both procedures. The most common emergency pathology that requires EVD placement is acute hydrocephalus, which is typically associated with sizable ventricles [28], thus meaning the procedure is usually straightforward. However, EVD placement can be a hazardous procedure, and consistent practice during early training years through SBE can help accelerate the initial gradual skill acquisition phase in a safe learning environment [11]. Repeated practice during early training years goes some way to increasing fluency and ensuring trainees require fewer attempts to perform appropriate ventricular drain placement on patients, thus reducing the likelihood of repeated mispositioning [29] and subsequent complications such as infection and intraparenchymal hemorrhage [30]. A myriad of simulator modalities exist to accommodate practice of these techniques such as perfused cadaveric models [31], or commercial synthetic based models [19], and models that are deemed impactful but haven't yet undergone rigorous validity evaluation (Fig. 1).

Certain spinal and oncological procedures, including laminotomy, laminectomy, lumbar microdiscectomy, and excision of convexity meningiomas, ranked highly on the list and are considered appropriate for inclusion in advanced neurosurgical training. These tend to be more difficult cases, which are typically performed under supervision by mid-level trainees. Spinal anatomy is complex with high levels of surgical precision required in order to prevent dural, nerve and spinal cord injury (SCI). Complication rates, which encompassed open, microendoscopic (ME) and percutaneous approaches, varied from 10.8% to 12.5% in lumbar microdiscectomy patients [32]. Nerve root damage and exploratory work that started at the incorrect vertebral level are two of the contributory root causes. Intraoperative error may be reduced through the practice of these techniques on pig cadavers, as the anatomy is not too dissimilar to human, and can allow for practice of many of the steps involved in spinal surgical cases (Fig. 2). Its disadvantages include the lack of realistic muscle groups and fascicle to accurately portray separation of muscle through dissection for anterior approaches, as well as the requirement for bespoke licenced wet labs to allow practice. Synthetic simulation options exist, which are cost effective and have collated sufficient validation metrics to deem them useful in teaching and learning [33].

Supratentorial convexity meningioma resection is a common procedure on elective neurosurgical theatre lists, requiring the full breadth of competent microsurgical dissection skills to ensure full tumour devascularisation and detachment [34, 35]. Trainees at the later stages of their training are likely to be proficient in performing convexity craniotomies, so the development of high-fidelity task trainers should focus on simulating pre-existing cranial access where necessary, thereby omitting the craniotomy component, and simulating the remaining anatomy, such as the dura, associated vascular structures and the meningioma itself, for example. This would avoid learner cognitive overload and maximise the impact of these SBE sessions. This procedure climbed 10 places in the final subjective re-ranking phase, as the KOLs prioritised more prevalent potentially technically demanding neurological pathologies over less common ones. There is still a need for newly appointed neurosurgical consultants in tertiary centres to perform fundamental generalist procedural lists even in the face of the expanding tendency of sub-specialisation [36]. Our research findings are reflective of this.

While simulation models and modalities exist for every procedure on the final list, their effective integration into neurosurgical training requires a holistic approach that goes beyond mere availability. SBE should be strategically Integrated into existing neurosurgery curricula [14], making it mandatory and scheduling it alongside clinical rotations with protected time to attend. Without this, SBE may be deprioritised due to clinical duties. Training bodies must recognise SBE as essential and work with health service administration to balance service demands with educational needs, ensuring sustainable integration. Multi-institutional support is essential for overcoming barriers and integrating SBE into neurosurgical training [37]. Remote or virtual platforms [38], low cost educational tools and simulation models [16, 39, 40] and obtaining equipment loans through collaborations with industry partners can mitigates issues faced with cost and subsequently improve access in resource-limited programmes. Faculty training in simulation pedagogy is key for delivering quality performance feedback, targeted instruction and objective assessment [41–43]. Although many educators are experts in their clinical fields, effective simulation facilitation requires specialised pedagogical skills and instructional design expertise [44].

Conducting a general needs assessment of procedural skills for SBE in neurosurgery is the first step in curriculum development. SBE curricula will require some flexibility as neurosurgery training in the UK and Ireland is outcomes-based, meaning that some trainees reach particular competency milestones ahead of others. Further research is needed to complete targeted needs assessments [15], align training goals and objectives, and further refine educational strategies for SBE in neurosurgery. Researchers should leverage multi-jurisdictional approaches to develop standardised simulation-based training frameworks, enabling broader applicability across neurosurgical training programmes. For instance, curriculum developers aiming to thematically develop a trauma-related SBE programme for junior neurosurgical trainees, might consider some procedural skills such as positioning, pinning and flap design (1), burr hole haematoma evacuation (4), trauma flap craniotomy (7), EVD insertion (3) and ICP probe insertion (2). This sequence generally prioritises life-saving decompression first (burr hole or craniotomy), followed by CSF drainage through an EVD, and finally ICP monitoring to guide ongoing treatment.

Strengths and limitations

One strength is the methodology used in this study, which is a widely recognised and utilised framework for obtaining consensus in the sphere of surgical simulation training. A multi-jurisdiction consensus approach also allowed us to obtain a broader institutional level view from KOLs. However, our study has several limitations. We captured demographic data only from respondents of the first survey, and not from the remaining rounds. Snowballing sampling was used to recruit participants, due to the small and highly specialised target group, although this approach carries the risk of bias. Participants from 12 neurosurgical subspecialties were included, but epilepsy was not represented. Additionally, spinal and general neurosurgery made up significant contributions, which may have influenced the procedures prioritised in our final list. Although a sizable pool of participants was identified, the response rate remained low across all three rounds of the Delphi process. While this reflects the inherent challenges of recruiting neurosurgical experts, it may affect the generalisability of the findings. However, the consistency of responses across rounds suggests that consensus had stabilised, reinforcing the reliability of the expert opinions collected.. Lastly, the focus of this study was on acquiring technical skills. Postgraduate surgical education universally acknowledges the need of training surgeons in non-technical skills, a comparable study methodology should seek to identify the crucial soft skills needed by neurosurgery trainees at key junctures throughout training.

Conclusion

In this study, we utilised the CAMES-NAF to identify through consensus 47 neurosurgical procedures that should be prioritised for SBE. An emphasis was placed on more commonly occurring procedures, with a particular priority placed on acute cranial trauma care, degenerative spine, neuro-oncology and CSF diversion procedures.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-06922-4.

Supplementary Material 1: Appendix 1. Description of each phase of the CAMES-NAF utilised in this study.

Supplementary Material 2: Appendix 2. Raw list of procedures derived from JCST curriculum and brainstorming phase.

Supplementary Material 3.

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Authors' contributions
AR: Conceptualisation and design, Data curation, Data Collection, Analysis, Interpretation of results, Methodology, Writing – original draft, preparation, Writing – review & editing. DK: Conceptualisation, Data Collection, Interpretation of results, Writing – review & editing. DC: Data Collection, Analysis, Writing – original draft. VH: Data Collection, Writing – review & editing. GZ: Analysis, Writing – review & editing. LK: Writing – review & editing. LJN: Writing – review & editing. DZK: Analysis, Writing – review & editing. DM: Writing – review & editing. JFC: Writing – review & editing. CC: Writing – editing, statistical analysis. NM: Writing – review & editing. CMC: Conceptualisation and design, Analysis, Methodology, Writing – original draft, Writing– review & editing, Supervision.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The Royal College of Surgeons Ireland (RCSI) University of Medicine and Health Sciences' research ethics committee granted ethical permission through application 202212011, and all participants signed informed consent.

Consent for publication
Not required.

Competing interests
The authors declare no competing interests.

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