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Educational Status of Minimally Invasive Spine Surgery

Situação educacional da cirurgia minimamente invasiva da coluna

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Introduction The objective of this study was to understand how spine surgeons learn minimally invasive spine surgery (MISS) and how the COVID-19 pandemic impacted the educational experience of MISS. Potential solutions for increasing the spine surgeon's access to MISS educational resources were also discussed.

Methods An internet survey was distributed to neurosurgical and orthopedic spine surgeons across multiple online platforms from April to June 2021, asking specific questions about education and training for MISS. Online survey tools were used to contact spine surgeons in the five geographical continents.

Keywords

Abstract

- MISS
- ► spine surgery
- minimally invasive surgery
- cadaver-laboratory
- online education
- ► COVID-19

Results A total of 303 spine surgeons responded to the survey: 272 (89.7%) neurosurgeons and 31 (10.3%) orthopedic surgeons. The six countries with the greatest number of participants were: Argentina (n = 70; 23.1%), India (n = 47; 15.5%), Brazil (n = 34; 11.2%), Pakistan (n = 10; 3.3%), Mexico (n = 9; 3.0%), and Chile (n = 8; 2.6%). Conclusion Most spine surgeons were able to attend virtual learning events during the pandemic, but cadaveric study was still considered the gold standard for learning MISS. Multidisciplinary effort is needed to develop structured curriculums for teaching MISS that include a variety of educational tools such as cadaver laboratory, guidance from experienced surgeons, and virtual demonstrations.

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Palavras-chave	Introdução O objetivo desse estudo foi entender como os cirurgiões de coluna aprendem técnicas minimamente invasivas e como a pandemia de COVID-19 impactou essa atividade. Soluções em potencial para aumentar o acesso a ferramentas educa- cionais de cirurgia minimamente invasiva são discutidas. Métodos Uma pesquisa realizada na internet para neurocirurgiões e ortopedistas em múltiplas plataformas on-line de abril a junho de 2021, perguntando especificamente questões sobre o estado educacional e de treinamento em cirurgia minimamente invasiva de coluna. Plataformas online específicas foram utilizadas para alcançar cirurgiões de coluna nos cinco continentes geográficos. Resultados Um total de 303 cirurgiões de coluna responderam à pesquisa: 272 (89,7%) neurocirurgiões e 31 (10,3%) ortopedistas. Os seis países com os maiores números de respostas foram: Argentina (<i>n</i> = 70; 23,1%); Índia (<i>n</i> = 47; 15,5%); Brasil (<i>n</i> = 34; 11,2%), Paquistão (<i>n</i> = 10, 3,3%), México (<i>n</i> = 9; 3,0%) e Chile (<i>n</i> = 8; 2,6%).
 cirurgia de coluna minimamente invasiva treinamento online COVID-19 pandemia cadáver 	Conclusão A maioria dos respondentes foi capaz de frequentar cursos online durante a pandemia, porém cursos cadavéricos ainda são considerados o padrão-ouro para o aprendizado de técnicas minimamente invasivas. Um esforço multidisciplinar será necessário para desenvolver um currículo estruturado que inclua uma variedade de ferramentas educacionais como laboratório cadáver, tutoria por pares mais experientes e demonstrações virtuais.

Introduction

Minimally invasive spine surgery (MISS) is attracting interest as a feasible alternative to open surgery, with benefits such as decreased blood loss, less soft tissue and muscle injury, lower rates of surgical site infections, and reduced length of hospital stay.^{1,2,3} Interest in MISS is increasing steadily not only among spine surgeons but also among patients. In a prospective survey, up to 80% of the patients reported a preference for MISS should the need of a spine surgery arise at a later date.⁴ Recently, there has been substantial advancements in MISS technology including specific retractor systems (portals), coupled with illumination, microscopes and endoscopes for magnification, and 3D navigation imaging techniques. These improvements in technology, along with increased learning opportunities-such as cadaver courses and laboratorieshave equipped spine surgeons with tools to develop their skills and become more familiar with the philosophy and approaches of MISS. This technique has also been touted as less costly, with more economic value than open techniques, especially in developed countries.^{5,6,7} However, there is still ambiguity as to whether this is true for all spine procedures.⁸ Given the high cost and steep learning curve for implementing MISS into routine spine surgery practices, we sought to better understand its current status. Therefore, we presented an internet survey to both neurosurgical and orthopedic spine surgeons across various online platforms to examine their practice regarding the use of MISS surgical techniques, as well as access to educational resources and availability of instruments for learning. We also aimed to identify potential bottlenecks for the worldwide adoption and patient access to it.

The detailed objective of this study was to understand how spine surgeons learn and practice MISS, as well as how the COVID-19 pandemic impacted this activity. We also discussed potential solutions to increase the spine surgeons' access to educational resources.

Materials and Methods

This cross-sectional study was performed using an online survey consisting of 23 questions via Google Forms (Google LLC., Alphabet Inc., Mountain View, CA, USA). The Google form was accessible through a hyperlink from April 21 to June 8, 2021. The questionnaire was designed in the English language and distributed to neurosurgical and orthopedic spine surgeons. Four social media platforms were used to contact spine surgeons in six geographical continents (North and South America, Europe, Africa, Asia, and Oceania): Facebook (Facebook Inc; Menlo Park, CA, USA), LinkedIn (Microsoft Corp., Sunnyvale, CA, USA), WhatsApp (Facebook Inc., Menlo Park, CA, USA), and Telegram (Telegram Messenger LLP., London, United Kingdom). The survey was posted in various forums that were created exclusively for topics related to neurosurgery and spine surgery (i.e., clinical cases) in the prior listed platforms.

Survey

Questions in the survey were related to spine surgeon demographics (country and city of practice), age, years of practice, features of their respective institutional features (number of members on team), specialty, types of surgeries more frequently performed (decompression vs. fusion), as well as specific questions regarding MISS, such as surgery experience, access to technology, access to educational training, types of approaches learned and comfortably performed, opinion about preferred educational strategies for

Question	IS
1	Do you provide consent for this survey? The responses collected here can be used for statistical analysis, research purposes, and to guide actions toward a better learning environment?
2	What is your specialty?
3	Please select the country that you work in:
4	Please mention the city where you work:
5	What is your age?
6	What is the current duration of your experience in neurosurgery (in completed years)?
7	What kind of set up are you working in?
8	How many neurosurgeons are there in your team?
9	What percentage of your total practice is related to spinal disorders?
10	What percentage of your total spine practice is via MISS approach?
11	How much of your spine practice involves fusion?
12	How much of your fusions are via MISS approach?
13	Are minimally invasive spine surgery (MISS) instruments, tools and apparatus being usually available to you?
14	Did you ever had an opportunity to be trained in a MISS spine case? You can check more than one box.
15	How often do you attend cadaver-lab?
16	Before the COVID-19 pandemic, how often did you use to travel to other countries with the objective of attending MISS spine course or cadaver-lab?
17	Have you ever attended virtual MISS teaching?
18	What do you think is the gold standard for MISS learning?
19	Who funded your MISS teaching? Can check more than one option.
20	Do you think practice in cadaver is important before doing a real case?
21	Which all of these procedures are you trained at?
22	Which all of these procedures do you perform independently?
23	How do you think the COVID-19 pandemic affected your ability to learn MISS?

Table 1 List of 23 questions included in the online questionnaire

Abbreviation: COVID-19, coronavirus disease 2019; MISS, minimally invasive spine surgery.

learning the related techniques, and opinion about how COVID-19 impacted access to education. **-Table 1** shows the survey questionnaire.

Analysis

The answers from the survey were analyzed based on different aspects: neurosurgical versus orthopedic spine surgeons; geographical location of the practicing surgeon; institutional setup (government vs. private); and age of the surgeon. Countries located in Central America (Caribbean Islands and Continental countries) were all considered in the North American analyses. Responses from participants who did not provide consent for use of their data in the present manuscript were excluded from analysis. The statistical analysis was performed using R language v 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).⁹ Categorical data were expressed as percentages, while continuous data were expressed as means with standard deviation (SD). Categorical data were analyzed using the Chi-Square test or the Fisher exact test, wherever indicated. If the continuous data met the condition of normality, then the Student *t*-test or analysis of variance (ANOVA) was implemented; otherwise, nonparametric counterparts were used. A p-value < 0.05 was considered statistically significant.

Results

A total of 308 spine surgeons answered the survey during the aforementioned time period. Of those, 5 (1.6%) did not give their consent to utilize their answers for research purposes, so they were excluded from the analysis. Hence, the responses of 303 participants were included in the present study.

Demographics

Out of the 303 respondents included in this study, 272 (89.7%) were neurosurgeons and 31 (10.3%) were orthopedic spine surgeons. Age of the respondents ranged from 23 to 70 years old (mean: 40.83 ± 8.75). The six countries with greatest number of participants were Argentina (n = 70; 23.1%), India (n = 47; 15.5%), Brazil (n = 34; 11.2%), Pakistan (n = 10; 3.3%), Mexico (n = 9; 3.0%) and Chile (n = 8; 2.6%). All countries included in the survey, with their respective number of participants, are summarized in **-Table 2** and **-Fig. 1**.

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n = 129 (42.6%)	70 (23.1%)	3 (1.0%)	34 (11.2%)	8 (2.6%)	4 (1.3%)	1 (0.3%)	5 (1.6%)	1 (0.3%)	3 (1.0%)												
South America	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Peru	Uruguay	Venezuela												
n = 1 (0.3%)	1 (0.3%)																				
Oceania	Australia																				
n = 23 (7.6%)	2 (0.6%)	3 (1.0%)	1 (0.3%)	9 (3.0%)	2 (0.6%)	1 (0.3%)	5 (1.6%)														
North America	Dominican Republic	Guatemala	Honduras	Mexico	Panama	Trinidad & Tobago	United States														
n = 29 (9.6%)	1 (0.3%)	1 (0.3%)	5 (1.6%)	5 (1.6%)	1 (0.3%)	1 (0.3%)	2 (0.6%)	7 (2.3%)	1 (0.3%)	1 (0.3%)	2 (0.6%)	2 (0.6%)									
Europe	Austria	France	Germany	Italy	Poland	Portugal	Romania	Russia	Spain	Switzerland	Ukraine	United Kingdom									
<i>n</i> = 104 (34.3%)	1 (0.3%)	6 (2.0%)	47 (15.5%)	1 (0.3%)	2 (0.6%)	4 (1.3%)	2 (0.6%)	1 (0.3%)	2 (0.6%)	10 (3.3%)	2 (0.6%)	1 (0.3%)	7 (2.3%)	4 (1.3%)	2 (0.6%)	2 (0.6%)	6 (2.0%)	1 (0.3%)	2 (0.6%)	1 (0.3%)	
Asia	Afghanistan	Bangladesh	India	Indonesia	Iraq	Jordan	South Korea	Lebanon	Nepal	Pakistan	Philippines	Qatar	Saudi Arabia	Syria	Taiwan	Thailand	Turkey	United Arab Emirates	Uzbekistan	Vietnam	
n = 17 (5.6%)	1 (0.3%)	5 (1.6%)	1 (0.3%)	1 (0.3%)	3 (1.0%)	1 (0.3%)	2 (0.6%)	3 (1.0%)													
Africa	Botswana	Egypt	Ethiopia	Mauritius	Nigeria	South Africa	Sudan	Zambia													

Table 2 Countries from which survey respondents originate

Abbreviation: n, number of respondents (%).

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Fig. 1 World map of countries from which survey respondents originate.



Fig. 2 2D pie charts showing distribution of answers to questions 6 and 7 about demographics.

It is important to highlight that 34 (11.5%) of the respondents were residents in-training, 91 (30.0%) had up to 5 years of post-residency practice, 67 (22.1%) had 6 to 10 years of practice, 67 (22.1%) had 11 to 20 years of practice, 31 (10.2%) had 21 to 30 years of practice, and 13 (4.2%) had more than 30 years of practice (Fig. 2). Furthermore, 165 (54.4%) of the contributors worked at a government institution or teaching hospital, while 138 (45.5%) of respondents worked at private institutions (**Fig. 2**). A significantly larger number of participants affiliated with government institutions was observed in Africa (n = 16, 94.1% vs. n = 1, 5.88%) and Europe (n = 24, 82.7% vs. n = 5, 17.2%) compared with those working in private institutions (p < 0.0001). The mean and SD of members in the surgical team was 11.7 ± 17.9 in Africa, 6.1 ± 6.2 in Asia, 12 ± 8.4 in Europe, 4.4 ± 5.9 in North America, and 6.0 ± 6.9 in South America. The mean and SD

of members in the surgical team was 9.2 ± 9.7 for government institutions, and 3.9 ± 3.4 for private institutions (p = 0.0002).

Spine Practice

Regarding medical practice, 30 respondents (10%) reported 100% of their total practice relating to spine disease; 64 (21%) reported 76% to 99%; 97 (32%) reported 51% to 75%; 79 (26%) reported 26% to 50%; and 33 (11%) reported less than 25% (**-Fig. 3**). Furthermore, 6 respondents (2%) reported 100% of their spine-related procedures involving a MISS approach; 30 (10%) reported 76% to 99%; 37 (12%) reported 51% to 75%; 64 (21%) reported 26% to 50%; and 167 (55%) reported less than 25% of spine-related procedures involving MISS (**-Fig. 3**). As for spine-related procedures involving fusion, 3 respondents (1%) reported 100%; 12 (4%) reported 76% to 99%; 70 (23%)



Fig. 3 2D pie charts showing distribution of answers to questions 9, 10, 11, and 12 about spine surgery practice.

reported 51% to 75%; 121 (40%) reported 26% to 50%; and 97 (32%) reported less than 25% (**~ Fig. 3**). Finally, 6 respondents (2%) reported 100% of their spine fusions being performed via MISS; 18 (6%) reported 76% to 99%; 33 (11%) reported 51% to 75%; 33 (11%) reported 26% to 50%; and 212 (70%) reported less than 25% of spine fusions being performed via MISS (**~ Fig. 3**).

MISS Training

When surgeons were asked about availability of MISS instruments, tools, and apparatuses in their practices, 28.9% had easy access, 25.6% experienced minor obstacles that did not dramatically impair access, 23.7% faced major obstacles, and 21.8% reported rare or no access at all. Whereas 58.6% of spine surgeons in Europe reported easy access to MISS instruments, only 5.9% of spine surgeons in Africa reported easy accessibility (p = 0.0003). Among the respondents who used MISS for less than 25% of their spine cases, only 14.9% (n = 25) had easy access to a related apparatus. On the other hand, among the respondents who used MISS for 76% to 99% of their spine cases, 62% (n = 18) had easy access to the necessary apparatus (p < 0.0001).

When asked about opportunities for training in MISS spine cases, 146 spine surgeons (48.1%) attended a cadaver laboratory, 83 (27.3%) attended a spine bony model demonstration, 105 (34.6%) attended an instrument workshop, 77 (25.4%) attended an online virtual demonstration, 95 (31.3%) learned while assisting a more experienced surgeon during a live case, 63 (20.7%) learned during residency, 39 (12.8%) learned during fellowship, and 66 (22.1%) never had an opportunity to train in MISS.

Regarding frequency of attending cadaver laboratory for learning MISS techniques, 15 participants (4.9%) reported attending every 6 months, 89 (29.3%) at least once a year, 123 (40.5%) at least once in the last 5 years, 28 (9.2%) at least once in the past 10 years, and 16 (5.2%) reported no attendance at a cadaver laboratory in the last 10 years.

When asked how often participants traveled to other counties for educational purposes of learning MISS techniques (cadaver laboratory and/or specialized course) before the COVID-19 pandemic, 39 (12.8%) answered every 6 months, 81 (26.7%) at least once a year, 91 (30.0%) at least once in the last 5 years, 23 (7.5%) at least once in the past 10 years, and 69 (22.7%) had not traveled in the past 10 years. Only 11.7% of participants from Africa used to travel every year compared with 34.4% and 37.7% in Europe and South America, respectively (p < 0.0001). Only 7.7% of participants from South America had not traveled to other countries in the past 10 years for the purposes of learning MISS techniques, compared with 64.7% from Africa (p < 0.0001).

Respondents were also asked if they ever attended a virtual MISS teaching event, as well as their opinion about the event's utility: 83 spine surgeons (27.3%) reported prior attendance and perceived them as useful, 95 (31.3%) reported prior attendance and perceived them as somewhat useful, 10 (3.3%) reported prior attended but did not perceive them as useful, 69 (22.7%) reported no prior attendance but perceived them as useful, 34 (11.2%) reported no prior attendance and perceived them as somewhat useful, and 12 (4.0%) reported no prior attendance and perceived them as not useful.



Fig. 4 Radar plot showing distribution of learning opportunities for training in MISS.

When asked about what educational platform should be the gold standard for learning MISS techniques, 155 spine surgeons (51.1%) preferred the cadaver laboratory, 134 (44.2%) preferred ongoing live cases with patients and more experienced surgeons, 7 (2.3%) preferred bony model demonstrations, 6 (1.9%) preferred workshop demonstrations, and only 1 (0.3%) preferred virtual demonstrations (**- Fig. 4**).

The question "Who funded your MISS teaching?" allowed respondents to select more than one option. Here, the answers were: 208 (68.6%) self-funded, 55 (18.1%) institution-funded, 33 (10.8%) government-funded, 67 (22.1%) partially industry-funded, and 16 (5.2%) fully-industry funded.

When asked about the importance of practicing in cadaver laboratory before performing a live case, 186 spine surgeons (61.4%) thought this was an essential part of MISS learning, 95 (31.3%) thought that this was important but not essential, 16 (5.2%) felt comfortable performing MISS without practicing in cadaver laboratory, and 6 (2.0%) thought that this was not important.

Participants were also asked about training experiences for different MISS procedures: 77 spine surgeons (25.4%) reported prior training for transpoas lateral lumbar interbody fusion (LLIF); 59 (19.5%) for prepsoas oblique lumbar interbody fusion (OLIF); 167 (55.1%) for transforaminal lumbar interbody fusion (TLIF); 202 (66.6%) for decompressive procedures such as laminectomy, foraminotomy, and diskectomy; 114 (37.6%) for endoscopic procedures; 70 (23.1%) for cervical procedures such as tubular foraminotomies or facet cages; 170 (56.1%) for percutaneous pedicle screw and rod fixation; 24 (7.9%) for deformity correction techniques; 47 (15.5%) for image-guided navigated procedures or robotic systems; and 166 (54.7%) for other procedures. The spine surgeons reported independent operation for the following MISS procedures: 52 (17.1%) for

LLIF; 29 (9.5%) for OLIF; 123 (40.6%) for TLIF; 159 (52.5%) for decompressive procedures such as laminectomy, foraminotomy, and diskectomy; 81 (26.7%) for endoscopic procedures; 65 (21.4%) for cervical procedures such as tubular foraminotomies or facet cages; 132 (43.5%) for percutaneous pedicle screw and rod fixation; 19 (6.2%) for deformity correction techniques; 41 (19.8%) for image-guided navigated procedures or robotic systems; and 156 (51.5%) for other procedures such as vertebroplasty, kyphoplasty, and pain procedures.

Pandemic Impact

Regarding how the COVID-19 pandemic impacted the respondents' ability to learn MISS techniques, 125 spine surgeons (41.2%) reported a significant effect in terms of an



Fig. 5 (A) Minimally-invasive decompressive procedure (foraminolaminectomy) performed through a tubular retractor (access portal) ensures satisfactory neural decompression and radicular pain relief. (B) Minimally-invasive circumferential multi-stage fusion procedure utilized for degenerative deformity correction: preoperative image on left shows lumbar degenerative scoliosis; postoperative image on right shows 3-levels lateral lumbar interbody fusion from L2 to L5 associated with 4-levels posterior percutaneous pedicle screw and rod fixation from L2 to S1. Note that, in this particular case, the patient had an anterolumbar interbody fusion at L5 to S1, which was performed via opened traditional exposure.

inability to experience useful learning activities, 117 (38.6%) reported a moderate effect in that prepandemic normalcy has not returned, 29 (9.6%) reported a mild effect in that prepandemic normalcy has returned, and 32 (10.5%) reported no effect at all. Therefore, 79.8% of spine surgeons were affected by the COVID-19 pandemic in that access to MISS education was either completely or significantly limited (41.2% completely limited and 38.6% significantly limited).

Discussion

The MISS technique treats spinal disease via minimal alteration of natural anatomy, while simultaneously delivering clinical outcomes to a similar degree as open surgery (**~Fig. 5**).^{1,2,3,8} There are a few advantages of MISS over open surgery, such as shorter hospital stays and less postoperative pain for most procedures.^{10,11}

The philosophy of MISS is echoed by Luis Tumialan: "Opened traditional exposure is more a consequence of the midline incision than of an actual need to expose the requisite anatomy to accomplish the operation, while MISS is the opposite, almost every millimeter of exposure is granted by an access port."¹²

Although a promising alternative to traditional open surgery, MISS is not without its challenges. It is associated with a high cost for implementation in most countries, as well as a steep learning curve that involves understanding anatomical landmarks through narrow surgical ports and limited visualization of the surgical cavity, all without tactile sensation.^{13,14} It is difficult to precisely estimate the learning curve for MISS, as there is a high variability between different types of procedures: whereas previous reports indicated a minimum of 39 cases to become 90% proficient in MISS TLIF, other reports indicated 72 as the minimum to become 90% proficient in MISS lumbar discectomy.^{15,16,17} With this complex learning curve, it is therefore essential for the community to develop standard educational programs to minimize learning curve-induced complications. Combined with the COVID-19 pandemic, the challenge of learning from early 2020 to mid-2021 was even steeper, as residents across various surgical specialties reported a significant decline in cases and a shift to online didactics.¹⁸ This internet survey attempted to understand the gaps in the learning process for this technique, as well as how COVID-19 impacted access to education.

The present study found significant differences in MISS tool availability between social media-using spine surgeons in Africa and Europe, despite both regions reporting spine surgeon practice predominantly in government or academic institutions. The low access to MISS tools in Africa found in this study is not surprising considering a recent global survey reported an acceptance-to-performance lag gap to be highest in Africa and the Middle East compared with lower rates in Europe, Asia, and South and North America.¹⁹ This gap was defined as the percentage of spine surgeons who perceived MISS as part of mainstream spine surgery to the percentage of spine surgeons who actually performed it in their practices. The higher gap between perceived MISS acceptance into mainstream spine surgery and physical deployment of the

techniques in Africa and the Middle East suggests that both regions have possibly delayed access to the necessary tools.¹⁹ Furthermore, in the present study, access to MISS tools was a major determinant of MISS practice regardless of region. There were significantly more spine surgeons who reported it as representing 76% to 99% of their overall caseload with easy access to the necessary tools than those spine surgeons who reported it as representing less than 25%. Although outside the scope of this study, this may be due to a lack of support from national societies endorsing MISS in formal treatment guidelines, as there is a paucity of recommendation sheets in the current literature. Future studies could focus on examining whether access to this technique is associated with higher rates of implementation in practice.

Most of the spine surgeons who responded to this survey reported a prior opportunity to learn MISS techniques via attending cadaver laboratory. At the same time, 69.9% of spine surgeons included in this study attended cadaver laboratory either every 6 months, at least once a year, or at least once in the last 5 years. This suggests that the main educational tool for learning MISS in the pre-pandemic era was via cadaveric study. It seems clear that development of a structured curriculum will need to include training on cadavers. This suggestion is further supported by Sharif et al., who determined that cadaveric study, access to appropriate tools, and the guidance of experienced surgeons were associated with shorter learning curves for attaining MISS proficiency.¹⁶ Although, outside the scope of this study, Sharif et al. further determined that as the spine surgeon's experience with this technique increases, the operative time and length of hospital stay improve.¹⁶ In summary, we recognize the importance of routine practice, especially with cadaveric study, as MISS requires learning spine surgery without the traditional aspect of tactile sensation.

We also sought to understand how spine surgeons learned MISS during the COVID-19 pandemic era. Whereas 62% of spine surgeons in this study reported attendance to at least one virtual event, 38% of them reported no virtual attendance. Furthermore, 50.1% found virtual learning useful, 42.5% found it somewhat useful (not sufficient), and 7.2% did not consider it useful. When comparing opinions about the gold standard for learning MISS, 51.1% of spine surgeons considered cadaveric study, 44.2% considered guidance from an experienced, and only 0.3% considered virtual demonstration. Even though we found cadaveric study as the most appreciable method of learning MISS, virtual demonstration played a vital role with learning surgical techniques, especially during the COVID-19 pandemic. This is supported by Aziz et al., who found that resident education for online didactics transitioned to completely online platforms in 80.6% of their resident respondents across the United States in 2020.¹⁸ Although virtual learning does not replace handson training with cadavers or in the operating room, it appears to be a useful supplement when access to in-person events becomes hampered by extreme circumstances. It remains to be seen, however, how purely online didactics during the COVID-19 pandemic will adequately prepare graduating residents for fellowships and independent practice.

In the present study, 79.8% of spine surgeons were affected by the COVID-19 pandemic in that educational access for learning MISS was either completely or significantly limited, and have not presently returned to prepandemic levels. From these professionals, 41.2% reported a complete inability to experience a useful MISS learning event since the start of the pandemic. Considering that resident didactic training in the United States shifted to online platforms for 80.6% of surgical residents due to COVID-19, the lack of return to normal educational access for MISS is not surprising.¹⁸ Moreover, nearly 45% of the respondents in this survey originated from South America. When combining the COVID-19 pandemic with international travel restrictions, spine surgeons from certain regions of the world are limited from accessing MISS technology, more commonly spine surgeons from South America. Guiroy et al. previously found that this group of spine surgeons is significantly limited from accessing the necessary resources, as only 43% had access to microscopy; 34% had access to cages such as those for ALIF, LLIF, or TLIF; only 26% had access to percutaneous screws; and an additional 71% reported never having access to navigation.²⁰ The authors further determined that the predominant constraints for learning MISS were related to implementation costs and lack of face-to-face educational activities.²⁰

Access to MISS educational resources is essential for acquiring proficiency. As such, based on the findings presented from this survey, we propose potential solutions for increasing the neurosurgical or orthopedic spine surgeon's access to education: investment from governments, academic institutions, or surgical societies in fellowship programs; creation of organized leadership in the subject; standardization of virtual didactics; simulations including augmented reality or 3D printed models; and restoration of on-site cadaver laboratories.

Limitations

The present study has some limitations. Considering that the study design was based on a population survey, there was an inherent weakness of self-selection bias. There was also a significant response rate from South America when compared with other regions of the world, thereby limiting generalizability. Out of the 303 respondents in this survey, only one originated from Australia or Oceania, so this geographic territory was essentially removed from analysis. The United States and China were also misrepresented here, since a vast majority of spine surgeons who employ MISS are from these territories. Our attempts to reach surgeons in both territories were unsuccessful, thereby lending to an incomplete comparison to these geographic regions. The sample presented in this study, therefore, does not reflect the current state of worldwide MISS practice. Future studies may implement a more expansive protocol that includes participation from spine surgeons in the United States and China. Additionally, there may be interregional differences between surgical practices and training that were not considered. For example, not every neurosurgical or orthopedic spine surgeon in every region would be reluctant or interested in changing their practices to include MISS. Lastly, we did not utilize any form of two-factor authentication for verification of spine surgeon identity. It is therefore possible that a respondent included in the analysis was not a spine surgeon, despite only social media forums consisting of spine surgeons were accessed when sending the questionnaire online.

Conclusion

This survey reached 303 neurosurgical and orthopedic spine surgeons from April 2021 to June 2021 with most responses originating from South America. Even though most of the spine surgeons who responded to this survey were able to attend virtual MISS learning events during the COVID-19 pandemic, they still considered cadaveric study as the gold standard for learning MISS. Among other tools, spine surgeons found that guidance from an experienced surgeon was an invaluable learning experience, with nearly similar rates as that of cadaveric study. Therefore, a multidisciplinary effort is needed to develop structured training programs for teaching MISS, including cadaver laboratory, guidance from experienced surgeons, and virtual demonstrations for spine surgeons, particularly those from South America.

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Conflict of Interests

Jahangir Asghar is a consultant for NuVasive, Medtronic, and Immertec. Jay D. Turner is a consultant for NuVasive, SeaSpine, and AlphaTec. The other authors report no conflicts of interest regarding presented methods or findings. No external research grants were received to support this work.

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