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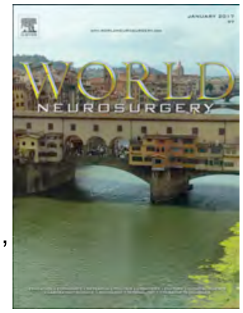

Defining Innovation in Neurosurgery: Results from an International Survey

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Abstract

Background:

Innovation is a part of the daily practice of neurosurgery. A clear definition of what constitutes innovation is currently lacking, however, and opinions vary from continent to continent, from hospital to hospital, and from surgeon to surgeon.

Methods:

In this study, we distributed an online survey to neurosurgeons from multiple countries to investigate what neurosurgeons consider innovative, by gathering opinions on several hypothetical cases. The anonymous survey consisted of a total of 52 questions and took approximately 10 minutes to complete.

Results:

A total of 355 neurosurgeons across all continents excluding Antarctica completed the survey. Neurosurgeons achieved consensus (>75%) in considering specific cases to be innovative, including laser resection of meningioma, focused ultrasound for tumor, oncolytic virus, DBS for addiction, and photodynamic therapy for tumor. Although the new dura substitute case was not considered innovative, there was consensus among neurosurgeons indicating that IRB approval was still necessary to maintain ethical standards. Furthermore, although 90% of neurosurgeons considered an oncolytic virus for GBM to be innovative, only 78% believed that IRB approval was necessary prior to treatment.

Conclusions:

Our results indicate that innovation is a heterogeneous concept among neurosurgeons that necessitates standardization to ensure appropriate patient safety without stifling progress. We discuss the ethical drawbacks of not having a clear definition of innovation, the current challenges in achieving a unified understanding of innovation in neurosurgery, and offer suggestions for uniting the field going forward.

Introduction

Innovation is at the heart of neurosurgery. In a continually evolving field, neurosurgeons must constantly assess and reassess the most appropriate and effective treatments for each patient. Innovation is conducted by neurosurgeons investigating novel treatments for brain tumors in major academic institutions, as well as those performing creative surgeries in low resource settings across the world.[1, 2] Yet, something so ubiquitous among neurosurgeons remains difficult to define with consensus. To this day, great heterogeneity exists in what surgeons consider innovative [3, 4]. Various interpretations of what constitutes innovation leads to a lack of standardization of assessing innovation across surgeons, departments, institutions, and nations. Additionally, proof of the innovative nature of a project is often a key component of securing grant funding; therefore, efforts to standardize what should be considered innovative could be beneficial to funding agencies.

Attempts to standardize the definition of innovation have been presented. The Society of University Surgeons has proposed discerning between variations, innovations, and research.[5] Some have suggested splitting innovations by type, such as minor modifications of standard procedures, major modifications of standard procedures, and innovations that are new to the institution but have been validated elsewhere.[6] Others have suggested a rating of surgical innovations directly related to the amount of oversight deemed necessary.[7] Despite these attempts, along with many other suggestions for appropriate oversight in surgery[8,9-16], a clear answer does not exist.

Lack of consistency in the general surgical literature warrants an investigation of what neurosurgeons themselves consider innovative. To this point, the definition of innovation has yet to be evaluated specifically among neurosurgeons. Using a survey consisting of hypothetical cases, this study aims to describe what neurosurgeons consider innovative. This study also discusses how the definition of innovation impacts aspects of patient care, influences appropriate oversight, and promotes effective collaboration in the field of neurosurgery.

Methods

Survey Development

An online survey was developed to identify trends in the opinions of neurosurgeons on the definition of innovation in the field. In total, the anonymous survey consisted of 52 questions, and took approximately 10 minutes to complete. Respondents could exit the survey at any point. Demographic data was collected from each respondent including sex, annual case volume, lifetime case volume, years of experience, type of practice, subspecialty, group size, and continent of practice.

Eleven hypothetical cases were written highlighting past and contemporary advances in neurosurgical instrumentation, methodology, or both. For each case, respondents were asked to select their opinion via Likert scale assessment (strongly disagree, disagree, neither disagree nor agree, agree, strongly agree) on the following statements: 1) This case is an example of innovation in neurosurgery; 2) By not having obtained some sort of approval from the IRB or an innovation committee for this case, the neurosurgeon violated ethical standard in this case; 3) Advancing the field of neurosurgery was valued more than individual patient care. Lastly, respondents were asked what type of innovation they considered each case: none, minor modification of a standard procedure, major modification of a standard procedure, or a radical innovation. Likert scales, rather than open-ended answers, were chosen to help foster a sense of consensus among a heterogeneous population. The eleven cases were chosen based on themes identified in recent neurosurgical literature, including technical and technological advances that were considered by the authors to include relatively minor to more radical advancements. These cases are listed in **Table 1**.

Survey Distribution

The survey was sent to members of the Committee on Ethics and Legal Affairs of the World Federation of Neurosurgical Societies (WFNS) and the Ethico-Legal Committee of the European Association of Neurosurgical Societies (EANS). Members were encouraged to distribute the survey within the departments of their respective home institutions. The survey was subsequently distributed to all individual members of the EANS. The overwhelming majority of responses was collected in the first week of distribution. A reminder was sent at two weeks after initial distribution. Following several days without incoming responses, the survey was then closed. Responses were collected from November 21, 2016 to December 30, 2016.

Data Analysis

Survey data was collected and analyzed in IBM SPSS Version 22 (IBM, Armonk, New York, USA, 2013). Nominal variables, including basic respondent demographics and Likert scale responses, were summarized using counts and percentages. Subsequent dichotomization of Likert scale responses was performed, such that one category ranged from strongly disagree to neither disagree nor agree, and another category included agree to strongly agree. In determining whether there was consensus of opinion, an a priori set value of 75% or more of respondents falling in either category was used as a cutoff for all questions in this study.

Results

Respondent Demographics

A total of 355 of approximately 1500 neurosurgeons (~23.7%) completed the survey, an expected response rate for this kind of questionnaire;[17] 85% were male, with respondents from all continents excluding Antarctica. Demographics and practice characteristics are summarized in **Table 2**. No significant demographic variables (including sex, annual or lifetime volume, experience, practice type, subspecialty, practice size, or continent of origin) were determined to influence how participants responded to the following questions (data not shown).

Question 1: This case is an example of innovation in neurosurgery.

Initial Likert scale responses to Question 1 and subsequent dichotomization are shown in Supplementary **Table 1** and **Figure 1**, respectively. Notably, cases 5, 6, 7, 8, and 10 were considered more innovative by neurosurgeons (≥75% indicated agree or strongly agree).

These cases corresponded to laser-resection of a meningioma, focused ultrasound for meningioma, viral injection into a tumor cavity, DBS treatment for addiction, and PTD for an irresectable glioma, respectively. Conversely, case 1 was rarely considered innovative (≤25% indicated agree or strongly agree). This case corresponded to the dura substitute.

Question 2: By not having obtained prior approval, ethical standards were violated. Likert scale responses to Question 2 are shown in Supplementary **Table 2**. Neurosurgeons generally responded that the virus for GBM in case 7 violated ethical standards without prior approval from an IRB or innovation committee. Although the dura substitute in case 1 was not considered innovative (**Table 3, Figure 1**), most neurosurgeons believed that ethical standards were violated by not seeking prior approval from IRB or an innovation committee (Supplementary **Table 2, Figure 2**). Finally, neurosurgeons predominantly (≥75%) did not believe that any ethical standards were breached in the endoscopic third ventriculostomy in case 4 nor using the new high-speed drill in case 11.

Question 3: Advancing the field of neurosurgery was valued more than individual patient care.
The survey responses for Question 3 are presented in Supplemntary **Table 3** and **Figure 3**. Neurosurgeons displayed a consensus (≥75%) that advancing the field of neurosurgery was not valued more than individual patient care in cases 4, 9, and 11, but these were just over the set threshold of 75%. These cases were the endoscopic third ventriculostomy, laser resection of meningioma, and the new high- speed drill, respectively. Before dichotomization, neither disagree nor agree was a common (20-30%) answer for almost every case.

Question 4: What type of innovation is this?
The results for Question 4 are presented in Supplementary **Table 4** and **Figure 4.** Considering consensus at 75%, cases 1, 2, 4, 9, and 11 fell were generally considered less innovative, while case 7 was generally considered more innovative. Cases 3, 5, 6, 8, and 10 showed less consensus.

Discussion

These findings indicate that, similar to other fields of surgery[18-20], neurosurgery lacks a clear consensus about what constitutes innovation. The varied responses shown here are likely a reflection of the complexity and lack of consensus in defining innovation and determining appropriate oversight for innovative procedures. For example, it is interesting to note that only 10% of respondents did not consider an oncolytic virus to be innovative, yet more than double this number at 22% of respondents did not believe an IRB or equivalent was necessary. Because this scenario is still considered experimental therapy, our findings may indicate a lack of consistency in educating neurosurgeons on ethical standards in investigative research across the globe.

The absence of finding demographic variables that significantly predicted responses could be influenced by insufficient power in this study. Nevertheless, having an unclear definition poses serious ethical and practical issues that warrant further discussion.

The Need for Standardizing a Definition

Ethically, physicians are called to do no harm. Rapid application before proper evaluation has historically led to compromising patient safety; for example, the ubiquitous use of frontal lobotomy before it was properly evaluated led to numerous undesired consequences.[21] Being able to *a priori* define what constitutes innovation would thus ensure appropriate evaluation of patient safety and ethical care before implementing an innovation into practice.

Often, the person introducing the innovation is the surgeon using the novel technique or device. In scenarios where the surgeon is the one who strongly believes in the promise of the innovation, innovator bias may prevent the surgeon from thoroughly evaluating the potential harms associated with the new intervention.[22] Such lack of perceived clinical equipoise, as well as other personal conflicts of interests are therefore just as important to be aware of as financial conflicts of interests.[23] Non-biased evaluation may help to limit the effect of such conflicts of interest in cases where a new idea is clearly defined as an innovation.

Furthermore, the principle of patient autonomy is contingent upon informed consent,[24] and it is controversial whether or not the consent patients provide in new surgeries is truly informed.[25] A key component of informed consent is that the relevant risks and benefits are disclosed to the patient, as well as the details of the procedure itself. If a new innovation is being implemented, in which the risks are unknown, the patient may not be truly informed to offer appropriate consent.[26] Even if certain patients tend to put full trust in their surgeon without knowing all of the details of the procedure,[27] it is important that all relevant information be available to the patient and the surgeon in order to make an informed decision plan. Again, knowing when to critically evaluate a novel innovation and when to simply use a new type of suture depends on how innovation is defined.

The principle of justice can also be explored, both in regard to over-enrolling vulnerable patient populations as well as under-enrolling patients from disadvantaged backgrounds. Because severely ill neurosurgical patients may not have the cognitive ability to adjudicate risks and benefits, as well as having a strong emotional drive to attempt any option feasible, these patients are susceptible to being easily persuaded into a novel treatment.[28] Regarding under-access, minority and low-income neuro-oncology patients have worse access to surgical care than Caucasian patients or those who have higher incomes, respectively.[29] Since many new innovations tend to be costly, low-income patients may not be able to access the latest and potentially most effective treatments.[30] Conversely, dangerous innovations may be forced onto minority populations as has occurred in Tuskagee.[31] Without a proper framework of innovation or appropriate oversight, these injustices are prone to exacerbation. Potentially compromising these core ethical principles thus necessitates a standard definition of innovation in order to promote ethical and practical patient safety.

The Difficulty in Defining Innovation in Neurosurgery

Innovations are not unique to neurosurgery. They occur in numerous medical specialties as well as every industry outside of medicine. In the business literature, innovations can broadly be categorized into sustaining and disruptive innovations.[32] Sustaining innovations improve an existing product and maintain the incumbent firm. One example can be the latest version of an existing smartphone. Disruptive innovations introduce a new firm that radically disturbs an existing industry, such as the effect of Uber on the taxi industry.[33] Businesses can predict the type of innovation something will be, because they use consumer reports and market predictions to guide the development and marketing of their products. Surgery, however, is not driven primarily by consumer requests and other market forces. It is guided by surgeon preference, patient outcomes, and peer review. [34] In addition to differences between business and medicine, innovation in surgery specifically varies from other fields of medicine.[27] Medical innovations, such as devices or new drugs, undergo a rigorous and thorough evaluation before they are approved for the clinical market. Once they are introduced, these innovations are believed to be safe and effective in achieving the desired effect. Thus, there is a clear border between research and clinical care in medicine. Surgery is more complicated. Since the Food and Drug Administration or an equivalent organization does not typically review the safety and efficacy of new surgical procedures, [35] it is noteworthy that research and clinical care are not mutually exclusive in surgical hypothesis testing. Surgical innovation in both the research and the clinical paradigm may contain untested novel ideas, [7] but innovation in research is aimed at generating generalizable knowledge,[36,37] while innovation in clinical care is aimed at improving the outcome of the individual patient.[36] When new surgical procedures are implemented in patients, generating universal knowledge thus coincides with the aim of ameliorating the suffering of the individual patient. Such overlap, along with the lack of oversight, has obfuscated a clear definition of innovation in the surgical field.

One recent attempt to quantify innovation in neurosurgery was accomplished by measuring the number of neurosurgical patents between 1960 and 2010. [38] One limitation of this approach is that it may severely underestimate the extent of innovation in neurosurgery by only focusing on patents, the overwhelming majority of which relate to solely technological innovations without including technical innovations or off-label use of existing patent technology.[39] Off-label use in particular helps delineate what may be considered innovative from what is considered research. For example, innovation can occur without an IRB or ethical board review when a clear and documented discussion between the physician and patient leads to informed consent of off-label use. Varying legislature allows these practices to occur in certain countries, and only when this off-label use is retrospectively analyses and presented is it considered research. Another difficulty in defining innovation is its temporal nature. When a new procedure or technology is initially introduced, its novelty can only diminish going forward. This progression is not linear, but rather goes through branching phases, from initially being studied to community-wide acceptance and subsequent refinement – a process termed progressive scholarly acceptance. [40]

Lack of definition: implications for oversight

As indicated, these results show that neurosurgeons do not agree on what constitutes innovation, and achieving a definition would allow appropriate regulation. Some fear that oversight may stifle innovation and the continual advancement of surgery;[41] however, appropriate oversight that balances patient safety and the surgeon's autonomy is the goal. Many proposals have been suggested for achieving appropriate oversight in cases where deviations from the norm take place, whether they be technical or technological deviations. We have previously reviewed[6] the proposals for various types of innovations, including those which suggest national regulation for major modifications or radical innovations[42] as well as those that suggest an institutional surgical innovation committee (SIC).[22,43,44]

The first step in determining appropriate oversight for an innovative surgery is to determine which operations require an evaluation. On one extreme, every operation may be considered a deviation from the norm as surgeons tailor their operations to the uniqueness of each presentation.[34] However, it would be impractical and inefficient to evaluate every deviation from the norm. The Macquarie Surgical Innovation Identification Checklist (MSIIT) has been introduced as a simple checklist that is currently being tested in its ability to identify when a procedure qualifies as "innovative".[45] It suggests that scenarios where the techniques, instruments, and/or devices used are new to the hospital or new to the surgeon should acquire further information regarding necessary training, patient communication, and an evaluation of past use of the novelty elsewhere. If a technique, instrument, and/or device is being used for a new indication, in a sex or age where such differences or comorbidities are relevant, the MSIIT suggests that further information should be acquired regarding potential consequences of the innovation, whether such outcomes are publishable, and whether special preparations should be put in place to accommodate the innovation. The value of the MSIIT is not that it seeks to create stringent criteria for what constitutes innovation, but rather aims to identify which surgical procedures warrant further information and oversight when necessary. Another noteworthy endeavor is the IDEAL (Idea, Development, Exploration, Assessment, Long-term follow up) collobaration,[46] which seeks to discuss appropriate oversight at all stages of innovation. It includes suggestions such as a negative database of failed ideas, mandating detailed technical descriptions of novel approaches, exploring the learning curve of new innovations, expanding and assessing the innovation in multi-center trials, and finally monitoring long term outcomes. Recent review of two neurosurgical procedures, namely the endoscopic endnoasal approach for skull base meningiomas and the WovenEndobridge for endovascular treatment of intracranial aneurysm, suggest that the process of innovation does not currently follow the path outlined in the IDEAL framework,[47] emphasizing the need for more appropriate oversight.

After identifying which procedures warrant further oversight, the regulation that is deemed appropriate could be determined by an SIC. An SIC may be comprised of experienced surgeons, ethicists, engineers, and other relevant stakeholders. When a new technique or device is being introduced, the SIC can critically evaluate the scientific validity of the proposal, ensure that the patient if truly informed about all known risks and the novelty of the procedure, and confirm that the necessary adaptations to the novel procedure are made available to the surgeon. When an innovation has been proven effective, there will be a learning curve that must be overcome before other colleagues are able to effectively incorporate it into common practice.[48,49] SIC's can serve as facilitators that connect experiences surgeons with similar ideas and experiences to foster educational dialogue between colleagues.

Overall, surgical innovation is a ubiquitous phenomenon that remains poorly defined. Without a proper definition, patient safety and ethical care are at risk. Despite the difficulties in producing an exact definition of surgical innovation, programs that facilitate critical feedback and opportunities for experienced surgeons to share their knowledge[50] would promote an environment conducive to collaborative learning and appropriate patient safety.

Strengths and Limitations

This is the first survey of its kind to acquire the opinions of hundreds of neurosurgeons from numerous continents. It shows that neurosurgery, like many other fields of surgery, does not have a universal definition of innovation. This paper discusses the ethical and practical concerns associated with not having a unified definition and offers suggestions to overcome barriers in place.

Although these results were created based on response from 355 respondents, 75% of the respondents are based in Europe. Further surveys should involve larger numbers of respondents from other continents in order to determine if opinions vary based on respective continental and national regulations. Additionally, 68% of respondents are from academic institutions and thus may have underlying user bias in assessing what constitutes innovation. Another limitation is that first-hand experience with innovation was not directly inquired about in the respondent demographics, which may have also revealed bias in the responses. Furthermore, the cases present a limited spectrum of innovation as these cases can be considered possible extensions of current surgical practices, rather than genuinely novel approaches or treatments. Finally, although this study discusses the necessity for a unified definition of innovation in neurosurgery, it does not present a clear-cut algorithm that can be applied to determine if a new idea qualifies a surgical innovation. Further studies could elicit possible definitions from neurosurgeons first-hand, how common innovation is seen in their respective practices, and the factors involved in surgeons deciding to adopt innovative practices.

Conclusion

This study indicates that neurosurgeons lack a clear definition of innovation. This lack of consensus poses practical and ethical concerns relevant to appropriate oversight of innovative procedures. Surgeons should actively seek critical feedback on new ideas from peers and relevant stakeholders in a collaborative environment. In the future, appropriate steps should be taken to define innovation in neurosurgery so that neurosurgeons can use innovation to advance the field of neurosurgery without the risk of compromising patient safety.

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Figure Legends

Figure 1. Survey Responses to Question 1: This case is an example of innovation in neurosurgery.

Figure 2. Survey Responses to Question 2: By not having obtained prior approval, ethical standards were violated.

Figure 3. Survey Responses to Question 3: Advancing the field of neurosurgery was valued more than individual patient care.

Figure 4. Survey Responses for Question 4: What type of innovation is this case?

Table 1. Case Descriptions

Case Number	Topic	Description
1	Dura Substitute	A patient undergoes a craniotomy for a convexity meningioma. When closing, the neurosurgeon uses a dura substitute that has never been used in patients, and the only safety and efficacy data available are from animal studies
2	Supramaximal Resection	A patient with recurrent high-grade glioma presents for surgery. The surgeon uses a supra-maximal technique for resection, removing all of the contrast-enhancing tissue as well as some surrounding tissue, with the hope of delaying or preventing recurrence or tumor progression.
3	New Vascular Balloon Device	A patient presents with carotid stenosis and a family history of stroke. Instead of undergoing a carotid endarterectomy, the patient is treated with balloon angioplasty. This is the first time this device will be used in patients.
4	Endoscopic Third Ventriculostomy	A patient requires endoscopic third ventriculostomy. During the case, the surgeon employs the use of a new catheter to create the opening in the floor of the third ventricle. This catheter has been used for other indications.
5	Laser resection of meningioma	A surgically-accessible meningioma is resected using a thulium laser instead of traditional resection. The laser has been used for other indications in humans, however not for this purpose.
6	Focused Ultrasound	A patient presents with a skull-base meningioma. Rather than attempting traditional resection, the surgeon employs focused ultrasound therapy.
7	Virus for GBM	A patient with glioblastoma multiforme (GBM) undergoes surgical resection. Following resection, the tumor cavity is injected with modified adenovirus in an attempt to stimulate the host immune system against any remaining GBM cells.
8	DBS for Addiction	A patient with a 10-year history of opioid addiction presents for therapy. The surgeon decides to use DBS to stimulate the nucleus accumbens, in the hope of alleviating the patient's addiction.
9	New Pedicle Screws	A patient requires lumbar laminectomy and fusion. The surgeon uses new pedicle screws that are claimed to reduce post-operative pain.
10	Photodynamic Therapy	A patient presents with an irresectable malignant glioma. A biopsy using 5-ALA is performed. Upon biopsy, the surgeon leaves a light source in place for a few days with the aim to kill remaining tumor cells.
11	New High-Speed Drill	A patient requires a transsphenoidal approach for resection of a pituitary adenoma. During the opening of the sella, the surgeon uses a new drill whose manufacturers claim it reduces the risk of lesioning the surrounding structures.

Table 2. Respondent demographics and practice characteristics.

Sex		Percentage (%)
	Male	85
	Female	15
Annual Volume		
	<50	6
	501-100	14
	101-200	26
	201-300	28
	301-400	11
	401-500	5
	>500	10
Lifetime Volume		
	<500	11
	501-1000	15
	1001-2000	20
	2001-3000	13
	3001-4000	10
	4001-5000	10
	5001-10000	14
	>10000	8
Experience		
	In residency	22
	<5 years out	26
	6-10 years out	18
	11-20 years out	19
	21-30 years out	9
	>30 years out	7
Practice Type		
	Academic	68
	Private Practice	12
	Neither	20
Specialty		
	Pediatrics	6
	Functional	3
	CV	12
	Tumor	22

	Spine	17
	Trauma	3
	General (None)	38
Practice Size		
	1-2 neurosurgeons	11
	3-5 neurosurgeons	21
	6-10 neurosurgeons	35
	11-15 neurosurgeons	19
	>15 neurosurgeons	14
Continent		
	NA	4
	SA	2
	Europe	75
	Africa	7
	Asia	12
	Australia	0.3

Note that cells contain % of total responses

Supplementary Table 1. "This case is an example of innovation in neurosurgery."

	SD	D	N	A	SA
Dura Substitute	28	38	13	19	2
Supramaximal Resection	11	42	19	22	6
New Vascular Balloon Device	7	16	11	52	14
Endoscopic Third Ventriculostomy	4	14	15	59	8
Laser resection of meningioma	3	8	9	66	14
Focused Ultrasound	7	10	8	54	21
Virus for GBM	1	4	5	45	45
DBS for Addiction	1	4	13	58	24
New Pedicle Screws	5	18	20	50	7
Photodynamic Therapy	2	12	11	51	24
New High-Speed Drill	4	22	21	47	6

Note that cells contain % of total responses
SD: Strongly Disagree, D: Disagree, N: Neither disagree nor agree, A: Agree, SA: Strongly Agree

Supplementary Table 2. "By not having obtained some sort of approval from the IRB or innovation committee for this case, the neurosurgeon violated ethical standards."

	SD	D	N	A	SA
Dura Substitute	2	6	9	43	40
Supramaximal Resection	12	44	18	18	8
New Vascular Balloon Device	2	12	18	42	26
Endoscopic Third Ventriculostomy	8	49	24	16	3
Laser resection of meningioma	3	27	24	35	11
Focused Ultrasound	3	16	13	41	27
Virus for GBM	3	8	11	29	49
DBS for Addiction	1	12	23	35	29
New Pedicle Screws	7	42	21	23	7
Photodynamic Therapy	1	13	16	41	29
New High-Speed Drill	14	47	21	15	3

Note that cells contain % of total responses
SD: Strongly Disagree, D: Disagree, N: Neither disagree nor agree, A: Agree, SA: Strongly Agree

Supplementary Table 3. "Advancing the field of neurosurgery was valued more than individual patient care."

	SD	D	N	A	SA
Dura Substitute	9	21	22	36	12
Supramaximal Resection	13	37	23	22	5
New Vascular Balloon Device	5	24	26	34	11
Endoscopic Third Ventriculostomy	7	37	32	22	2
Laser resection of meningioma	7	25	27	35	6
Focused Ultrasound	5	22	22	38	13
Virus for GBM	5	22	19	33	21
DBS for Addiction	4	21	31	32	12
New Pedicle Screws	9	37	31	19	4
Photodynamic Therapy	4	24	26	33	13
New High-Speed Drill	11	39	28	19	3

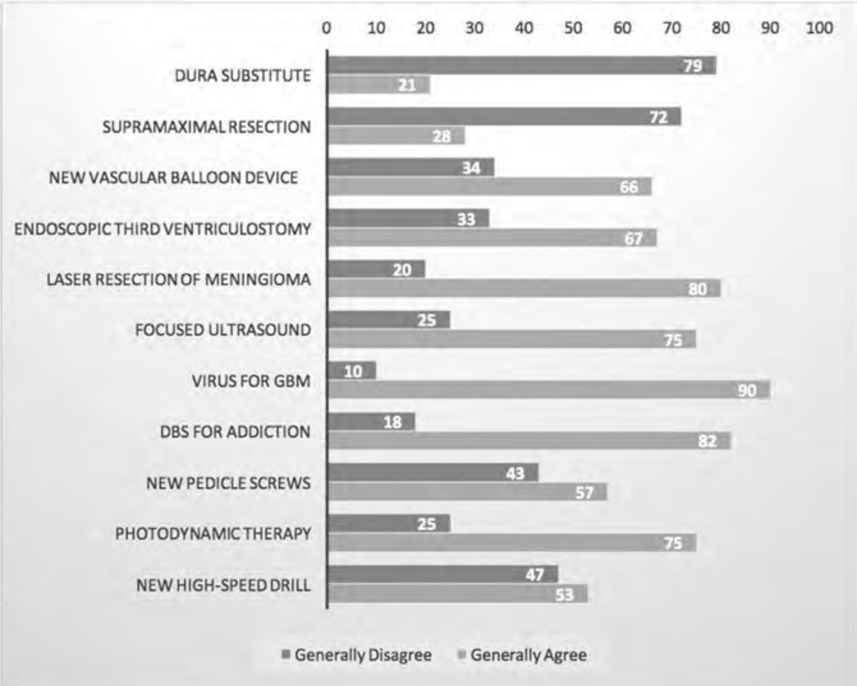
Note that cells contain % of total responses
SD: Strongly Disagree, D: Disagree, N: Neither disagree nor agree, A: Agree, SA: Strongly Agree

Supplementary Table 4. "What type of innovation is this?"

	Not a type of innovation	Minor Modification	Major Modification	Radical Innovation
Dura Substitute	47	44	7	2
Supramaximal Resection	43	40	15	2
New Vascular Balloon Device	20	25	37	18
Endoscopic Third Ventriculostomy	15	75	10	0
Laser resection of meningioma	10	35	39	16
Focused Ultrasound	15	14	26	45
Virus for GBM	5	9	29	57
DBS for Addiction	7	19	35	39
New Pedicle Screws	22	66	9	3
Photodynamic Therapy	14	14	33	39
New High-Speed Drill	31	59	8	2

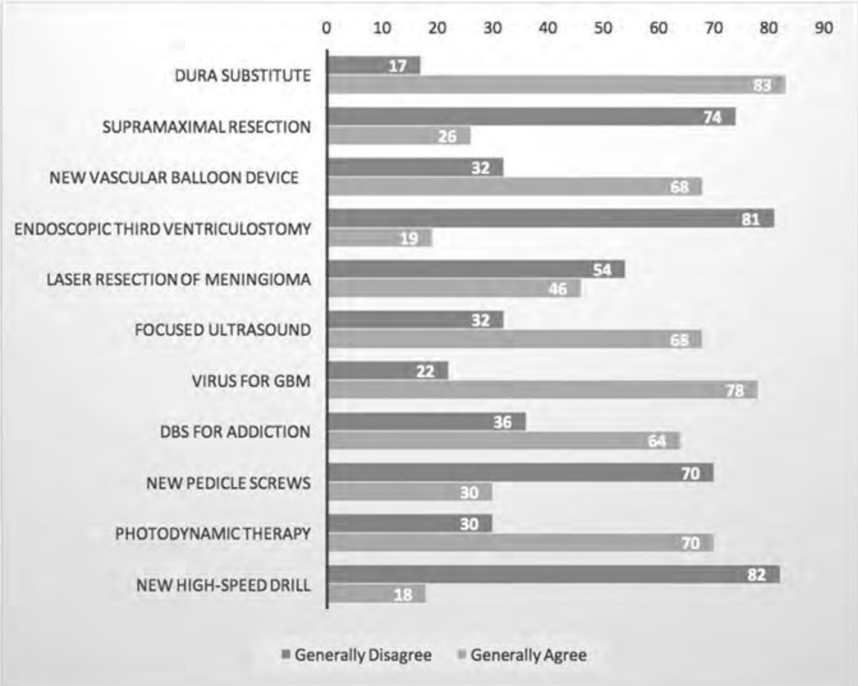
Note that cells contain % of total responses

Figure 1. Survey Responses to Question 1: This case is an example of innovation in neurosurgery.



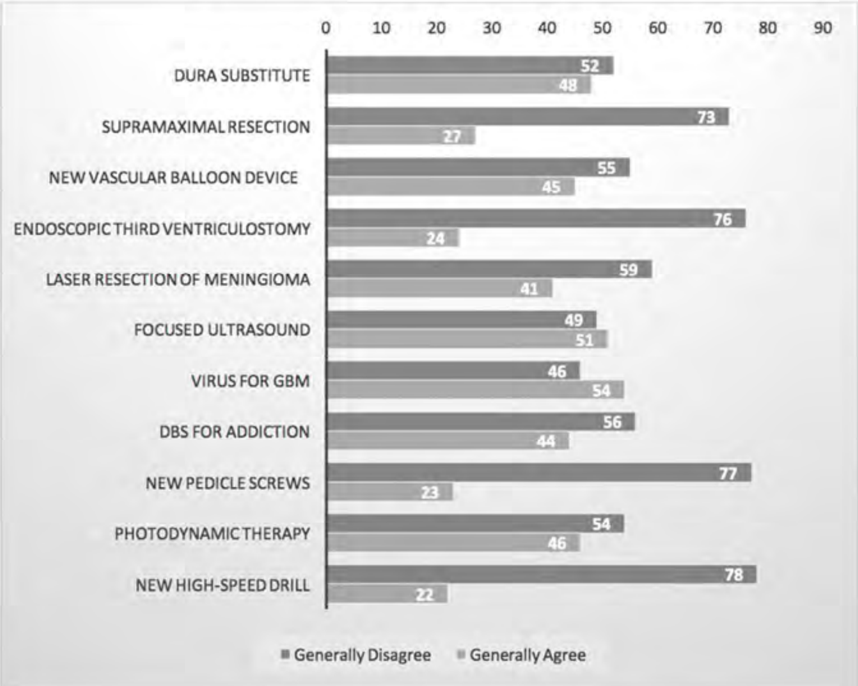
Note that Generally Disagree includes "neither disagree nor agree"

Figure 2. Survey Responses to Question 2: By not having obtained prior approval, ethical standards were violated.



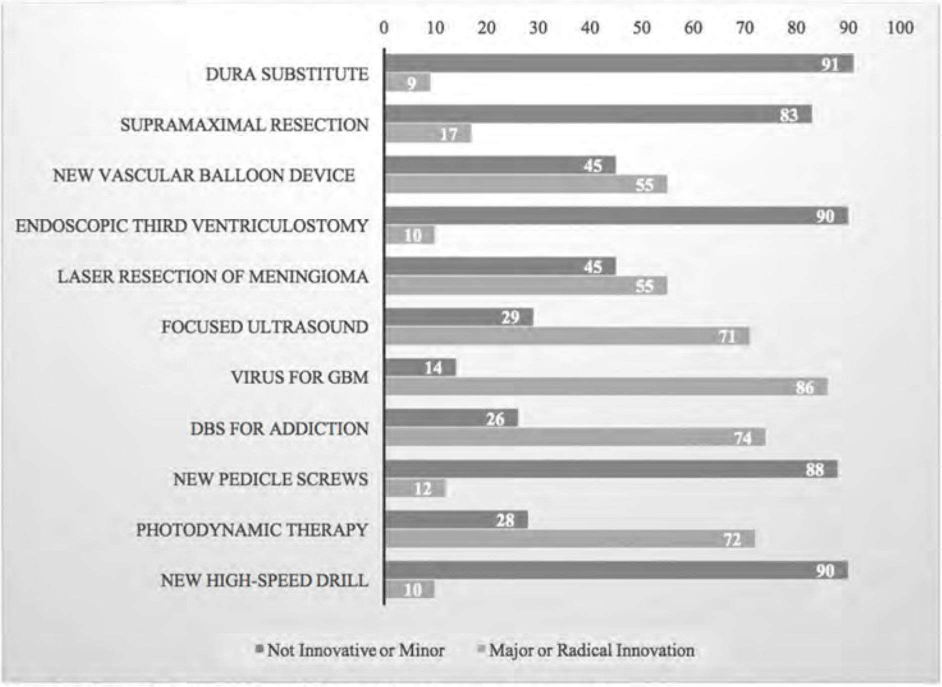
Note that Generally Disagree includes "neither disagree nor agree"

Figure 3. Survey Responses to Question 3: Advancing the field of neurosurgery was valued more than individual patient care.



Note that Generally Disagree includes "neither disagree nor agree"

Figure 4. Survey Responses for Question 4: What type of innovation is this case?



Note that Generally Disagree includes "neither disagree nor agree"

Highlights

- A definition of innovation in neurosurgery is currently lacking
- There is wide heterogeneity of opinion among neurosurgeons on what constitutes innovative procedures
- There are significant ethical implications in the absence of a clear definition
- Steps should be taken to help identify which innovations warrant further oversight without stifling scientific progress

Abbreviations

DBS, Deep Brain Stimulation; EANS, European Association of Neurosurgical Societies; GBM, Glioblastoma Multiforme; MSIIT, Macquarie Surgical Innovation Identification Checklist; PTD, Photodynamic therapy; SIC, Surgical Innovation Committee; WFNS, World Federation of Neurosurgical Societies

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