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ORIGINAL ARTICLE

Artificial intelligence and telemedicine in the field of anaesthesiology, intensive care and pain medicine

A European survey

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BACKGROUND The potential role of artificial intelligence in enhancing human life and medical practice is under investigation but the knowledge of the topic among healthcare providers is under-investigated.

OBJECTIVES To investigate knowledge of artificial intelligence in physicians working in the field of anaesthesiology, intensive care, and pain medicine. As secondary outcomes, we investigated the main concerns on the implementation of artificial intelligence.

DESIGN Online survey.

SETTING Anaesthesiology, intensive care and pain medicine.

VOLUNTEERS We invited clinicians specialised in anaesthesia, resuscitation, intensive care and pain medicine who were active members of the European Society of Anaesthesiology and Intensive Care (ESAIC).

INTERVENTION Online survey from 28 June 2022 to 29 October 2022.

MAIN OUTCOME MEASURES Primary outcome was to investigate knowledge of artificial intelligence and telemedicine of participants.

RESULTS A total of 4465 e-mails were sent and 220 specialists, age 46.5 ± 10.2; 128 men (58.2%) responded to the survey. In general, some knowledge of artificial intelligence and machine learning was reported by 207 of 220 (94.1%) and 180 of 220 (81.8%) members, respectively. In anaesthesiology, 168 of 220 (76.4%) and 151 of 220 (68.6%) have heard of artificial intelligence and machine learning. In intensive care, 154 of 220 (70.0%) and 133 of 220 (60.5%) had heard of artificial intelligence and machine learning, while these figures were much lower in pain medicine [artificial intelligence: only 70/220 (31.8%) and machine learning 67/220 (30.5%)]. The main barriers to implementing these tools in clinical practice were: lack of knowledge of algorithms leading to the results; few validation studies available and not enough knowledge of artificial intelligence. Knowledge of telemedicine was reported in 212 of 220 (96.4%) members.

CONCLUSION Most anaesthesiologists are aware of artificial intelligence and machine learning. General thinking about the application of artificial intelligence in anaesthesiology, intensive care and pain management was positive overall, with most participants not considering this tool as a threat to their profession.

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KEY POINTS

- Most anaesthesiologists are aware of artificial intelligence and machine learning, but this knowledge is more related to anaesthesia and intensive care, and less so in pain medicine.
- The general approach of anaesthesia, intensive care and pain medicine clinicians towards artificial intelligence is positive.
- The general approach of anaesthesia, intensive care and pain medicine clinicians towards telemedicine is positive.
- Ethical, legal issues and a lack of understanding of certain algorithms are the main issues likely to hinder the application of artificial intelligence in clinical practice.

Introduction

The term 'artificial intelligence' refers to all technologies that allow computers to mimic human intelligence. Artificial intelligence relies on algorithms enabling machines to 'reason' and carry out tasks including problem-solving, object and word recognition and decision-making. Deep learning and machine learning are sub-categories of artificial intelligence. Not dissimilar to humans, deep learning and machine learning can improve through exposure to 'training data'.[1] In recent years, artificial intelligence has taken the first steps toward its implementation into daily clinical practice in anaesthesiology. Many artificial intelligence programmes are currently available for practical use, for example, the Food and Drug Administration (FDA) recently approved an artificial intelligence medical device intended to help identify anatomical structures in ultrasound images to facilitate regional anaesthesia.[2] A pre-operative machine learning risk algorithm capable of estimating the likelihood of death and eight other post-operative complications following surgery has been available online for some years now.[3] Another example is represented by a machine learning-derived early warning system for detecting hypotension, which has been tested and validated and is now available on the market.[4] Online, there is also available a machine learning algorithm capable of predicting the risk of acute kidney injury and progression to end-stage renal disease after total knee arthroplasty.[5] In this context, the discussion on the role of artificial intelligence has become increasingly important. Laypeople, economists, scientists, and politicians are aggressively debating this topic. However, the general public's understanding of artificial intelligence could be better, and there are mixed feelings about it. Although most people are positive about artificial intelligence's potential to enhance human life, there are also discussions about moral dilemmas, loss of control and unintended effects of using artificial intelligence carelessly.[6] As suggested in the 'lethal triad' for new technologies, there are three main threats that could hamper the implementation and dissemination of artificial intelligence; these are inconsistent data quality, ethical and legal issues and the lack of the appropriate digital infrastructure.[7] Moreover, as for all medical devices, it will be necessary to prove that the clinical outcomes of artificial intelligence-based tools are as good or better, and overcome the uncertainty of how it can be integrated into clinical workflow efficiently. An unanswered but crucially important question is whether artificial intelligence will ultimately increase healthcare quality at an affordable cost? Without the challenging effort required to address these problems, the medical community risks succumbing to the hype around artificial intelligence and missing the opportunity to fully utilise its promise.[8] Ultimately, it is important to investigate clinicians' concerns about artificial intelligence, as user bias could be another obstacle to implementing artificial intelligence in daily practice.[9] van der Sande *et al.*[10] investigated the perspective of intensive care unit (ICU) personnel on artificial intelligence-based clinical decision support tools, and the majority of participants (88/125, 71%) did not trust artificial intelligence or had a neutral opinion.

On a different note, a more simplistic but rather important use of the technology is represented by telemedicine, defined by the World Health Organization as the provision of healthcare services via the use of communication technology to diagnose and treat diseases in a more time-efficient approach with significant potentials of cost-savings.[11] Potential growth areas for telemedicine implementation include virtual pre-operative evaluation and remote intra-operative and postoperative care.[12] An example is represented by the tele-anaesthesia performed in 2013 on patients located in Pisa, but the anaesthesia administration was controlled from Montreal. This successfully demonstrated how such technology could help in areas with a shortage of anaesthesiologists.[13]

To clarify several aspects about the level of knowledge of artificial intelligence, machine learning and telemedicine, we conducted a web-based online survey inviting physicians affiliated to two societies in the fields of anaesthesiology, intensive care and pain medicine. We also explored their main concerns regarding the implementation of artificial intelligence, and which actions are needed to allow adequate diffusion and development of artificial intelligence technologies.

Methods

Study design and participants

Following recommendations and approval from the European Society of Anaesthesiology and Intensive Care (ESAIC) and the Italian Society of Anaesthesia, Analgesia, Resuscitation and Intensive Care (SIAARTI) Research

Committees, this voluntary-initiated anonymous survey was carried out from 28 June 2022 to 29 October 2022.

The Declaration of Helsinki and other pertinent standards and laws were followed throughout the process. It was not necessary to obtain approval from an Ethical Committee, Internal Review Board or Licensing Committee because participation did not compromise the participants' physical or psychological integrity, no biomaterials were obtained and the survey was anonymous.

All individuals provided their informed consent before answering the survey. The survey was created using the Google forms platform and was tested by the study group. The ESAIC secretariat emailed the survey link to all clinicians specialised in anaesthesia resuscitation, intensive care and pain medicine who were active members of ESAIC. A total of 4465 e-mails were sent. No rewards were given for joining the survey. Participants were provided with a translated version of the questions into their own language.

The survey included 39 questions, 7 of them concerning the characteristics of the responder and their hospital. The remaining 33 were divided as follows: 5 on artificial intelligence, 4 on machine learning, 13 on artificial intelligence and machine learning jointly and 6 on telemedicine. The entire version of the questionnaire is available: Supplement Survey Questions, http://links.lww.com/EJAIC/A53.

On average less than 10 min was required to complete the survey. Respondents were not permitted to omit questions. Most of the questions were multiple choice, while some permitted multiple answers and, importantly, some were adaptive so that their presentation was conditional on the answers to previous questions. A back button allowed respondents to examine and edit their responses.

Statistical analysis

Continuous variables were reported as mean ± SD, categorical variables as number (%). Sample characteristics were summarised, and the responses' absolute and relative frequencies were reported in tables. We fitted a series of latent class models and considered the survey questions as class-defining variables to identify qualitatively different subgroups within the respondents. We fitted models with latent classes ranging from two to five classes. The model selection criterion was based on the Bayesian information criterion, log likelihood ratio test and the size of the smallest class. The latent class model was estimated using the expectation–maximisation method, which allows the full use of data from all responders. The significance level was set at 5%. All statistical analyses were carried out using R version 4.1.2 (R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/).

Sample size calculation

We calculated the sample size for the survey from the question 'Have you ever read at least one article on artificial intelligence/machine learning in anaesthesiology, intensive care or pain medicine?'.

A prevalence of 50% was assumed, leading to a more conservative (larger) sample size of 223 respondents to achieve a precision of 6.5% for a 95% confidence level, considering a population of 10 000 anaesthesiologists.

Results

The main definitions of technologies covered in this survey are summarised in Table 1.

There were 220 participants in the survey from 143 cities and 38 different countries: mean age 46.5 ± 10.23, 128 men (58.2%). The geographical distribution of respondents is shown in Fig. 1. The majority of the respondents worked mostly in anaesthesiology, followed by intensive care and pain medicine (Table 2). Their work experience is shown in Supplementary Figure 1, http://links.lww.com/EJAIC/A54.

Artificial intelligence and machine learning knowledge

Knowledge about artificial intelligence and machine learning was reported by 207 of 220 (94.1%) and 180 of 220 (81.8%) members, respectively. Among the whole population of respondents, 168 of 220 (76.4%) and 151 of 220 (68.6%) declared they had heard of artificial intelligence and machine learning with reference to anaesthesiology. Similar figures were reported for intensive care, with 154 of 220 (70.0%) and 133 of 220 (60.5%) that have heard of artificial intelligence and machine learning. Conversely, only 70 of 220 (31.8%) and 67 of 220 (30.5%) were aware of the use of artificial intelligence and machine learning in pain medicine.

In total, 137 of 220 (62.3%) respondents had read at least one article on artificial intelligence or machine learning in anaesthesiology, intensive care or pain medicine. Among these participants, 49 of 137 (35.8%) found it difficult to read because of the methodology employed in the studies. Some 87.7% (193/220) of the respondents said they favour the use of tools adopting artificial intelligence or machine learning algorithms (Table 3).

Issues limiting the implementation of artificial intelligence

When asked about the main deterrents in implementing these tools in clinical practice, the main reasons reported were: lack of knowledge of the specific algorithm that leads to the results, the lack of validation studies and not enough knowledge on artificial intelligence in general. Similarly, 192 of 220 (87.3%) of participants reported they would use scores produced by artificial intelligence or machine learning, with the main deterrents to employing

Table 1 Common terms, definitions and practical examples used in artificial intelligence

Tools	Most used definition in medicine	Practical examples in anaesthesiology, intensive care and pain medicine
Artificial intelligence	Techniques that enable computers to mimic human intelligence function.[1]	Improvement of resources management Assistance in nonexpert training Improve peri-operative evaluation Assistance in the decision-making process
Machine learning	A field of computer science that deals with teaching computers to perform tasks by giving them the ability to study patterns in data, without being explicitly programmed.[13]	Peri-operative risk stratification Prediction of intra-operative adverse events Management of postoperative pain Management of operating room and intensive care unit resources Prediction of therapy response Identification of anatomical structures in order to assist procedures
Deep learning	A type of ML that learns on its own how best to represent data as a hierarchy of concepts, with each concept defined through its relation to simpler concepts.[13]	Monitoring depth of anaesthesia Identification of ultrasound anatomical structures
Artificial neural networks	Network composed of nodes or 'neurons' that each perform a computational operation and through which information flows by means of weighted interconnections; to learn to perform a specific task, these weights can be tuned.[13]	Identification of US anatomical structures Prediction of difficult intubation and airway evaluation
Telemedicine	The provision of healthcare services via the use of communication technology for the diagnosis and treatment of diseases and for continuing education of healthcare providers in settings where distance is a factor.[14]	Remote pre-operative evaluation Monitoring postsurgical patients Territorial healthcare services.
Big data	A large amount of electronic health data, difficult to manage by traditional software.[15]	Basic tool for creation of new artificial intelligence algorithms
Clinical decision support system	Variety of computerised tools and interventions essential to achieve the full benefits of electronic health records and computerised physician order entry.[16]	Tool for decision making systems Correct prescription of drugs (allergy, dose, interaction, contraindication)
Blockchain technology	Emerging technology being applied for creating innovative solutions; its network is used in the healthcare system to preserve and exchange patient data through hospitals, diagnostic laboratories, pharmacy firms, and physicians.[17]	Storage and connection of cryptographic records Sharing and authorisation of information
Wearable device(s)	Intelligent devices that can be wearable with the aim of assisting people.[18]	Intrahospital tracking of patients and resources Remote monitoring of patients
Electronic health record	The electronic documentation of a patient's medical history and care.[19]	Safe and always available approach to patient medical history and clinical character of
Internet of things	The network of Internet-connected medical devices, hardware, infrastructure, and software applications used to connect healthcare information technology.[20]	Creation of accurate database Drug dosage decision-making Mapping patient data directly into simulator environments before a procedure to enable practice.

Fig. 1 Heatmap representing geographical distribution of the participants' working centres; the scale is expressed in quantiles.

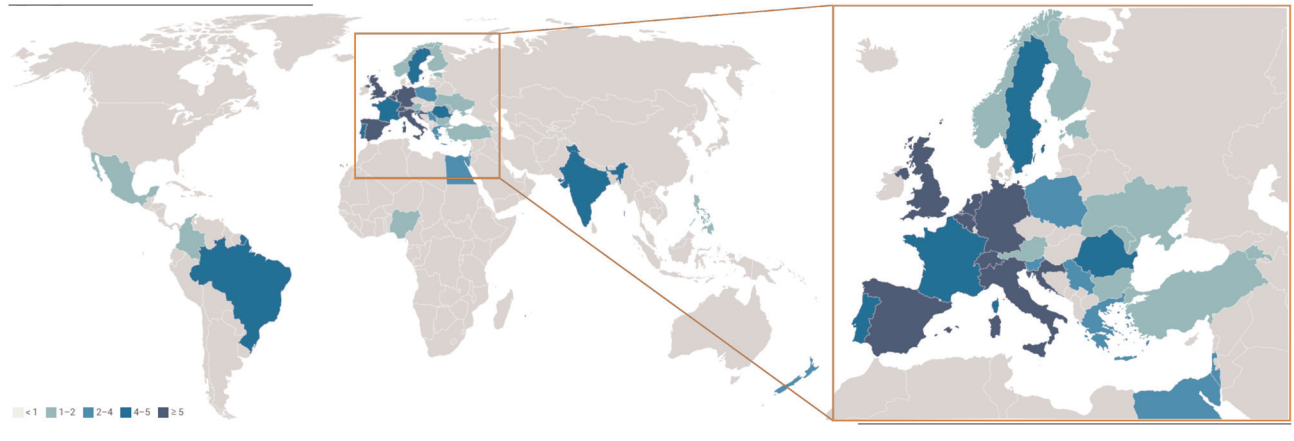


Table 2 Characteristics of participants

	Overall ($n = 220$)
Age	46.5 ± 10.23
Sex (male)	128 (58.2)
Years of work experience	
1 to 5 years	31 (14.1)
6 to 15 years	57 (25.9)
>6 years	123 (55.9)
Resident doctor (in training)	9 (4.1)
Percentage of time of working activity in anaesthesiology area	
0%	17 (7.7)
0 to 25%	39 (17.7)
26 to 50%	43 (19.5)
51 to 75%	50 (22.7)
76 to 100%	71 (32.3)
Percentage of time of working activity in intensive care area	
0%	71 (32.3)
0 to 25%	56 (25.5)
26 to 50%	42 (19.1)
51 to 75%	27 (12.3)
76 to 100%	24 (10.9)
Percentage of time of working activity in pain medicine area	
0%	109 (49.5)
0 to 25%	89 (40.5)
26 to 50%	16 (7.3)
51 to 75%	4 (1.8)
76 to 100%	2 (0.9)

Data are mean ± SD and *n* (%).

them being the same as for artificial intelligence/machine learning tools (Table 4 and Fig. 2).

From the cluster analysis, it emerged that physicians with more than 16 years of work experience are also those who claim to be the ones with more knowledge about artificial intelligence and who are more positive about investments in artificial intelligence and machine learning. Anaesthesiologists were the most concerned that artificial intelligence and machine learning could replace a clinician's work in the future. Finally, intensivists were the most skeptical towards artificial intelligence and identified its main use as being for prognostic models only.

Artificial intelligence training

Interestingly, 208 of 220 (94.5%) of colleagues answered that training using new artificial intelligence and machine learning technologies could enhance their confidence with these tools and a similar number (211/220, 95.9%) believed that training could lead to greater use of these technologies. A large proportion of respondents (198/220, 90.0%) reported they would have attended courses on this topic. Only 106 of 220 (48.2%) members believed that artificial intelligence and machine learning technologies would improve significantly their work activity in the future, and 91 of 220 (41.4%) reported an expected moderate improvement.

Will artificial intelligence replace your work?

Some 81.4% (179/220) of the participants did not believe that these new technologies would replace the work of the anaesthesiologist. For the remaining 18.6%, their answers to the adaptive questions indicated the most recurring themes were the ability for artificial intelligence to autonomously manage a closed loop in anaesthesiology, to increase overall patient safety through better monitoring and to manage a huge amount of data. The final threat perceived was that artificial intelligence/machine learning could reduce the anaesthesiologist to an airway technician employed for the manual procedures only. Less frequent concepts were scattered around the general idea of performance (efficiency, effectiveness and precision) and better ability to manage the cognitive burden.

Investing in artificial intelligence and fields of development

When asked how important is investment in technologies based on artificial intelligence and machine learning

Table 3 Knowledge of artificial intelligence and machine learning

	Overall ($n = 220$)
Have you ever heard of artificial intelligence in general? Yes	207 (94.1)
Have you ever heard of machine learning? Yes	180 (81.8)
Have you heard of artificial intelligence in medicine? Yes	196 (89.1)
Have you ever heard of artificial intelligence in anaesthesiology? Yes	168 (76.4)
Have you ever heard of artificial intelligence in intensive care? Yes	154 (70.0)
Have you ever heard of artificial intelligence in pain medicine? Yes	70 (31.8)
Have you ever heard of machine learning in anaesthesiology? Yes	151 (68.6)
Have you ever heard of machine learning in intensive care? Yes	133 (60.5)
Have you ever heard of machine learning in Pain Medicine? Yes	67 (30.5)
Have you ever read at least one article on artificial intelligence/machine learning in anaesthesiology, intensive care or pain medicine? Yes	137 (62.3)
Did you find it difficult to read? Yes	49 (35.8)
In which aspect did you find it most difficult?	
Evaluate its clinical usefulness	6 (12.2)
Understanding of the methods	36 (73.5)
Understanding of the results	7 (14.3)
Would you employ a tool that uses an artificial intelligence and/or machine learning algorithm? Yes	193 (87.7)

Data are *n* (%).

Table 4 Main deterrents to use of an artificial intelligence-based tool

	Overall ($n = 220$)
Legal and medical liability issues	97 (44.1)
Not enough knowledge on artificial intelligence in general	88 (40.0)
Lack of knowledge of the specific algorithm that leads to the result	101 (45.9)
Other...45	6 (2.7)
No deterrents at all	2 (0.9)
Prognostic models predicting mortality	152 (69.1)

Data are *n* (%).

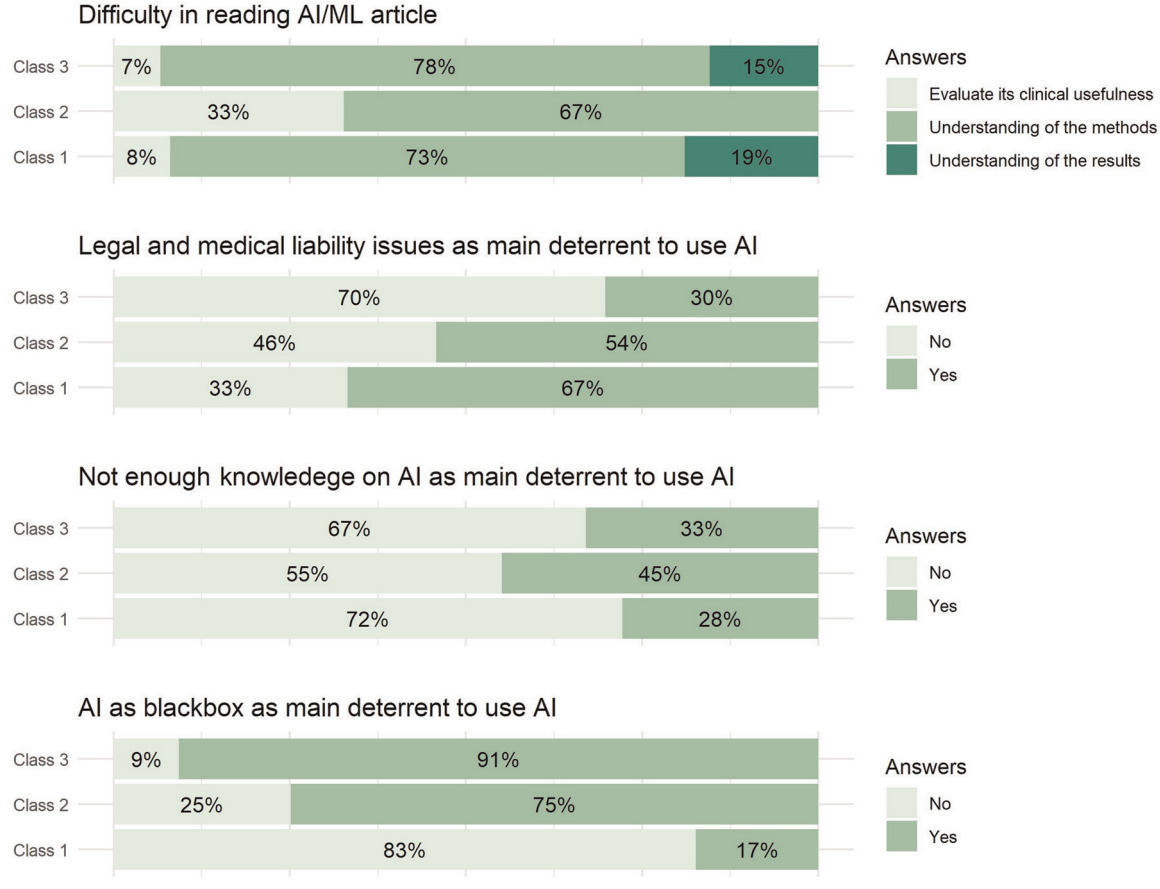
algorithms in anaesthesiology, intensive care and pain medicine, 119 of 220 (54.1%) replied that it is very important. The main uses in clinical practice were found to be prognostic models predicting mortality; models of support for the doctor in therapeutic choices for the patient (clinical decision support system such as drug dosage adjustment and indications for the start of organ support therapy); monitoring models integrated in electronic health records able to provide real-time assessments of the risk of developing complications; and diagnostic support models (e.g. imaging exam reporting and early diagnosis of sepsis).

Regarding ethical and legal issues, these influence the use of these technologies according to the answers of 168 of 220 (76.4%) respondents. Similarly, 178 of 220 (80.9%) stated they would have felt more encouraged to use such tools in the presence of clearer legislation (Table 5 and Fig. 3).

Telemedicine

Regarding telemedicine, 212 of 220 (96.4%) participants had heard of it in general, whereas 150 of 220 (68.2%) had heard of it in the context of anaesthesiology, intensive care or pain medicine. The respondents believed that the main uses of telemedicine in these fields were tele-visits, in-hospital tele-monitoring and out-of-hospital remote monitoring. Most respondents (172/220, 78.2%) believed that telemedicine tools could improve their work, and most of them felt that these instruments could offer benefits to patients such as improved accessibility to care, implementing distance monitoring systems and

Fig. 2 Clustering of responses on the main deterrents to use of an artificial intelligence-based tool.



Three classes were identified: class 1 is represented by respondents with 16 years or more of work experience; class 2 is represented mostly by those who work in intensive care; class 3 is composed mostly by those who work in anaesthesiology.

Table 5 Employment of artificial intelligence and machine learning

	Overall ($n = 220$)
Would you employ a score that uses an artificial intelligence and/or machine learning algorithm? Yes	192 (87.3)
Do you think that training dedicated to the use of new artificial intelligence and machine learning technologies in the anaesthesiology field can lead to greater confidence in them? Yes	208 (94.5)
Do you think that training dedicated to the use of new artificial intelligence and machine learning technologies in the anaesthesiology field can lead to greater use of the same? Yes	211 (95.9)
Would you take an artificial intelligence and/or machine learning course in anaesthesiology, intensive care and/or pain medicine? Yes	198 (90.0)
Do you think these technologies will improve your work in the future?	
Not at all	5 (2.3)
Little	18 (8.2)
Moderately	91 (41.4)
Much	106 (48.2)
Do you think that in the future your work can be replaced by these new technologies? Yes	41 (18.6)
Do you think that today it can be useful to invest in technologies based on artificial intelligence and machine learning algorithms in anaesthesiology/intensive care/pain medicine?	
Not at all	3 (1.4)
Little	17 (7.7)
Moderately	81 (36.8)
Much	119 (54.1)
How much do you think that ethical–legal issues affect the use of these technologies to date?	
Not at all	8 (3.6)
Little	44 (20.0)
Moderately	86 (39.1)
Much	82 (37.3)
If the legislature were clearer in this regard, would you be more incentivised in using these technologies?	
Not at all	12 (5.5)
Little	30 (13.6)
Moderately	92 (41.8)
Much	86 (39.1)

Data are *n* (%).

decreasing the time patients spent in hospital (Table 6 and Fig. 4).

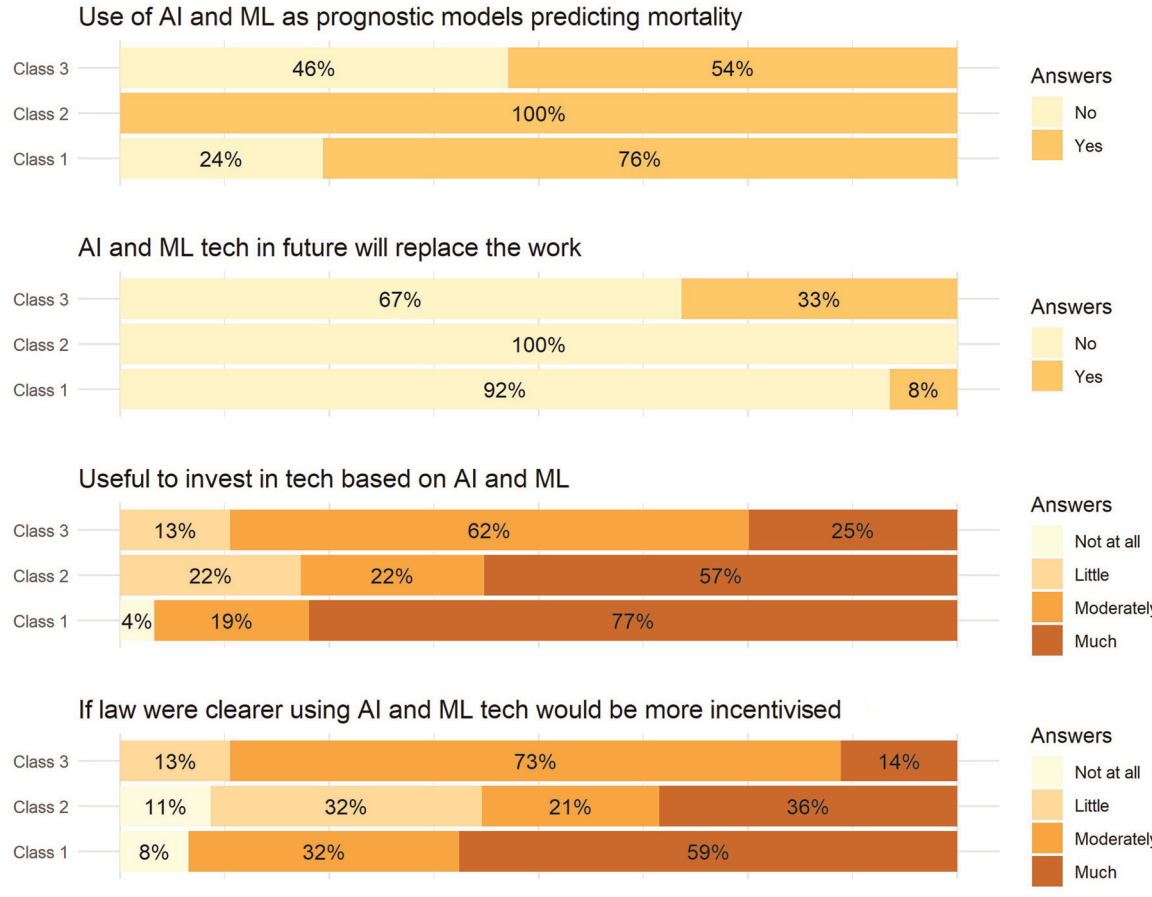
Discussion

Our international survey, involving 220 clinicians who were active members of ESAIC, found that most specialists are aware about artificial intelligence and machine learning, but this knowledge is more related to anaesthesia and intensive care and less so to pain medicine. Only 13 clinicians reported that they had never heard about artificial intelligence (mean age of 46, 9 women) without any statistically significant demographic difference with the other groups of participants. This can be mainly linked to two factors: less scientific literature on the topic; only a small fraction of the respondents works in the field pain medicine. The main obstacles to the implementation of artificial intelligence resulted from a lack of knowledge of the specific algorithm that led to the result, the fact that only a few validation studies were available, not enough knowledge on artificial intelligence in general and the lack of understanding in medical artificial intelligence.

A large majority of respondents (208/220, 94.5%) answered that training using of new artificial intelligence and machine learning technologies could enhance their confidence with these tools, and a similar number (211/220, 95.9%) believed that training could lead to greater use of these technologies. A large proportion of respondents (198/220, 90.0%) reported they would attend courses on this topic. Only 106 of 220 (48.2%) members believed that artificial intelligence and machine learning technologies would significantly improve their work activity in the future, with 91 of 220 (41.4%) expecting only a moderate improvement.

Although most respondents were in favour of improving their knowledge on artificial intelligence/machine learning with ad hoc courses and lessons, as stated above, less than half believed that artificial intelligence and machine learning technologies would significantly improve their work activity in the future. These apparently discordant findings may be explained by different time frames, particularly in the current state of art: clinicians believe that artificial intelligence is unlikely to significantly improve their work, probably because of fear of increased workload, a lack of confidence in the technologies and a lack of personnel dedicated to the management of the instrumentation.[21] However, they would still be willing to open up to these technologies in the future by increasing their knowledge and subsequently assessing the added value in clinical practice. As regards telemedicine, participants consider it as a useful tool for improving patients' access to care and only eight physicians have never heard of telemedicine (mean age 49, six women), with two of them having not even heard of artificial intelligence. No statistically significant demographic difference was found with the other respondents. Most believe artificial intelligence can be a key tool for remote monitoring both in the in-hospital and out-of-hospital

Fig. 3 Clustering of responses on employment of artificial intelligence and machine learning.



Three classes were identified: class 1 is represented by respondents with 16 years or more of work experience; class 2 is represented mostly by those who work in intensive care; class 3 is composed mostly by those who work in anaesthesiology.

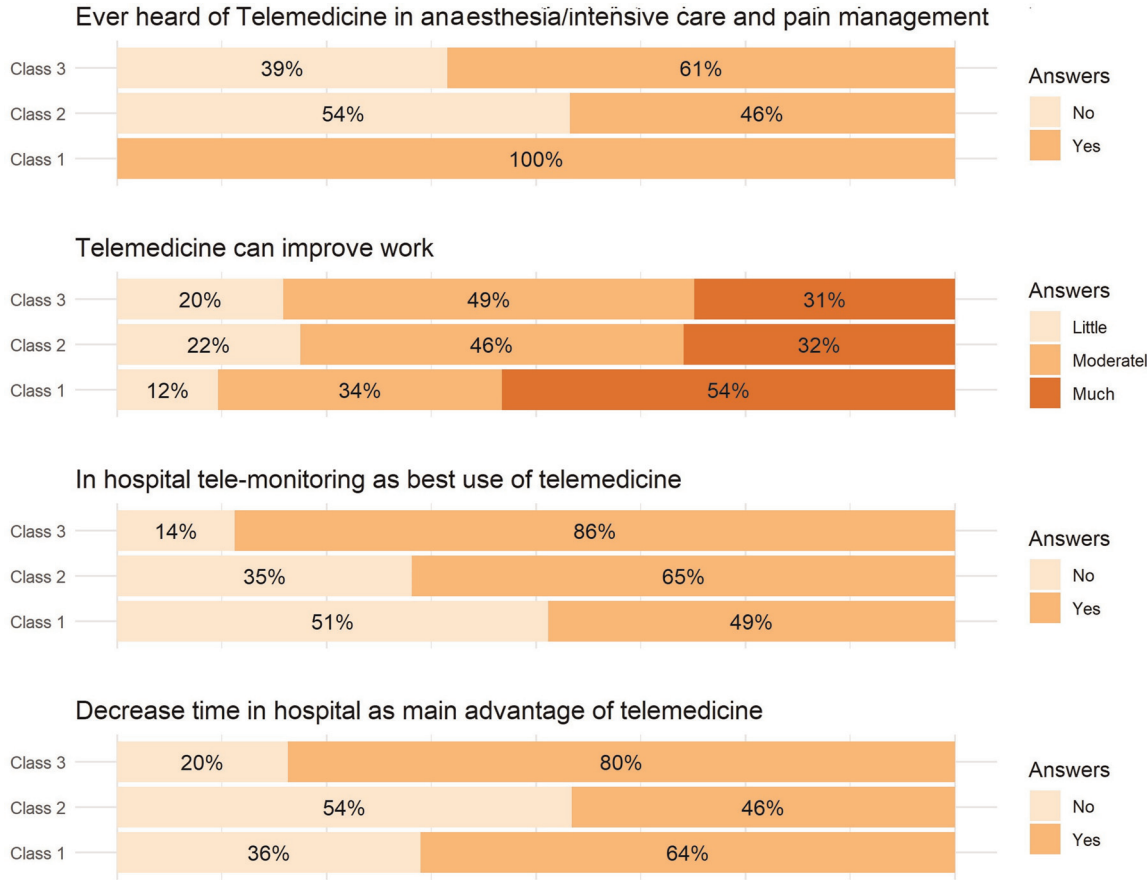
Table 6 **Responses on telemedicine**

	Overall ($n = 220$)
Have you ever heard of telemedicine? Yes	212 (96.4)
Have you ever heard of telemedicine in anaesthesiology/intensive care/pain medicine? Yes	150 (68.2)
Do you think that telemedicine tools could improve your work?	
Not at all	4 (1.8)
Little	44 (20.0)
Moderately	89 (40.5)
Much	83 (37.7)
Do you think that telemedicine tools could offer benefits to patients? Yes	205 (93.2)
Best use of telemedicine (multiple choice)	
In-hospital tele-monitoring	149 (67.7)
Out-of-hospital remote monitoring	150 (68.2)
Access to consulting colleagues	1 (0.5)
I do not know	17 (7.7)
Resident on call instruction from senior doctors	1 (0.5)
Advantage of telemedicine (multiple choice)	
Implement monitoring systems	154 (70.0)
Decrease the time spent in hospital	128 (58.2)
Improve accessibility to care	156 (70.9)

settings. To our knowledge, this is the first survey investigating the level of knowledge and the opinions on artificial intelligence and telemedicine systems involving ESAIC active members specialised in anaesthesia, intensive care and pain medicine.

The data also indicated that respondents with more than 16 years of work experience are also those who claim to be more confident with artificial intelligence technologies and who support investment in artificial intelligence and machine learning technologies. Those who work in the field of anaesthesiology are the ones most concerned that artificial intelligence and machine learning could replace the clinician in the future. Finally, those working in intensive care are the most skeptical towards artificial intelligence, identifying its main use as being for prognostic models only. Despite the current artificial intelligence technology available allowing the development of algorithms able to discriminate best treatment strategies for each patient, a serious ethical and legal problem arises;

Fig. 4 Clustering of responses on telemedicine.



Three classes were identified: class 1 is represented by respondents with 16 years or more of work experience; class 2 is represented mostly by those who work in intensive care; class 3 is composed mostly by those who work in anaesthesiology.

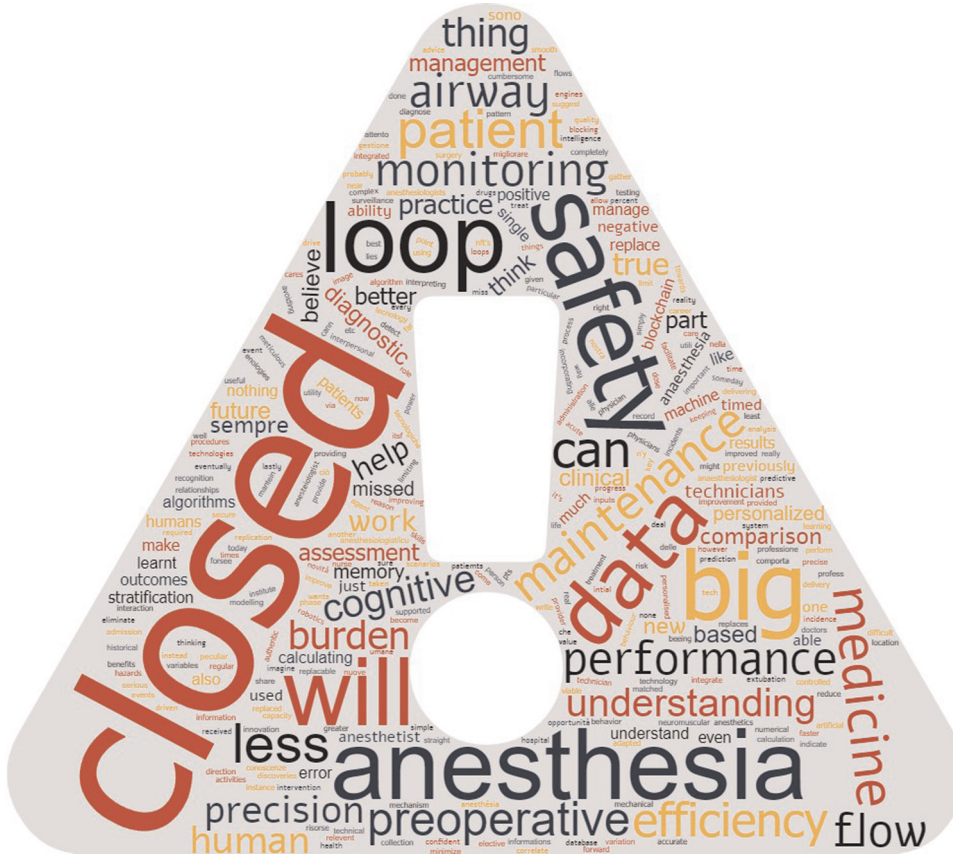
can a possible error of the machine algorithm be attributed to the doctor in charge?[22–24] In this regard, science is moving more and more towards implementation of explainable artificial intelligence technologies that allow clinicians to have all the data required to autonomously evaluate the validity of the decision made (or better, suggested) by the software.[25] In fact, regardless how technically accurate a 'blackbox' system may be, opacity in medical artificial intelligence systems can constitute a significant barrier to the realisation of improved downstream patient health outcomes.[26,27] In line with this idea, in our survey, a lack of understanding of medical artificial intelligence technology emerged among the main deterrents to implementing these technologies. Concepts and fears gathered with open answers are graphically summarised in the word cloud (Fig. 5).

As 19th century luddism demonstrated, fears can erroneously lead to a rejection of technology. Still, when studied and discussed, these fears could represent the starting point for integrating the work between artificial and human intelligence leading to hybrid clinical decision-making.[1] Furthermore, current artificial intelligence tools are focused on predicting final diagnostic labels instead of helping clinicians throughout the whole process of diagnosis. This concept highlights the importance of shifting the role of diagnostic artificial intelligence from predicting labels to interpreting context and providing cues.[28] The general approach to artificial intelligence that emerged from our study turned out to be positive overall, with the majority of participants who do not consider artificial intelligence as a threat to their profession but rather a valuable assistance in daily practice.

Our study has some strengths but we also acknowledge several limitations. A strength of our survey was the availability of multilanguage options; moreover, we also collected demographic and other personal data allowing us to characterise the predominant work setting for each respondent. Another strength is that we surveyed only physicians specialised in anaesthesia, intensive care or pain medicine.

Unfortunately, our survey had a small response rate (4.92%) considering the total number of ESAIC active members, but this is a known issue for surveys as reported

Fig. 5 Word cloud representing the absolute word count of answers about the possibility of being replaced by artificial intelligence.



in similar studies.[10,29–31] Most responses came from Italy (104/220), lowering the external validity. Furthermore, there could be a self-reported bias since it is probable that those who responded to the survey are those more interested or intrigued by the topic.

Conclusion

Our survey showed that most anaesthesiologists are aware of the potential role of artificial intelligence and machine learning, but this seems predominantly confined to anaesthesia and intensive care, and much less in the setting of pain medicine. The general thinking about the application of artificial intelligence in anaesthesia, intensive care and pain management was positive overall, with the majority of participants not considering it as a threat to their profession in the future but rather a valuable support. Ethical, legal issues and a lack of understanding of certain algorithms seem the main issues hindering the application of artificial intelligence in clinical practice.

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