A Survey on the Availability, Usage and Perception of Neuromuscular Monitors in Europe

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Funding

This research was funded by the Flanders Innovation and Entrepreneurship Fund (VLAIO), the Willy Gepts Fund for Scientific Research, the Society for Anesthesia and Resuscitation of Belgium (BeSARPP), and the Vrije Universiteit Brussel (VUB).

Abstract

Purpose

Neuromuscular blocking agents (NMBAs) are routinely administered to patients in a multiplicity of anesthetic settings. Absence of postoperative residual neuromuscular block is widely considered an anesthetic patient safety mandate. Despite the increasing availability of a wider range of commercial quantitative neuromuscular monitors, the availability and use of neuromuscular monitoring devices is deemed to be suboptimal even in countries with above-average health system ratings. The present study aims to more precisely characterize the perceived availability, cost sensitivity and usability of neuromuscular monitoring devices within European anesthesia departments.

Methods

A pre-registered internet-based survey assessing the availability, cost sensitivity and usability of neuromuscular monitoring devices was distributed as e-mail newsletter by the European Society of Anaesthesiology and Intensive Care (ESAIC) to all of its active full members. The survey was available online for a total of 120 days.

Results

Having targeted a total of 7472 ESAIC members, the survey was completed by a total of 692 anesthesiologists (9.3%) distributed across 37 different European countries. Quantitative monitors were reported to be proportionally more available than qualitative ones (87.6% vs. 62.6%, respectively), as well as in greater monitor-per-operating room ratios. Most anesthesiologists (60.5%) expressed moderate confidence in quantitative monitors, with artifactual recordings and inaccurate measurements being the most frequently encountered issues (25.9%). The commercial pricing of quantitative devices was considered more

representative of a device's true value, when compared to qualitative instruments (average cost of €4.500 and €1.000 per device, respectively).

Conclusion

The availability of quantitative NMM in European operating theaters has increased in comparison with that reported in previous decades, potentially indicating increasing monitoring rates. European anesthesiologists express moderate confidence in quantitative neuromuscular monitors, along with a sentiment of adequate pricing when compared to their qualitative counterparts. Trust in quantitative monitors is marked by caution and awareness for artifactual recordings, with a consequent expectation that developments focusing on accuracy, reliability and ergonomics of neuromuscular monitors be prioritized.

Keywords: neuromuscular monitoring; availability; usability; survey; Europe; European;

1 Introduction

Neuromuscular Blocking Agents (NMBAs) are routinely administered to patients in a multiplicity of anesthetic settings. The availability of several monitoring devices allowing an accurate measurement of the degree of neuromuscular block during anesthesia has raised the need for an evidence-based use of NMBAs. The absence of residual neuromuscular blockade is now widely considered an anesthetic patient safety mandate, as incomplete recovery has been established as a strong contributor to post-anesthesia morbidity and mortality.[1,2] Considering the proven imprecise, inaccurate and inter/intra-observer variability of the human senses to estimate adequate neuromuscular recovery after NMBA use, an adequate assessment of neuromuscular recovery can only be assured by means of an objective (quantitative) methodology.[2] Despite the above mentioned facts, the availability of neuromuscular monitoring devices is deemed to be suboptimal even in countries with above-average health system ratings.[3,4] The present study aims to more precisely characterize perceived availability, cost sensitivity and usability of available neuromuscular monitoring devices within European anesthesia departments.

2 Methods

Approval of the present internet-based survey was obtained from the ethics committee (EC) of the University Hospital Brussels (UZ Brussels, Belgium), on December 16, 2020. As per EC recommendations, the survey's approval request was subdivided in 3 parts, each pertaining to a different survey subtopic: availability (reference 2020-344), cost-sensitivity (reference 2020-436) and usability (reference 2020-437). As such, a pre-trial registration was concordantly carried out for each separate subtopic (www.clinicaltrials.gov references NCT04517578, NCT04564404 and NCT04559386, respectively). The survey was composed in English and

proof-read by the authors HC and MV. The survey was not translated to any other languages when distributed. Questions were further validated a priori for consistency, comprehension, and coherence by three authors (HC, MV and JP). To facilitate the distribution and storage of the online survey, the surveying tool Qualtrics© (www.qualtrics.com) was adopted. The questions composing the survey can be found in Appendix A.

Distribution of the survey was carried out by means of an e-mail newsletter disseminated by the European Society of Anaesthesiology and Intensive Care (ESAIC), which was sent to a total of 7472 full members. The electronic link to the survey was provided in the invitation message. The first newsletter was sent on the 10th of November 2021 and a subsequent reminder on the 19th of November 2021. In cumulative terms, the newsletter e-mail was opened by a total of 4653 members (62.3%). Of these, 692 (9.3%) fully completed the survey.

All questions were formatted into the Qualtrics XM interface, and the survey questionnaire was designed to be completed in under 5 minutes – the average time required to complete the test by the authors with an additional 2-minute allowance. Possible responses were listed for each question, and participants interactively selected their choices. Responses were drafted and discussed by several authors (HC, MV, PF & JP). Depending on the question, participants could have additional remarks (e.g., to describe neuromuscular monitors that were not listed by the investigators). Qualtrics is Internet Protocol-address sensitive, therefore respondents could not duplicate and re-submit answers after the initial completion of the survey. However, double survey submission could not be prevented if a different IP address were adopted by the respondent. The acquired data were stored electronically in 2 separate databases: one at the Qualtrics cloud storage environment and another stored locally at UZ Brussels. Data integrity on both databases was maintained using a time-stamped identifier and logging system that

recorded any modifications and changes to the respective database. The survey was available online for a total of 120 days.

The goal of the present survey was to determine the perceived availability, usability, and general cost of quantitative and qualitative neuromuscular monitors throughout Europe. Additionally, results were differentiated based upon the pre/post-training status of the respondents. Frequency tables and graphical representations were used to summarize the demographic data and the clinical survey details within each cohort of anesthesia practitioners.

3 Results

Demographics. In total, the respondents of the survey were distributed across 37 different European countries. Table 1 displays responding countries ranked by number of answers. French anesthesiologists topped the response rate ranking, being responsible for 25% of total answers. These were followed by Belgium and Switzerland with 17.8% and 12.9% of responses, respectively. A choropleth map of absolute responses per country is depicted in Figure 1.

Figure 1: Choropleth map of absolute survey answers

The majority of the respondents were anesthesia consultants (78.9%, n = 516), and the remainder were anesthesia trainees/registrars (21.1%, n = 138). Total number of complete responses equaled 692. The total number of partial responses equaled 439, with 22 of these having a completion rate of 80% of questions or higher. Tables 2 and 3 detail the total number of responses per question.

Table 1: Responding countries ranked by number of respondents

Country	**Survey Respondents**	
	Number (n)	Percent of Total (%)
France	173	25.0%
Belgium	123	17.8%
Switzerland	89	12.9%
Germany	51	7.4%

UK, Portugal	33 (each)	4.8% (each)
Netherlands	30	4.3%
Spain	28	4.0%
Italy, Sweden	19 (each)	2.7% (each)
Austria	16	2.3%
Greece	10	1.4%
Finland, Romania	6 (each)	0.9% (each)
Turkey, Croatia	5 (each)	0.7% (each)
Hungary, Czechia	4 (each)	0.6% (each)
Poland, Norway, North Macedonia, Slovenia, Latvia, Cyprus	3 (each)	0.4% (each)
Slovakia, Lithuania, Estonia, Malta	2 (each)	0.3% (each)
Iceland, Ukraine, Belarus, Serbia, Denmark, Ireland, Moldova	1 (each)	0.1% (each)
Bulgaria, Bosnia and Herzegovina, Albania, Montenegro, Luxembourg, Andorra, Monaco,	0	0%

Liechtenstein, San
Marino, Kosovo

Availability. The availability characteristics of neuromuscular monitors are presented in Table 2. The reported availability of quantitative neuromuscular monitors greatly surpasses that of qualitative instruments (87.6% vs. 62.6%, respectively). Regarding their distribution, 41.3% of the respondents indicated that 1 qualitative instrument was available per operating room, compared to 61.4% for quantitative monitors. As for the respondents working in operating theaters in which both types of monitors were available, 60.1% indicated that the average ratio is 1 monitor per operating room (either quantitative or qualitative), compared to 13.5% and 13% expressing that the approximate availability is 1 monitor per 2 or 3 operating rooms (either quantitative or qualitative). When asked about the specific type of quantitative neuromuscular monitoring units, the top three most common monitors were the TOF-Watch (27.2%; Organon Ireland/Merck Sharp & Dohme, Cork, Ireland; out of production), ToFscan (24.3%; IDMED/Dräger, Marseille, France) and the Datex-Ohmeda M-NMT (11.7%; GE Healthcare, Chicago, IL, USA). A total of 17.6% of respondents indicated that they were unaware of the specific models available to them.

Table 2: Availability of neuromuscular monitors

Some questions allowed multiple answers, while others were only applicable in the case of a positive answer. These subtleties explain the discrepancy between the different absolute answer numbers across different questions.

Question	**Number of responses (n, %, 95%CI)**	
Are conventional nerve stimulators (quaLitative monitors) available in your department?		
Yes	420	62.6% (58.9 – 66.3%)
No	251	37.4% (33.7 – 41.1%)
	N = 671	
If conventional nerve stimulators (quaLitative monitors) are available, how are they distributed?		
1 per operating room	216	41.3% (37.1 – 45.5%)
1 per 2 operating rooms	54	10.3% (7.7 – 12.9%)
1 per 3 operating rooms	100	19.1% (15.7 – 22.5%)
Other [See Appendix B for more details]	153	29.3% (25.4 – 33.2%)
	N = 523	
Are quaNtitative TOF monitors available in your department?		
Yes	588	87.6% (85.1 – 90.1%)
No	83	12.4% (9.9 – 14.9%)
	N = 671	
If yes, which units are available?		
TOF Scan	205	24.3% (21.4 – 27.2%)
TOF-Watch	230	27.2% (24.2 – 30.2%)
Datex-Ohmeda M-NMT	99	11.7% (9.5 – 13.9%)
Datex-Ohmeda E-NMT	65	7.7% (5.9 – 9.5%)
TOF-Cuff	28	3.3% (2.1 – 4.5%)
TwitchView	9	1.1% (0.4 – 1.8%)
TetraGraph	8	0.9% (0.3 – 1.5%)
I am unaware of the specific model	149	17.6% (15.0 – 20.2%)
Other	52	6.2% (4.6 – 7.8%)
	N = 845	
If quaNtitative TOF monitors are available, how are they distributed?		
1 per operating room	373	61.4% (57.5 – 65.3%)
1 per 2 operating rooms	82	13.5% (10.8 – 16.2%)
1 per 3 operating rooms	79	13.0% (10.3 – 15.7%)
Other [See Appendix B for more details]	73	12.0% (9.4 – 14.6%)
	N = 607	
If you have both a qualitative and quantitative monitor, what is the average ratio of monitors per operating room?		
1 per operating room	264	60.1% (55.5 – 64.7%)

1 per 2 operating rooms	56	12.8% (9.7 – 15.9%)
1 per 3 operating rooms	62	14.1% (10.8 – 17.4%)
Other [See Appendix B for more details]	57	13.0% (9.9 – 16.1%)
	N = 439	

Perception and usage. The respondents' perception and usage of neuromuscular monitors is summarized in Table 3, figures 2 and 3. When asked about the reliability of quantitative neuromuscular monitoring devices, the majority of both trainees/registrars and consultants found the output of neuromuscular monitors "somewhat reliable". Most of the remainder of both trainees and consultants (36.8% of total respondents) found the devices very reliable and trusted the displayed results. Trainees were proportionally more skeptical than consultants, with only 23.9% of them indicating maximum confidence on NMM, versus 40.5% of consultants (figure 3). Substantially more respondents (60.5%) found quantitative neuromuscular monitors somewhat reliable, often double-checking measurements, while 2.6% indicated that they did not find the monitors reliable (figure 2 and 3). When asked about the most frequent issues encountered when adopting quantitative neuromuscular monitors, artifactual recordings and inaccurate measurements (25.9%), lack of self-calibration (16.7%) and monitoring results that are not stored automatically (16.6%) were the three most encountered monitor-related issues. Similarly, the most sought out characteristics to improve neuromuscular monitors were self-calibration (20.6%), less cables or a wireless function (20.0%) and more accurate and reliable results (16.8%).

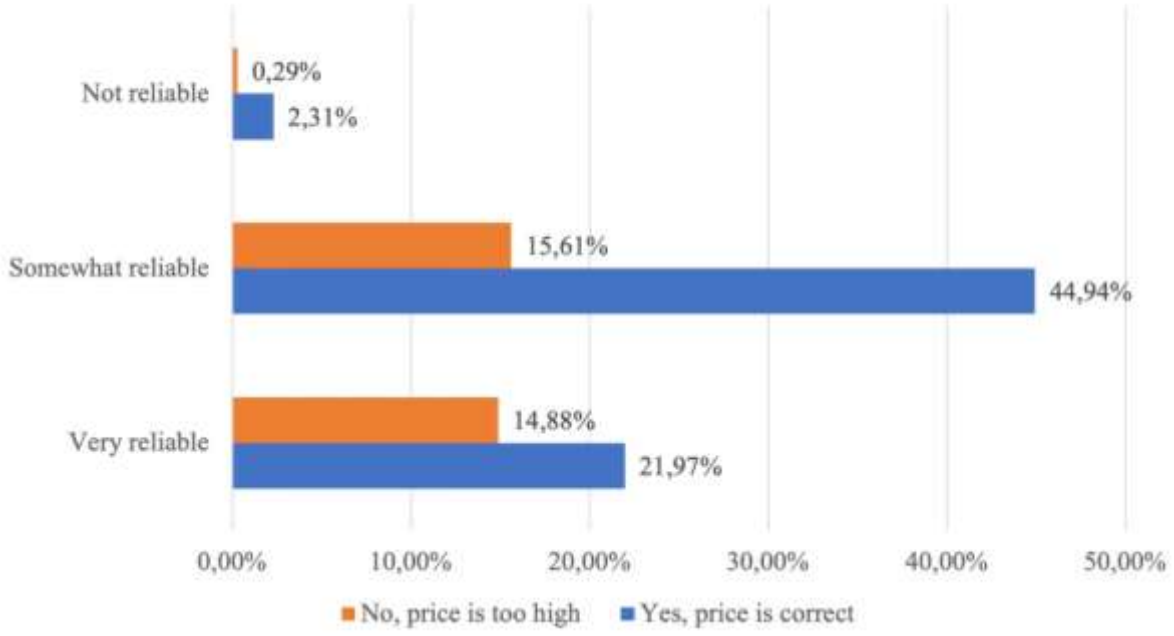

Figure 2: Perception of reliability Vs. perception of price of a quantitative neuromuscular monitor

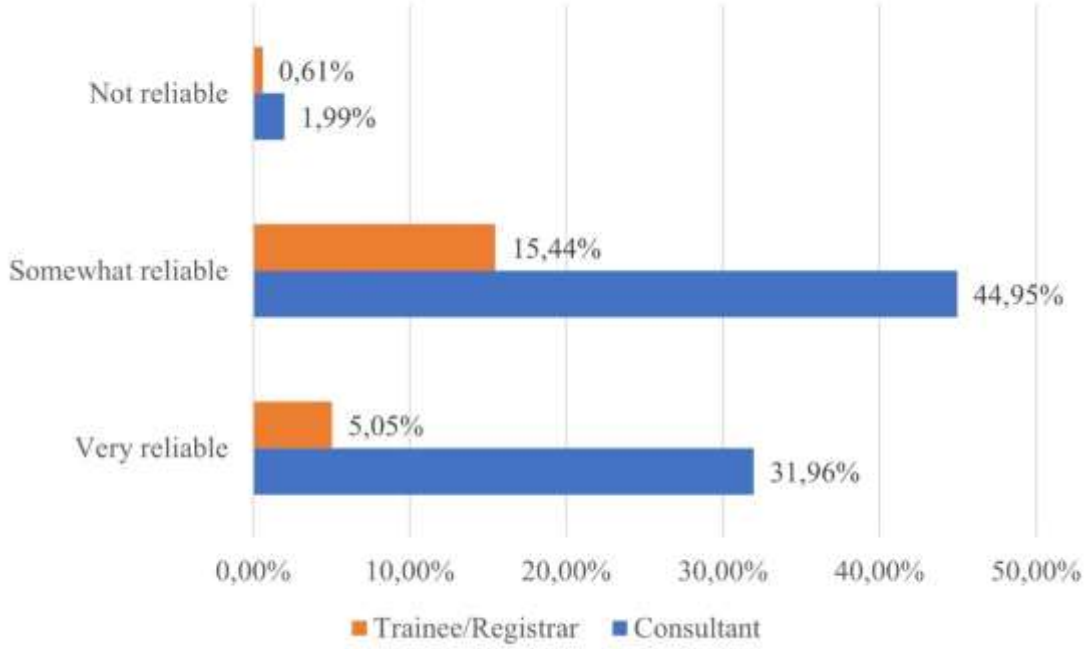

Figure 3: Perception of reliability of a quantitative neuromuscular monitor Vs. training status of the responding anesthesiologist

To assess the perceived value of a neuromuscular monitor for an anesthesiologist, the survey integrated several questions on the estimated pricing of qualitative instruments and quantitative neuromuscular monitors. After being presented a table with the commercial prices of quantitative neuromuscular monitors (price budget requests for sales within the BeNeLux region), 69.2% of our respondents believed the price of the device correctly represents its value, compared to 47.4% for qualitative devices (figures 2 and 3). As for the perceived value of consumables required for most EMG quantitative monitors, only 16.3% of our respondents believed that the product-specific EMG electrodes potentially offer added value.

Moreover, to estimate possible improvements that could enhance user experience, product usage, and the overall adoption of quantitative neuromuscular monitors in operating rooms, several questions were formulated to inform potential areas of improvement. When asked about the usefulness of a separate wireless monitor that could both stimulate and measure muscular responses, 55.8% responded that such a development would be very useful, compared to 6.8% that would not find it so. As for a portable sensor that could upgrade a qualitative neuromuscular instrument into a quantitative monitor, 78.2% would adopt this sensor when utilizing a conventional nerve stimulator. Finally, 53.6% of respondents would find it very useful if the TOF ratio/Post-tetanic Count (PTC) could be predicted and prospectively displayed on an anesthesia monitor, without necessarily using a monitoring device, compared to 9.7% that would find such a feature not useful.

Table 3: Usage and Perception of neuromuscular monitors

Question	**Number of Respondents (n, %, 95%CI)**	
How reliable do perceive existing quaNtitative (objective) Neuromuscular Monitoring devices?		
Very reliable, I trust the measurements and displayed results of the monitor.	255	36.8% (33.2 – 40.4%)

Somewhat reliable, I often double check if the measurements and that displayed results of the monitor are not erroneous.	419	60.5% (56.9 – 64.1%)
Not reliable, I do not trust the measurements and displayed results of the monitor.	18	2.6% (1.4 – 3.8%)
	N = 692	
Which of the following issues have you encountered when using quaNtitative (objective) neuromuscular monitoring devices?		
Artifactual recordings and inaccurate measurements	418	25.9% (23.8 – 28.0%)
Difficulty with the set-up	131	8.1% (6.8 – 9.4%)
Lack of self-calibration	269	16.7% (14.9 – 18.5%)
Lack of instructions on how to apply the monitor	70	4.3% (3.3 – 5.3%)
Hard to use interface	77	4.8% (3.8 – 5.8%)
Monitoring results are not stored automatically	268	16.6% (14.8 – 18.4%)
None	350	21.7% (19.7 – 23.7%)
Other [See Appendix B for more details]	31	1.9% (1.2 – 2.6%)
	N = 1614	
If quaNtitative TOF monitors could be improved, which characteristics would you prioritize?		
Self-calibration by the monitor	423	20.6% (18.9 – 22.3%)
Improve the set-up of the monitor	140	6.8% (5.7- 7.9%)
Less cables/Wireless function.	412	20.0% (18.3 – 21.7%)
Decision support/Interpretation support.	111	5.4% (4.4 – 6.4%)
Clear instructions on how to apply the monitor	124	6.0% (5.0 – 7.0%)
A user-friendly interface, where results and measurements and trends are clearly displayed	231	11.2% (9.8 – 12.6%)
More accurate and reliable results	346	16.8% (15.2 – 18.4%)
Automatic storage and documentation of monitoring results	253	12.3% (10.9 – 13.7%)
Other [See Appendix B for more details]	15	0.7% (0.3 – 1.1%)
	N = 2055	
Considering that a quaNtitative neuromuscular monitor costs on average €4.500, do you find that this price meets the expectations of the device?		
Yes, I believe the price of the device correctly represents its value.	479	69.2% (65.8 – 72.6%)
No, the price of the device is too high for the value it offers.	213	30.8% (27.4% - 34.2%)
	N = 692	
Considering that most EMG quaNtitative TOF monitors require specific EMG sensor electrodes (consumables) costing approximately €20 per piece (per patient), do you find that these company specific electrodes add specific value towards neuromuscular monitoring?		
Yes, I believe that the company specific EMG electrodes offer added value.	113	16.3% (13.5 – 19.1%)

No, I do not believe that the company specific EMG electrodes offer added value compared to standard EMG electrodes.	579	83.7% (80.9 – 86.5%)
	N = 692	
Considering that a conventional nerve stimulator (quaLitative monitor) costs approximately €1.000, do you find that this price meets the expectations of the stimulator?		
Yes, I believe the price of the stimulator correctly represents its value.	328	47.4% (43.7% - 51.1%)
No, the price of the stimulator is too high for the value if offers.	364	52.6% (48.9 – 56.3%)
	N = 692	
If a portable sensor would exist that could upgrade a conventional nerve stimulator (quaLitative monitor) into a quaNtitative TOF monitor, would you consider applying this sensor when utilizing a conventional nerve stimulator?		
Yes	541	78.2% (75.1% - 81.3%)
No	151	21.8% (18.7 – 24.9%)
	N = 692	
If a quaNtitative neuromuscular monitoring device could be controlled in a wireless fashion, i.e., a separate wireless monitor that can both stimulate and measure muscular responses, you would find this feature:		
Very useful	386	55.8% (52.1 – 59.5%)
Rather useful	259	37.4% (33.8 – 41.0%)
Not useful	47	6.8% (4.9 – 8.7%)
	N = 692	
If the TOF ratio/Post-tetanic Count (PTC) could be predicted and their expected future anesthesia course displayed on an anesthesia monitor during surgery by automatically integrating patient's parameters, without necessarily using of a monitoring device, you would find this approach of monitoring:		
Very useful	371	53.6% (49.9 – 57.3%)
Rather useful	254	36.7% (33.1 – 40.3%)
Not useful	67	9.7% (7.5 -11.9%)
	N = 692	

4 Discussion

In 2010, Naguib and colleagues published one of the few existing surveys that directly addressed the availability and usability of neuromuscular monitors across Europe.[4] With the exception of national surveys, no comparable pan-European assessments have taken place since. In the meantime, not only have new quantitative monitors made their way into operating theaters, but the body of literature on perioperative neuromuscular management has significantly increased, thereby reinforcing the essential role of quantitative monitoring in preventing postoperative residual neuromuscular block and resultant pulmonary complications.[2,5] Motivated by these changes, the present survey aimed to capture potentially changing dynamics on the availability and usability of neuromuscular monitors, and to similarly poll the end-users' pricing perceptions and monitor development needs.

In contrast to Naguib et al, the majority (87.6%) of the hereby answering European anesthesiologists reported that quantitative monitors predominated within their departments in comparison with qualitative devices. Moreover, these were available at a ratio of 1 monitor per operating room in more than 60% of the cases, compared with reported values of 44.5% one-decade earlier.[5] Within the available quantitative monitoring modalities, the majority (63.2%) of these was comprised of monitors based on acceleromyography (AMG) and kinemyography (KMG). A minority (9.7%) of the responders reported having electromyographic (EMG) devices in their departments. Despite the recognition of electromyography as the most accurate and clinically deployable alternative to the previous standard (mechanomyography, MMG), compact and user-friendly EMG monitors are currently commercially outnumbered by their AMG counterparts.[5,6] Moreover, the fact that the majority of the currently available EMG monitors have only been made available to anesthesiologists within the past few years, and because of their higher acquisition price and reliance on consumables, may explain the reported contrasting availability rates.

When questioned on the perceived reliability of quantitative devices, it becomes clear that very few practitioners completely distrust them. In fact, 36.8% indicated that these monitors are very reliable, while most responders (60.5%) were more cautious and indicated being moderately confident on the accuracy of the measurements, frequently double-checking their reproducibility. This trend was consistent with the fact that the most frequently reported issue relating to the use of quantitative monitors was the presence of artifactual recordings (25.9%). A combined analysis of these 2 questions additionally reveals that although more than 36% of the responders indicated a high degree of trust on the devices, only 21.7% indicated encountering no monitor-related problems. Curiously, trainees/registrars were proportionally more skeptical than consultants of a monitor's reliability. The reasons for such difference were not discriminated and can only be speculated upon. Nevertheless, they constitute a positive sign of awareness/sensibility for the potential pitfalls of these monitors.

On the topic of the most prioritized future developments, solutions that improve monitor ergonomics and ease of use were clearly favored. In fact, the potential existence of a wireless monitor, as well as a self-calibration feature, were the top 2 ranked desired features. For that purpose, a wireless neuromuscular monitor based on an existing 3-dimensional acceleromyography monitor has been recently made available.[7] Studies evaluating usability and reliability are expected to follow, while comparative performance trials are ongoing (NCT05231525).

In concordance with the frequently reported artifactual recordings, monitor developments yielding more accurate and reliable results were the third most desired improvement. Such prioritization is certainly understandable in the context of neuromuscular monitoring, where movement artifacts tend to contaminate measurements, especially (although not exclusively) in movement-dependent methodologies such as AMG. For this purpose, machine-learning based techniques that allow for an automatic filtering of neuromuscular

monitoring outliers have been proposed recently.[8] It is nevertheless important to recognize that perceived artifacts are not always synonymous with actual artifacts, but are frequently the result of misinterpretations due to clinicians' unfamiliarity with monitors and/or neuromuscular monitoring concepts.[9,10] Such considerations reiterate the multifactorial nature of the frequently reported clinical under-adoption of neuromuscular quantitative monitoring, as well as the crucial role of education for an effective implementation of neuromuscular monitoring within anesthesia departments.[5,11]

When analyzing the acceptance of market prices for both quantitative and qualitative devices, despite their relatively higher price, quantitative monitors are deemed worthy of the manufacturer price by approximately 70% of the respondents. In fact, the top limit of the quoted price intervals for the currently commercialized devices was used in the present survey, which can be argued that does not accurately represent the average price of the monitors within this category. Accurate and established AMG and EMG monitors can be purchased for half of the indicated price. Qualitative instruments (peripheral nerve stimulators), on the other hand, although significantly cheaper, do not enjoy the same degree of price acceptance. These results suggest an acknowledgement of the added value of quantitative monitors.[2]

Concerning the receptivity for monitor-independent neuromuscular endpoint prediction algorithms, more than 90% of the survey respondents indicated finding such a feature very or moderately useful. At present, such technologies are only available in the form of target concentration predictions derived from published pharmacokinetic models (f.e., Drager SmartPilot®, Lubeck, Germany), which, by not giving end-users a tangible clinical metric (a pharmacodynamic endpoint), remain largely difficult to correlate and implement clinically. Although integrated pharmacokinetic-pharmacodynamic (PK-PD) models are publicly available, their daily clinical accuracy is currently challenged by wide agreement intervals with clinical reality, once again reinforcing their role as a mere guidance technology, and not as a

monitoring substitute.[12-15] These considerations provide additional food for thought in the pro-con debates on the role of neuromuscular monitoring in the era of Sugammadex.[16]

The present survey's main limitation relates to its representativity. In fact, it is undeniable that the number of answers significantly underrepresents the total European anesthesia population, even though approximately 9.3% of the practitioners registered within the ESAIC were effectively reached. Nevertheless, the total number of answers is comparable with previously published surveys, and there is similarly a considerable geographic range within the obtained answers.[4] Ideally, several independent national initiatives would have been undertaken to assess the survey questions, with the results centralized a posteriori in order to allow for more target comparisons.

Similar to the survey of Naguib and colleagues, a potential responder bias cannot be excluded (practitioners with an interest on the topic might answer proportionally more than those uninterested in the topic).[4] It must be similarly recognized that there is a potential that the availability rates of neuromuscular monitors are inaccurate. In fact, it is not infrequent to have multiple different monitors available within a department, and a great proportion of these are commercialized as stand-alone devices, making them prone to becoming displaced/lost, and as such, being considered available when effectively they are not. The same considerations apply to the respondents' recall of monitor types and brands. Like the survey by Naguib and colleagues, our survey was also conducted in English only, which may have limited responses from those practitioners not facile with the English language.[4] In contrast with the survey of Naguib et al, no United States data has been collected in the present survey. Although not an a priori goal, it would have been interesting to compare transcontinental evolutions NMM availability and confidence.

On the topic of the perceived reliability of both quantitative and qualitative devices, the questions were formulated in such a way that it was implied that these were being compared to

one another. It can be argued that within the quantitative monitor category, different technologies can be considered to perform differently in terms of reliability, accuracy, and ease-of-use (AMG vs. EMG). Awareness to this fact might have conditioned how reliable/accurate quantitative monitors were judged by the responders.

Conclusion

The availability of quantitative NMM in European operating theaters has increased in comparison with that reported in previous decades, potentially indicating increasing monitoring rates. European anesthesiologists express moderate confidence in quantitative neuromuscular monitors, with trust in these devices being marked by caution and a frequent need of anesthesiologists to double-check their measurements. Nevertheless, the sentiment of adequate pricing of these monitors prevailed among the responders. Developments focusing on accuracy, reliability and ergonomics of neuromuscular monitors were prioritized by the survey respondents.

Appendix A

Q1	How reliable do perceive existing quaNtitative (objective) neuromuscular monitoring devices?
Q2	Which of the following issues have you encountered when using quaNtitative (objective) neuromuscular monitoring devices? Select all that apply.
Q3	If quaNtitative TOF monitors could be improved, which characteristics would you prioritize? Select all that apply.
Q4	Considering that a quaNtitative neuromuscular monitor costs on average €4.500, do you find that this price meets the expectations of the device?
Q5	Considering that most EMG quaNtitative TOF monitors require specific EMG sensor electrodes (consumables) costing approximately €20 per piece (per patient), do you find that these company specific electrodes add specific value towards neuromuscular monitoring?
Q6	Considering that a conventional nerve stimulator (quaLitative monitor) costs approximately €1.000, do you find that this price meets the expectations of the stimulator?
Q7	If a portable sensor would exist that could upgrade a conventional nerve stimulator (quaLitative monitor) into a quaNtitative TOF monitor, would you consider applying this sensor when utilizing a conventional nerve stimulator?
Q8	If a quaNtitative neuromuscular monitoring device could be controlled in a wireless fashion, i.e. a separate wireless monitor that can both stimulate and measure muscular responses, you would find this feature – Selected Choice.
Q9	If the TOF ratio/Post-tetanic Count (PTC) could be predicted and their expected future anesthesia course displayed on an anesthesia monitor during surgery by automatically integrating patient's parameters, without necessarily using of a monitoring device, you would find this approach of monitoring – Selected Choice.
Q10	Are conventional nerve stimulators (quaLitative monitors) available in your department?
Q11	If conventional nerve stimulators (quaLitative monitors) are available, how are they distributed? - Select all that apply.
Q12	Are quaNtitative TOF monitors available in your department?
Q13	If yes, which units are available? - Selected Choice
Q14	If quaNtitative TOF monitors are available, how are they distributed? - Selected Choice
Q15	If you have both a qualitative and quantitative monitors, what is the average ratio of monitors per operating room? - Selected Choice
Q16	What is your professional experience level?
Q17	Which hospital/clinic do you work in? (For geographical purposes. Data will be anonymized during processing) - Selected Choice

Appendix B

Open Answers Q2. Which of the following issues have you encountered when using quaNtitative (objective) Neuromuscular Monitoring devices ? Select all that apply. - Other [Text]

Sensitivity to hand positioning.
Unclear instructions and unintuitive design. Most nurses do not know how to setup NMT monitors correctly.
Missing automatic PTC measurements.
Neuromuscular monitors should not measure if there is no fading.
Monitors are highly dependent on positioning and preload.
Exceptionally high impedance of skin/tissue in obese patients.
Difficult to obtain a good set-up in the surgical position.
Exceptionally high impedance of skin/tissue in obese patients.
Problems with measuring if both arms are positioned along the body (laparoscopic procedures).

Q3. If quaNtitative TOF monitors could be improved, which characteristics would you prioritize? Select all that apply. - Other [Text]

Improving reliability when patient has arms stuck against his body.
Measurements independent of arm positioning.
Accessories for different measurement sites (hand, toe, face…).

Q11. If conventional nerve stimulators (quaLitative monitors) are available, how are they distributed? - Other [Text]

1 per 4 operating rooms (8 respondents)
1 per 5 operating rooms (13 respondents)
Less than 1 per 5 operating rooms (24 respondents)

Q14. If quaNtitative TOF monitors are available, how are they distributed? - Other [Text]

2 per 1 operating room (3 respondents)
1 per 4 operating rooms (6 respondents)
1 per 5 operating rooms (5 respondents)
Less than 1 per 5 operating rooms (17 respondents)

Q15. If you have both a qualitative and quantitative monitors, what is the average ratio of monitors per operating room? - Other [Text]

2 per 1 operating room (1 respondents)
1 per 4 operating rooms (1 respondents)
1 per 5 operating rooms (2 respondents)
Less than 1 per 5 operating rooms (2 respondents)

Disclosures:

SJB: Conflicts of Interest: S. J. Brull has intellectual property assigned to Mayo Clinic (Rochester, MN); has received research support (funds to Mayo Clinic) from Merck & Co, Inc (Kenilworth, NJ) and is a consultant for Merck & Co, Inc; is a principal, shareholder, and chief medical officer in Senzime AB (publ) (Uppsala, Sweden); and is a member of the scientific/ clinical advisory boards for the Doctors Company (Napa, CA), Coala Life, Inc (Irvine, CA), NMD Pharma (Aarhus, Denmark), and Takeda Pharmaceuticals (Cambridge, MA).

TFB received lecture fees from MSD, France.

The other authors did not have any conflict of interest.

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Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.