ORIGINAL CLINICAL RESEARCH REPORT

Artificial Intelligence in Anesthetic Care: A Survey of Physician Anesthesiologists

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BACKGROUND: This study explored physician anesthesiologists' knowledge, exposure, and perceptions of artificial intelligence (AI) and their associations with attitudes and expectations regarding its use in clinical practice. The findings highlight the importance of understanding anesthesiologists' perspectives for the successful integration of AI into anesthesiology, as AI has the potential to revolutionize the field.

METHODS: A cross-sectional survey of 27,056 US physician anesthesiologists was conducted to assess their knowledge, perceptions, and expectations regarding the use of AI in clinical practice. The primary outcome measured was attitude toward the use of AI in clinical practice, with scores of 4 or 5 on a 5-point Likert scale indicating positive attitudes. The anticipated impact of AI on various aspects of professional work was measured using a 3-point Likert scale. Logistic regression was used to explore the relationship between participant responses and attitudes toward the use of AI in clinical practice.

RESULTS: A 2021 survey of 27,056 US physician anesthesiologists received 1086 responses (4% response rate). Most respondents were male (71%), active clinicians (93%) under 45 (34%). A majority of anesthesiologists (61%) had some knowledge of AI and 48% had a positive attitude toward using AI in clinical practice. While most respondents believed that AI can improve health care efficiency (79%), timeliness (75%), and effectiveness (69%), they are concerned that its integration in anesthesiology could lead to a decreased demand for anesthesiologists (45%) and decreased earnings (45%). Within a decade, respondents expected AI would outperform them in predicting adverse perioperative events (83%), formulating pain management plans (67%), and conducting airway exams (45%). The absence of algorithmic transparency (60%), an ambiguous environment regarding malpractice (47%), and the possibility of medical errors (47%) were cited as significant barriers to the use of AI in clinical practice. Respondents indicated that their motivation to use AI in clinical practice stemmed from its potential to enhance patient outcomes (81%), lower health care expenditures (54%), reduce bias (55%), and boost productivity (53%). Variables associated with positive attitudes toward AI use in clinical practice included male gender (odds ratio [OR], 1.7; $P < .001$), 20+ years of experience (OR, 1.8; $P < .01$), higher AI knowledge (OR, 2.3; $P = .01$), and greater AI openness (OR, 10.6; $P < .01$). Anxiety about future earnings was associated with negative attitudes toward AI use in clinical practice (OR, 0.54; $P < .01$).

CONCLUSIONS: Understanding anesthesiologists' perspectives on AI is essential for the effective integration of AI into anesthesiology, as AI has the potential to revolutionize the field. (Anesth Analg 2023;XXX:00–00)

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This study was deemed exempt research by the University of Pennsylvania Institutional Review Board on November 23, 2020 (protocol no. 844568).

The authors declare that data supporting the survey findings are available within the paper and the supplementary files. Raw data are available on request.

During the preparation of this manuscript, the authors utilized the ChatGPT Default model (version GPT-3.5) developed by OpenAI as an AI-based tool to enhance clarity, coherence, and overall quality, while maintaining the original creative and intellectual contributions of the authors. After utilizing this tool, the authors reviewed and edited the content as necessary, taking full responsibility for the publication's content.

Reprints will not be available from the authors.

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KEY POINTS

- **Question:** Which factors inform physician anesthesiologists' attitudes toward using artificial intelligence (AI) in clinical practice?
- **Findings:** The study explored the associations between physician anesthesiologists' knowledge, exposure, and perceptions of AI and their attitudes toward using AI in clinical practice, the perceived association of AI with professional work, and the factors related to their attitudes and characteristics relevant to AI use in clinical practice.
- **Meaning:** This study reveals key factors for successfully integrating AI in anesthesia to enhance patient care and advance the profession.

GLOSSARY

AI = artificial intelligence; **ASA** = American Society of Anesthesiologists; **CIs** = confidence intervals; **CROSS** = Checklist for Reporting of Survey Studies; **ORs** = odds ratio; **SMDs** = standardized mean differences; **TAM** = Technology Acceptance Model; **UTAUT** = Unified Theory of Acceptance and Use of Technology

Artificial intelligence (AI) is radically transforming the way humans and machines work together.[1,2] In health care, the application of AI has tremendous potential as a tool for augmenting medical practice (eg, disease diagnosis, treatment selection, and patient monitoring), transforming translational research (eg, biomarker discovery, drug-target, and genetic variant identification), enhancing biomedical research (eg, automated data collection, and gene function elucidation), and simplifying health care management. Compared to other industries, however, the rate of AI adoption in medicine has been relatively slow.[3,4]

The term "artificial intelligence" was initially defined by John McCarthy in 1956 and refers to the emulation of human intelligence in machines. These machines are programmed to learn from experience and perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation.[5–9] Machine learning, a subset of AI, allows machines to learn from data without explicit programming. Instead of simply automating manual tasks, AI algorithms adapt and learn through complex mathematical formulas, enabling data-driven programming without human intervention.[10,11]

The capacity to derive valuable insights efficiently and reliably from complex data sources has led to the widespread adoption of AI in various medical specialties, including radiology, dermatology, and pathology.[12–14] AI solutions are already being used in anesthesiology to address opportunities throughout the perioperative care continuum.[15–18] For example, AI is being used to optimize preoperative health, facilitate ultrasound-driven regional anesthesia, monitor the depth of anesthesia, predict adverse perioperative events, and efficiently schedule operating rooms.[6,19–23] Despite the progress made, there are substantial obstacles hindering the acceptance and adoption of AI among anesthesiologists.

The main objective of this cross-sectional study was to investigate the factors associated with physician anesthesiologists' attitudes toward the use of AI in clinical practice. Our research model encompassed various factors related to technology adoption, such as current practice, familiarity with technology, beliefs, risk perception, risk acceptability, tradeoffs, error tolerance, and effort expectancy. Understanding the factors that shape physicians' attitudes and intentions to use AI is essential for promoting its integration into clinical practice. Neglecting the diverse knowledge, perceptions, and expectations of stakeholders regarding AI's application in health care can impede innovation, contribute to stress and burnout, and worsen existing disparities in health and technology.

MATERIALS AND METHODS

This nationwide web-based survey of physician anesthesiologists follows a cross-sectional design and adheres to the Checklist for Reporting of Survey Studies (CROSS) (Supplemental Digital Content, Supplemental Text Document A, http://links.lww.com/AA/E569).[24]

Data from survey respondents remained anonymous, with no personal information collected. The study was deemed exempt research by the University of Pennsylvania Institutional Review Board (protocol no. 844568) and used password-protected survey platform access for data security.

Sample Design

Population. The survey focused on US-based physician anesthesiologists who were members of the American Society of Anesthesiologists (ASA). The sample excluded medical students, CRNAs, physicians from other specialties, and those practicing outside the US. Survey participation was voluntary and uncompensated.

Sample. The study included a representative sample of 27,056 ASA active members, obtained from

ASA Analytics and Research Services, ensuring a comprehensive representation of the target population. Member descriptors such as age, gender, position, and practice region were considered in the sample.

Data Collection Protocol

Email Invitation and Reminders. Invitations were sent via ASA email accounts to increase open rates, and those who completed the survey were excluded from reminders. The survey was open from May 2 to June 13, 2021. Reminder emails were sent to eligible nonrespondents, with a maximum of 3 reminders. The first email on May 9 was from Dr Lane-Fall, the second on May 23 from Dr Hanson, and the final on June 5 jointly from Dr Hanson and Dr Lane-Fall. The last email specifically targeted incomplete questionnaire starters. Complete reminder email texts can be found in Supplemental Digital Content, Supplemental Text Document B, http://links.lww.com/AA/E569.

Survey Instrument. A team of 5 anesthesiologists conducted a literature review to define AI for the survey. They developed an initial set of 45 questions based on technology, electronic health records, and AI.[25–28] The Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) were referenced to guide the research model (Figure 1).[29,30] Nine physician anesthesiologists pilot-tested the questions, leading to revisions and a final survey of 42 questions (Supplemental Digital Content, Supplemental Text Document C, http://links.lww.com/AA/E569). The online survey was hosted on the Qualtrics platform and consisted of 3 sections: general AI, AI in medicine, and anesthesiology (addressing various aspects including health care quality, risks, attitudes toward the use of AI in clinical practice, and the potential effects on the workforce), and respondent characteristics. Participants provided consent and their responses were anonymous. The survey aimed to assess US-based physician anesthesiologists' familiarity, attitudes, and expectations regarding AI in clinical practice.

Primary Outcome Measure. The primary objective of the study was to evaluate participants' attitudes toward using AI in clinical practice. Using a 5-point Likert scale ranging from "Very negative" (1) to "Very positive" (5), respondents were asked to rate their sentiment. To simplify data interpretation and analysis, respondents' attitudes were categorized into 2 distinct groups. A positive attitude was assigned to individuals scoring 4 or 5, indicating a favorable attitude, while scores of 1, 2, or 3 were classified as negative or neutral attitudes.

Secondary Outcome Measures. Participants' expectations regarding the association of AI with their professional work were measured using a 3-point Likert scale. They were asked 2 questions: whether they believed their earning potential and the

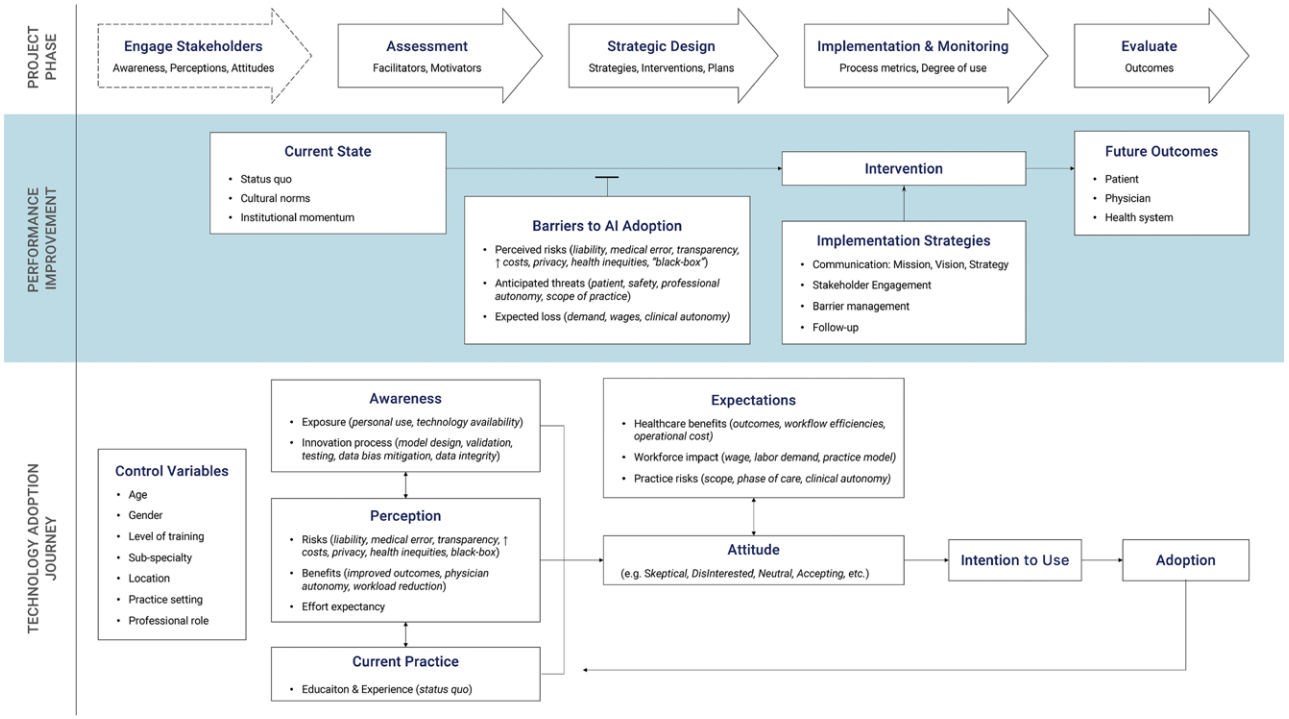

Figure 1. Proposed research model.

number of anesthesiologists required to serve the US population would be affected by AI in their lifetime. Responses were categorized as positive (indicating an increase) or negative/neutral (indicating a decrease or no change) for simplicity in data analysis.

Statistical Analysis

Patient- and Practice-Related Characteristics by Attitude Toward Using AI in Clinical Practice. Assessment of sample completeness and representativeness involved comparing available characteristics between survey respondents and ASA member descriptors. Standardized mean differences (SMDs) were used to quantify the magnitude of difference between the cohorts, with an SMD ≥ 0.20 considered indicative of a clinically important difference or potential imbalance. Effect sizes were categorized as small (SMD ≥ 0.20 to <0.50), medium (SMD ≥ 0.50 to <0.80), or large (SMD ≥ 0.80).[31] Univariate analysis was conducted to compare patient- and practice-related characteristics between respondents with positive and negative attitudes toward AI use in clinical practice. Furthermore, we investigated the perceived association of AI with various aspects of professional work. Categorical variables were presented as percentages. Incomplete survey responses were identified, and variables with missing values were denoted in the tables by specifying the denominator count. Missing data were not imputed.

Logistic Regression Analyses. Univariate and multivariable logistic regression was used to estimate the associations between candidate variates and the odds of having a positive attitude toward using AI in clinical practice. The thirteen variables outlined in Table 2 were considered for analysis. Each variable was given equal consideration, without any preconceived confounding variable assumptions, due to the uncertainty surrounding which variables, if at all, could act as confounders. The study used SAS PROC LOGISTIC to select variables for a logistic regression model. The entry and retention criteria were set at 0.25 and 0.1, respectively.[32] Ten potential covariates were identified through univariate analysis at the .25 α level. Three variables—age, position, and demand for anesthesiologists—were not significant at the 0.25 level and were excluded from subsequent models. No variables were eliminated during the iterative multivariable fitting process due to their lack of significance at the .1 α level. To be thorough, age, position, and demand for anesthesiologists were reevaluated 1 at a time with the 10 other covariates that had already been included in the model. However, these 3 variables did not individually reach statistical significance at the.1 α level, so they were not included in the final model. To address multiple comparisons, Bonferroni correction was applied by multiplying the P values by 45, representing the number of χ^2 tests being completed. This correction was utilized in both post hoc univariate and multivariable analyses. The significance threshold for all statistical tests was set at $\alpha = .05$.

The statistical analyses for this study were performed using SAS software (version 9.4, SAS Institute Inc) On Demand for Academics, IBM SPSS Statistics (version 28.0, IBM Corp.), and R 2023 (version 3.0, version 3.0, R Core Team).

Sample Size Justification. The sample size was calculated to estimate the prevalence of a positive attitude toward AI with a 5% margin of error. Based on the average proportions reported in previous studies, it was estimated that around 50% of physicians hold a positive attitude toward AI.[25–27,33,34] With this assumed prevalence rate, a minimum of 370 responses was determined to be necessary for the study.[35] To ensure sufficient sample size, physician anesthesiologists were recruited over a 6-week period, anticipating the collection of several hundred responses.

RESULTS

Physician Anesthesiologist Characteristics

Between May 2 and June 13, 2021, 27,056 eligible physician anesthesiologists received survey invitations via email. In the initial week, 14,921 invitations were opened, resulting in 581 unique survey clicks. From May 23 to June 6, 2021, 15,423 invitations were opened, with 309 unique survey clicks. Overall, there were 1596 unique survey clicks. The response rate was 4%, with 1086 completing the survey for analysis (Supplemental Digital Content, Supplemental Figure 1, http://links.lww.com/AA/E569).

There were moderate differences in baseline characteristics between survey respondents and ASA members, including a higher percentage of individuals aged 45 and older (66% vs 54%), fewer females (25% vs 30%), and more attending physicians (93% vs 83%) (Table 1). Most respondents (53%) had 0 to 20 years of experience and practiced at university/academic medical centers or community hospitals (39% each). The majority (94%) were primarily involved in clinical work and expressed overall satisfaction (93%) with their career choice as physician anesthesiologists.

Knowledge and Exposure to AI

Figure 2A presents respondents' baseline knowledge of AI. Among them, 61% had some knowledge, with gender differences observed (48% for females vs 66% for males, $P < .001$) (Supplemental Digital Content, Supplemental Table 1, http://links.lww.com/AA/E569). Community hospital physicians had lower AI

Table 1. Survey Respondent Demographics and Characteristics

Variable	Survey respondent (n = 1086)	ASA member[a] (n = 26,971)	Total (N = 28,057)	Standardized difference[b] (95% CI)	*P* value*
Age					<.001
25–34 y old	103 (9.5%)	4561 (16.9%)	4664 (16.6%)	0.34 (0.28–0.40)	
35–44 y old	263 (24.2%)	7822 (29.0%)	8085 (28.8%)		
45–54 y old	273 (25.1%)	5729 (21.2%)	6002 (21.4%)		
55–64 y old	341 (31.4%)	5979 (22.2%)	6320 (22.5%)		
65–74 y old	99 (9.1%)	2327 (8.6%)	2426 (8.6%)		
75 y or older	5 (0.5%)	156 (0.6%)	161 (0.6%)		
Missing	2 (0.2%)	397 (1.5%)	399 (1.4%)		
Gender, n (%)				0.23 (0.17–0.30)	<.001
Female	272/1085 (25.1%)	8198 (30.4%)	8470 (30.2%)		
Male	772/1085 (71.2%)	18,577 (68.9%)	19,349 (69.0%)		
Non-cisgender identity	41/1085 (3.8%)	196 (0.7%)	238 (0.8%)		
Position, n (%)				0.38 (0.32–0.44)	<.001
Attending	1014 (93.4%)	22,353 (82.9%)	23,381 (83.3%)		
Resident	72 (6.6%)	4618 (17.1%)	4676 (16.7%)		
Region, n (%)				0.25 (0.19–0.31)	<.001
Midwest	285/1085 (26.3%)	5843 (21.7%)	6128 (21.8%)		
Northeast	243/1085 (22.4%)	5862 (21.7%)	6105 (21.8%)		
Other	0/1085 (0.0%)	567 (2.1%)	567 (2.0%)		
South	310/1085 (28.6%)	9044 (33.5%)	9354 (33.3%)		
West	247/1085 (22.8%)	5655 (21.0%)	5902 (21.0%)		
Setting, n (%)					
Community hospital	424 (39.0%)				
University/academic medical center	422 (38.9%)				
Private/group practice clinic	204 (18.8%)				
Veterans affairs/government-based	21 (1.9%)				
Other	15 (1.4%)				
Years in practice, n (%)					
0–20 y	574/1084 (53.0%)				
20+ years	510/1084 (47.0%)				
Professional role, n (%)					
Mostly clinical	1013/1084 (93.5%)				
Mostly administrative	40/1084 (3.7%)				
Mostly teaching	16/1084 (1.5%)				
Mostly research	12/1084 (1.1%)				
Other	3/1084 (0.3%)				
Career satisfaction, n (%)					
Extremely satisfied	640/1085 (59.0%)				
Somewhat satisfied	364/1085 (33.5%)				
Neither satisfied nor dissatisfied	28/1085 (2.6%)				
Somewhat dissatisfied	38/1085 (3.5%)				
Extremely dissatisfied	13/1085 (1.2%)				
Prefer not to answer	2/1085 (0.2%)				

Abbreviations: AI, artificial intelligence; ASA, American Society of Anesthesiologists; CI, confidence interval.

[a]Demographic information was unavailable or incomplete for 535 of 27,506 (1.9%) ASA members.

[b]Standardized difference = difference in means or proportions divided by standard error; imbalance defined as absolute value greater than 0.20 (small effect size).

*Chi-square *P* value.

knowledge (55%) compared to academic medical center (65%) and private practice (67%) physicians ($P < .05$ and $P = .04$, respectively) (Supplemental Digital Content, Supplemental Table 2, http://links.lww.com/AA/E569). Additionally, 67% agreed they could identify AI examples in their daily routines, and 81% expressed openness to incorporating AI for enhancing their lives (Figure 2B, Supplemental Digital Content, Supplemental Table 3, http://links.lww.com/AA/E569). Nearly half (48%) considered AI the most significant technology of their lifetime. University/academic medical center physicians showed higher openness to AI (88%) than community hospital (76%) and private practice (79%) physicians ($P < .001$ and $P = .02$, respectively).

Attitude Toward Using AI in Clinical Practice

Attitudes toward using AI in clinical practice were assessed (Figure 2C). Nearly half of respondents (48%) expressed positive attitudes toward the use of AI in clinical practice, reflecting a growing acceptance of technology-driven health care. However, 36% had concerns, 42% felt hopeful, and 50% were curious about the potential impact of AI on health care. Regarding care preference, 75% favored human anesthesiologists over an AI anesthesiologist. Positive

Table 2. Factors Related to Positive and Negative Attitude Toward the Use of Artificial Intelligence in Clinical Practice

	How would you describe your feelings regarding using AI in your practice?		
Variable	**Negative/neutral (n = 569)**	**Positive (n = 514)**	***P* value***
Age			.01
25–34 y old	53 (51.5%)	50 (48.5%)	
35–44 y old	157 (59.7%)	106 (40.3%)	
45–54 y old	151 (55.5%)	121 (44.5%)	
55–64 y old	163 (48.1%)	176 (51.9%)	
65–74 y old	43 (43.4%)	56 (56.6%)	
75 y or older	1 (20.0%)	4 (80.0%)	
Gender, n (%)			<.001
Female	174 (64.0%)	98 (36.0%)	
Male	368 (47.9%)	401 (52.1%)	
Non-cis gender identity	26 (63.4%)	15 (36.6%)	
Position, n (%)			.35
Resident/fellow	34 (47.2%)	38 (52.8%)	
Attending	535 (52.9%)	476 (47.1%)	
Practice region, n (%)			.56
Northeast	136 (56.2%)	106 (43.8%)	
Midwest	150 (53.0%)	133 (47.0%)	
South	159 (51.3%)	151 (48.7%)	
West	124 (50.2%)	123 (49.8%)	
Practice setting, n (%)			<.001
University/academic medical center	183 (43.5%)	238 (56.5%)	
Community hospital	250 (59.1%)	173 (40.9%)	
Veterans affairs/government-based	12 (57.1%)	9 (42.9%)	
Other	11 (73.3%)	4 (26.7%)	
Private/group practice clinic	113 (55.7%)	90 (44.3%)	
Years in practice, n (%)			.001
0–20 y	328 (57.2%)	245 (42.8%)	
20+ years	240 (47.2%)	268 (52.8%)	
Primary role, n (%)			<.001
Clinical	551 (54.6%)	459 (45.4%)	
Research	1 (8.3%)	11 (91.7%)	
Teaching	9 (56.3%)	7 (43.8%)	
Administrative	6 (15.0%)	34 (85.0%)	
Other	1 (33.3%)	2 (66.7%)	
Knowledge of artificial intelligence, n (%)			<.001
Little or no knowledge	279 (66.7%)	139 (33.3%)	
Some knowledge	268 (45.6%)	320 (54.4%)	
Well versed	22 (28.6%)	55 (71.4%)	
I can think of an example of AI I use every day, n (%)			<.001
Disagree	139 (70.9%)	57 (29.1%)	
Neutral	108 (67.5%)	52 (32.5%)	
Agree	321 (44.3%)	404 (55.7%)	
AI is the most significant technology of my lifetime, n (%)			<.001
Disagree	142 (75.5%)	46 (24.5%)	
Neutral	230 (62.0%)	141 (38.0%)	
Agree	194 (37.4%)	325 (62.6%)	
I am open to the use of AI to improve my daily life, n (%)			<.001
Disagree	63 (95.5%)	3 (4.5%)	
Neutral	125 (93.3%)	9 (6.7%)	
Agree	378 (43.0%)	502 (57.0%)	
Do you believe your earning potential will be affected by AI in your lifetime? n (%)			<.001
Yes, it will decrease	309 (63.2%)	180 (36.8%)	
No, it will not change	240 (45.7%)	285 (54.3%)	
Yes, it will increase	20 (29.0%)	49 (71.0%)	
Do you believe the number of anesthesiologists required to serve the United States population will be affected by AI in your lifetime? n (%)			<.001
Yes, it will decrease	277 (56.3%)	215 (43.7%)	
No, it will not change	278 (51.3%)	264 (48.7%)	
Yes, it will increase	13 (27.7%)	34 (72.3%)	

Abbreviation: AI, artificial intelligence.
*Chi-square *P* value.

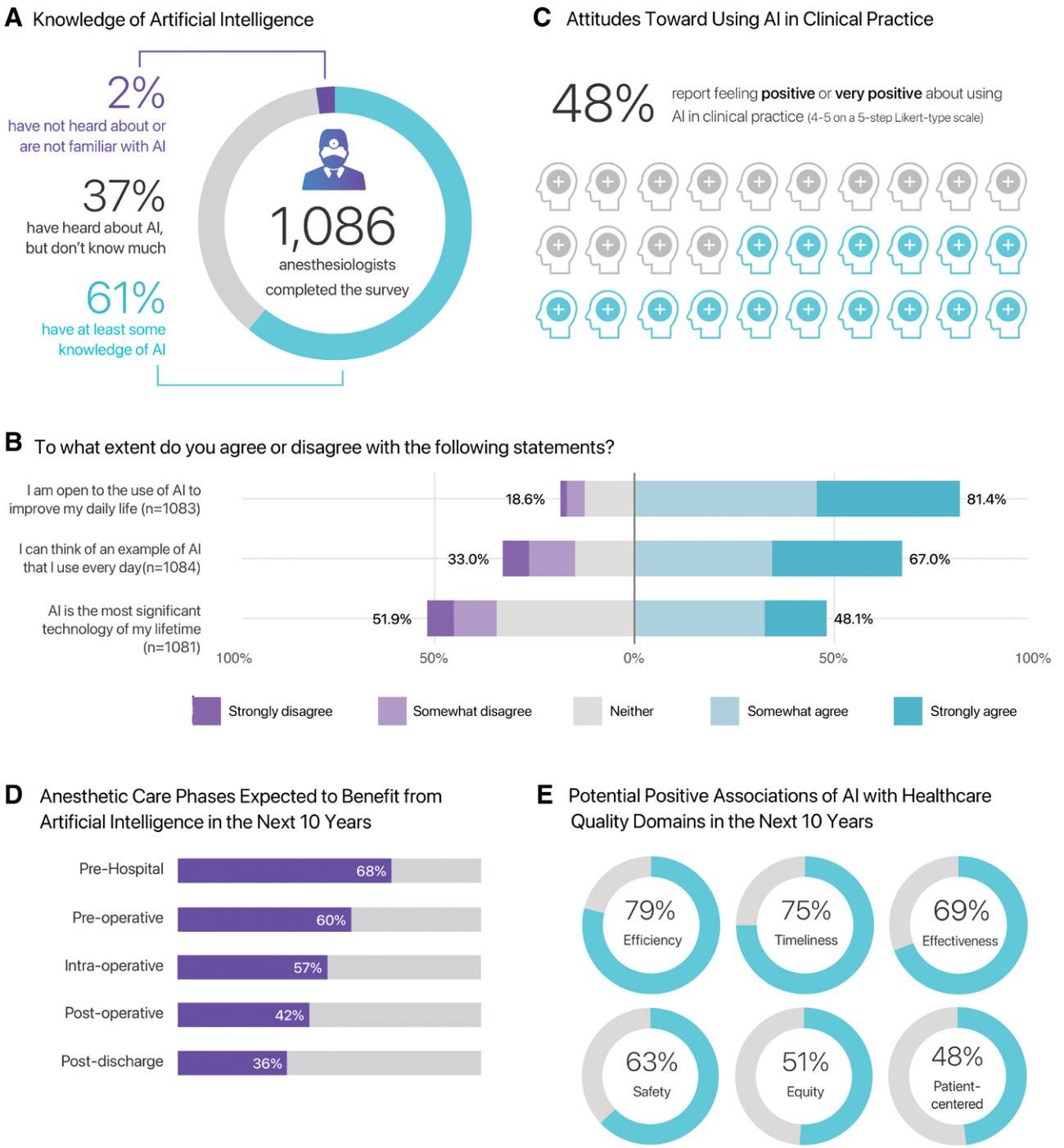

Figure 2. Overview of reported knowledge, exposure, attitudes, and expectations regarding the use of AI in clinical practice. A, Knowledge of AI. B, To what extent do you agree or disagree with the following statements?. C, Attitudes toward using AI in clinical practice. D, anesthetic care phases expected to benefit from AI in the next 10 years. E, Potential positive associations of AI with health care quality domains in the next 10 years. AI indicates artificial intelligence.

attitudes were more common among respondents aged 45 or older (50% vs 43%, $P = .02$), males (52% vs 36%, $P < .001$), those with AI knowledge (57% vs 33%, $P < .001$), and physicians with over 20 years of experience (53% vs 43%, $P < .01$) (Supplemental Digital Content, Supplemental Table 4, http://links.lww.com/AA/E569).

Perceived Risks of Using AI in Clinical Practice

Respondents identified algorithmic bias (15%), incorrect decisions based on AI recommendations (15%), and AI failures affecting patient care (14%) as key risks associated with the use of AI in clinical practice (Supplemental Digital Content, Supplemental Table 5, http://links.lww.com/AA/E569).

Expected Association of Using AI in Clinical Practice

The survey assessed physician anesthesiologists' views on the potential benefits of AI in anesthetic care and its association with health care quality in the next 10 years (Figure 2D, Supplemental Digital Content, Supplemental Table 5, http://links.lww.com/AA/E569). Physician anesthesiologists recognized the potential of AI in enhancing health care delivery in the prehospital (68%), preoperative (60%), and intraoperative (57%) phases of perioperative care. They believed AI could improve efficiency (79%), timeliness (75%), and effectiveness (69%) of care (Figure 2E, Supplemental Digital Content, Supplemental Table 5, http://links.lww.com/AA/E569).

In terms of expectations, approximately 46% of respondents believed that the integration of AI could lead to a decrease in demand for anesthesiologists, while 45% expected a decrease in earning potential. Most respondents anticipated AI surpassing humans in predicting adverse events (83%) and formulating pain management plans (67%), but fewer believed it could outperform humans in performing regional blocks (19%), intubations (19%), or empathetic care (6%) (Figure 3A). Female respondents (56% vs 40%, $P < .001$) and those with 0 to 20 years of experience (51% vs 38%, $P < .001$) were more likely to expect a decrease in earning potential compared to males and those with 20+ years of experience, respectively (Supplemental Digital Content, Supplemental Table 6, http://links.lww.com/AA/E569).

Barriers to Using AI in Clinical Practice

A majority of respondents (60%) identified a lack of algorithmic transparency as the primary barrier to using AI in clinical practice (Figure 3B). Concerns about malpractice and legal liability (47%) and the potential for medical errors (41%) were also expressed. Physicians with 0 to 20 years of experience more frequently identified barriers such as the risk of reinforcing health inequalities (20% vs 15%, $P = .03$), automating racism or biases (26% vs 15%, $P < .001$), lack of trust in AI among colleagues/leadership (19% vs 13%, $P = .01$), and lack of trust in AI among patients (40% vs 33%, $P = .02$) (Supplemental Digital Content, Supplemental Table 7, http://links.lww.com/AA/E569).

Facilitators to Using AI in Clinical Practice

Respondents highlighted key motivating factors for using AI in clinical practice, including enhancing health care outcomes (81%) and reducing costs (54%) (Figure 3B). Retaining control over treatment decisions (78%), validating data and reducing bias (55%), and potential time-saving benefits (53%) were also important motivating factors. Regarding motivation, female respondents were more likely than males to prioritize factors such as equal accuracy of AI tools across different races and ethnicities (49% vs 40%, $P = .04$) and patient information security (54% vs 46%, $P = .05$) (Supplemental Digital Content, Supplemental Table 8, http://links.lww.com/AA/E569). On the other hand, male respondents showed a higher inclination toward AI that saves time (56% vs 45%, $P = .01$) and tackles interesting problems (44% vs 32%, $P < .01$). In hypothetical scenarios, residents and fellows were more motivated than attending physicians to use AI in clinical practice when they understood the rationale behind AI-generated decisions (69% vs 48%, $P = .001$), perceived time-saving benefits (65% vs 52%, $P = .04$), and saw AI as a means to reduce doctor visits while maintaining medical quality (47% vs 33%, $P = .02$) (Supplemental Digital Content, Supplemental Table 8, http://links.lww.com/AA/E569).

Factors Associated With Attitudes Toward Using AI in Clinical Practice

Logistic regression was used to examine the factors linked to a positive attitude toward using AI in clinical practice (Tables 2 and 3). In multivariable analysis, males exhibited higher odds of having a positive attitude compared to females (odds ratio [OR], 1.7, 95% confidence interval [CI], 1.2–2.4, $P < .001$). Those with 20+ years of experience and in administrative roles also had higher odds of a positive attitude (OR, 1.8, 95% CI, 1.3–2.4, $P < .01$; OR, 5.4, 95% CI, 1.8–16.2, $P < .01$, respectively). Knowledge of AI played a significant role, with well-versed individuals having higher odds of a positive attitude (OR, 2.3, 95% CI, 1.2–4.4, $P = .01$), and those with some knowledge also showing higher odds (OR, 1.6, 95% CI, 1.2–2.2, $P < .01$) compared to those with little or no knowledge.

Attitudes toward using AI in clinical practice among physician anesthesiologists were associated with their beliefs and perceptions (Table 3). Believing AI to be a significant technology in one's lifetime was linked to higher odds of a positive attitude (OR, 2.2, 95% CI, 1.6–3.1, $P < .01$). Being open to AI for daily life improvement had substantially higher odds of a positive attitude (OR, 10.6, 95% CI, 5.2–21.8, $P < .01$). Believing earning potential would decrease due to AI was associated with significantly lower odds of a positive attitude (OR, 0.54, 95% CI, 0.40–0.73, $P < .01$).

Factors Related to the Perceived Association of AI With Earnings and Demand Among Anesthesiologists

Perceived associations of AI with earnings and demand among anesthesiologists were associated with gender and experience (Supplemental Digital Content, Supplemental Table 9, http://links.lww.com/AA/E569). Male anesthesiologists and those

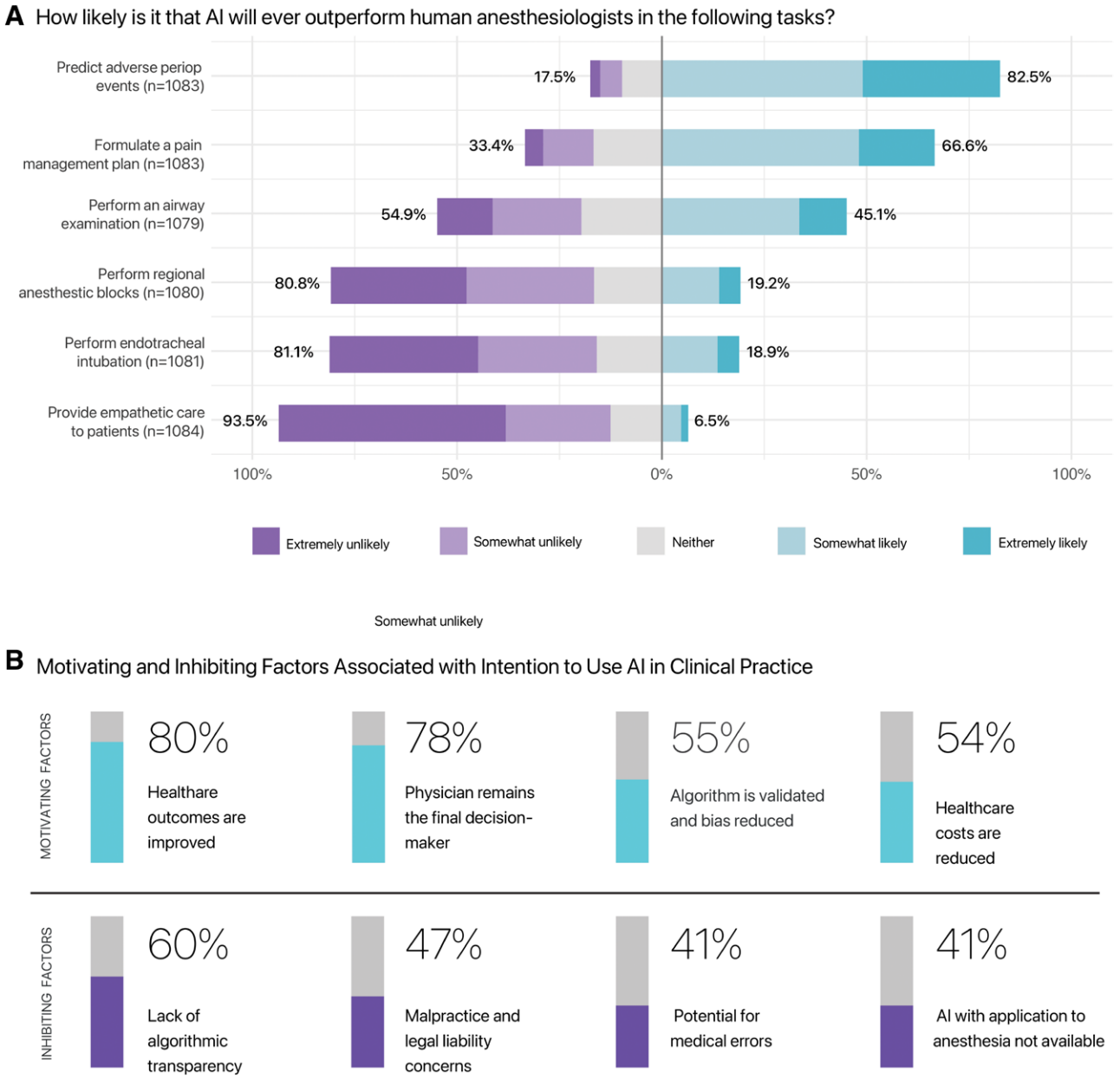

Figure 3. Expectations and factors associated with attitudes toward using AI in clinical practice. A, How likely is it that AI will ever outperform human anesthesiologists in the following tasks?. B, Motivating and inhibiting factors associated with intention to use AI in clinical practice. AI indicates artificial intelligence.

with over 20 years of experience were less likely to anticipate reduced earnings (OR, 0.54, CI, 0.41–0.71, $P < .001$ and OR, 0.58, CI, 0.46–0.74, $P < .001$, respectively). Respondents with over 20 years of experience also had lower odds of expecting decreased demand for anesthesiologists (OR, 0.73, CI, 0.58–0.93, $P = .01$).

DISCUSSION

This manuscript presents survey results that contribute to our understanding of US-based physician anesthesiologists' attitudes toward the use of AI in clinical practice. The findings reveal a positive attitude among a significant proportion of participants, aligning with previous studies across medical specialties, highlighting the broader acceptance and potential benefits of AI integration in health care.[36,37]

This study found that gender disparities exist in the attitudes of anesthesiologists towards AI, with male anesthesiologists having a more positive attitude than female anesthesiologists. These disparities may be due to differences in educational experiences, career paths, and professional networks. Ensuring gender parity and fairness in AI research and development, and creating more inclusive AI workplaces, will be critical to the fair and equitable implementation of AI.

Table 3. Multivariable Logistic Regression of Factors Associated With Positive Attitude Toward the Use of Artificial Intelligence in Clinical Practice

		Multivariable analysis[a]		
Variable	**n**	**Odds ratio (95% CI)**	***P* value[b]**	**Adjusted *P* value[c]**
Gender, n (%)				
Male	765	1.7 (1.2–2.4)	<.001	.03
Non-cisgender identity	40	1.4 (0.6–3.3)	.49	
Female	267	-	-	
Practice region, n (%)				
Northeast	239	0.86 (0.56–1.31)	.01	
Midwest	279	0.56 (0.36–0.87)	.47	
South	307	0.73 (0.48–1.09)	.12	
West	246	-	-	
Practice setting, n (%)				
University/academic medical center	415	1.7 (1.2–2.4)	<.01	.04
Veterans Affairs/government-based	21	0.66 (0.23–1.90)	.44	
Other	15	0.46 (0.12–1.73)	.25	
Private/group practice clinic	202	0.96 (0.64–1.44)	.84	
Community hospital	418	-	-	
Years in practice, n (%)				
20+ years	505	1.8 (1.3–2.4)	<.01	<.01
0–20 y	567	-	-	
Primary role, n (%)				
Research	12	5.0 (0.5–50.5)	.17	
Teaching	15	0.62 (0.18–2.19)	.46	
Administrative	40	5.4 (1.8–16.2)	<.01	.04
Other	3	0.73 (0.05–10.44)	.82	
Clinical	1002	-	-	
Knowledge of artificial intelligence, n (%)				
Well versed	76	2.3 (1.2–4.4)	.01	
Some knowledge	583	1.6 (1.2–2.2)	<.01	<.05
Little or no knowledge	413	-	-	
I can think of an example of AI I use every day, n (%)				
Disagree	195	1.0 (0.6–1.8)	.9	
Neutral	160	-	-	
Agree	717	1.6 (1.0–2.5)	.03	
AI is the most significant technology of my lifetime, n (%)				
Disagree	186	0.74 (0.45–1.19)	.21	
Neutral	368	-	-	
Agree	518	2.2 (1.6–3.1)	<.01	<.01
I am open to the use of AI to improve my daily life, n (%)				
Disagree	65	0.47 (0.11–2.00)	.31	
Neural	134	-	-	
Agree	873	10.6 (5.2–21.8)	<.01	<.01
Do you believe your earning potential will be affected by AI in your lifetime? n (%)				
Yes, it will decrease	480	0.54 (0.40–0.73)	<.01	<.01
No, it will not change	524	-	-	
Yes, it will increase	68	1.6 (0.9–3.1)	.12	

Abbreviations: AI, artificial intelligence; CI, confidence interval.

[a]Number of observations in the original data set = 1086. Number of observations used = 1072. Backward selection with an α level of removal of .05 was used. The following variables were removed from the model: age, position, practice region, and do you believe the number of anesthesiologists required to serve the US population will be affected by AI in your lifetime?

[b]Adjusted for multiple comparisons: Bonferroni correction was applied by multiplying the *P* values by 45, representing the number of χ^2 tests being completed. Adjusted *P* values are reported exclusively for statistically significant results ($P < .05$).

[c]$P < .05$ denotes a significant difference between treatment groups before Bonferroni correction for multiple testing.

The survey suggests that the participation of both experienced and early-career anesthesiologists in decision-making processes is crucial for effective AI policies. Experienced anesthesiologists exhibited more positive attitudes towards AI and lower expectations of earning decline or decreased demand, suggesting that they are more confident in the ability of AI to complement their work, rather than replace it. Harnessing the expertise of experienced physician anesthesiologists could help to align AI implementation with workforce needs and ensure that AI is used in a way that benefits all patients.

Despite a knowledge gap, most respondents were open to using AI for personal improvement but showed less enthusiasm for its professional use. Personal, patient, and technology-based concerns may contribute to this differential attitude toward using AI in clinical practice. Addressing knowledge gaps, fostering trust in AI, and addressing well-being

concerns may help policymakers effectively integrate AI into health care.

The survey found that one-third of respondents had concerns about the rapid proliferation of AI in health care. These concerns could be attributed to a lack of understanding of how AI works and a mistrust of algorithm-generated advice. The survey also revealed that concerns about malpractice and legal liability, as well as the possibility of medical errors, were associated with negative attitudes toward using AI in clinical practice. To realize the full potential of AI in anesthesiology, we must overcome the lack of understanding of technology and computer programming and the mistrust of algorithm-generated advice. Health care organizations must also develop clear AI policies to address malpractice and legal liability, and ensure safe and effective use.

Our study builds on previous research by investigating the wider impacts of AI on health and health care quality. Respondents agreed that AI can have positive effects on care metrics such as timeliness, effectiveness, and efficiency, supporting the idea that AI can improve health care delivery. Our survey also uniquely explored the perceived association of AI with safety, equity, and patient-centeredness, providing valuable insights for shaping policies and strategies to maximize the benefits of AI while addressing potential risks and challenges.

Physician anesthesiologists had mixed feelings about the integration of AI in their practice. They were optimistic about AI's potential to excel in certain tasks, such as predicting adverse events and formulating pain management plans. However, they had doubts about AI's ability to surpass humans in tasks that require precise dexterity and complex emotional skills, such as performing regional blocks, intubation, and providing empathetic care. While AI has the potential to improve clinical practice, concerns about the safety of AI-enabled technologies and its limited understanding of the human experience may explain these doubts. Educational programs should be created to help anesthesiologists learn about AI and its potential advantages and disadvantages.

We recommend that health care organizations, policy-making bodies, and physician anesthesiologists collaborate to create clear AI policies, procedures, and educational materials that address the concerns raised in this study and ensure the safe and effective use of AI in perioperative care.

LIMITATIONS

Several limitations should be taken into account when interpreting the survey findings. First, the limited number of variables available for comparing the survey respondents to the larger ASA membership made it difficult to conduct a comprehensive comparison between these groups. The findings did reveal slight variations in baseline demographics, such as lower mean age and a lower proportion of females, which were associated with a more positive attitude toward using AI in clinical practice among respondents. It is crucial to carefully assess the magnitude and scope of these differences when evaluating the generalizability of the findings to a larger ASA membership. Second, the response rate was relatively low, so the findings may be biased.[38–40] Future research should take steps to increase the response rate, such as sending personalized invitations, sending additional reminders, and using incentives. Third, the multivariable logistic algorithm used in the study has some limitations. It can omit jointly significant variables and retain nonsignificant variables that confound each other.

Despite its limitations, the survey findings provide valuable insights into the acceptance and implementation of AI in anesthesiology. The diversity of attitudes highlights the need to address concerns and develop tailored strategies to meet the diverse needs and expectations of different subgroups in the field. This approach will enable anesthesiology to realize the revolutionary potential of AI while ensuring its equitable access, acceptance, and implementation across all health care settings.

CONCLUSIONS

This survey of US-based physician anesthesiologists offers valuable insights into the adoption and implementation of AI in anesthesiology, highlighting both barriers and potential. Despite varying levels of AI knowledge, a significant proportion of physician anesthesiologists express optimism about incorporating AI into their clinical practice.

The survey also identifies specific factors that are associated with the acceptance and use of AI in this field. While caution should be exercised in generalizing the findings, they provide a foundation for further exploration and discussions regarding the integration of AI in anesthesiology. The presence of different attitudes towards AI in anesthesiology highlights the need to address concerns and develop tailored strategies to meet the diverse needs of different subgroups in the field. An inclusive approach to AI in anesthesiology is needed to ensure equitable access, acceptance, and implementation across all health care settings. Health care organizations, policy-making bodies, and physician anesthesiologists should collaborate to develop clear AI policies, procedures, and educational materials that address concerns and ensure safe use.

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DISCLOSURES

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REFERENCES

1. Buch VH, Ahmed I, Maruthappu M. Artificial intelligence in medicine: current trends and future possibilities. *Br J Gen Pract*. 2018;68:143–144.
2. Brynjolfsson E, McAfee A. The business of artificial intelligence. *Harvard Business Review* [Internet]. 2017 Jul [cited 2023 Jun 1]. Accessed June 1, 2022. https://hbr.org/2017/07/the-business-of-artificial-intelligence.
3. He J, Baxter SL, Xu J, Xu J, Zhou X, Zhang K. The practical implementation of artificial intelligence technologies in medicine. *Nat Med*. 2019;25:30–36.
4. Kuan R. Adopting AI in health care will be slow and difficult. *Harvard Business Review* [Internet]. 2019 Oct [cited 2023 Jun 1]. Accessed June 1, 2022. https://hbr.org/2019/10/adopting-ai-in-health-care-will-be-slow-and-difficult.
5. Deng Y, Xu X, Qiu Y, Xia J, Zhang W, Liu S. A multimodal deep learning framework for predicting drug-drug interaction events. *Bioinformatics*. 2020;36:4316–4322.
6. Devi SP, Rao KS, Sangeetha SS. Prediction of surgery times and scheduling of operation theaters in ophthalmology department. *J Med Syst*. 2012;36:415–430.
7. Rong G, Mendez A, Bou Assi E, Zhao B, Sawan M. Artificial intelligence in healthcare: review and prediction case studies. *Eng*. 2020;6:291–301.
8. McCarthy JJ, Minsky ML, Rochester N. Artificial intelligence. [Internet]. Massachusetts Institute of Technology; 1959 [cited 2023 Jun 1]. Accessed June 1, 2022. https://dspace.mit.edu/handle/1721.1/52263? show = full.
9. Meskó B, Görög M. A short guide for medical professionals in the era of artificial intelligence. *NPJ Digit Med*. 2020;3:126.
10. Ghahramani Z. Probabilistic machine learning and artificial intelligence. *Nature*. 2015;521:452–459.
11. Kulkov I. Next-generation business models for artificial intelligence start-ups in the healthcare industry. *Int J Entrepreneurial Behav Res*. 2021;29:860–885.
12. Thrall JH, Li X, Li Q, et al. Artificial intelligence and machine learning in radiology: opportunities, challenges, pitfalls, and criteria for success. *J Am Coll Radiol*. 2018;15(3 Pt B):504–508.
13. Haenssle HA, Fink C, Schneiderbauer R, et al; Reader study level-I and level-II Groups. Man against machine: diagnostic performance of a deep learning convolutional neural network for dermoscopic melanoma recognition in comparison to 58 dermatologists. *Ann Oncol*. 2018;29:1836–1842.
14. Martin DR, Hanson JA, Gullapalli RR, Schultz FA, Sethi A, Clark DP. A deep learning convolutional neural network can recognize common patterns of injury in gastric pathology. *Arch Pathol Lab Med*. 2020;144:370–378.
15. Zaouter C, Hemmerling TM, Lanchon R, et al. The feasibility of a completely automated total IV anesthesia drug delivery system for cardiac surgery. *Anesth Analg*. 2016;123:885–893.
16. Schäublin J, Derighetti M, Feigenwinter P, Petersen-Felix S, Zbinden AM. Fuzzy logic control of mechanical ventilation during anaesthesia. *Br J Anaesth*. 1996;77:636–641.
17. Hatib F, Jian Z, Buddi S, et al. Machine-learning algorithm to predict hypotension based on high-fidelity arterial pressure waveform analysis. *Anesthesiology*. 2018;129:663–674.
18. Komorowski M, Celi LA, Badawi O, Gordon AC, Faisal AA. The artificial intelligence clinician learns optimal treatment strategies for sepsis in intensive care. *Nat Med*. 2018;24:1716–1720.
19. Gram M, Erlenwein J, Petzke F, et al. Prediction of postoperative opioid analgesia using clinical-experimental parameters and electroencephalography. *Eur J Pain*. 2017;21:264–277.
20. Meijer F, Honing M, Roor T, et al. Reduced postoperative pain using nociception level-guided fentanyl dosing during sevoflurane anaesthesia: a randomised controlled trial. *Br J Anaesth*. 2020;125:1070–1078.
21. Ortolani O, Conti A, di Filippo A, et al. EEG signal processing in anaesthesia. Use of a neural network technique for monitoring depth of anaesthesia. *Br J Anaesth*. 2002;88:644–648.
22. Shalbaf A, Saffar M, Sleigh JW, Shalbaf R. Monitoring the depth of anesthesia using a new adaptive neurofuzzy system. *IEEE J Biomed Health Inform*. 2018;22:671–677.
23. Eagleman SL, Drover DR. Calculations of consciousness: electroencephalography analyses to determine anesthetic depth. *Curr Opin Anaesthesiol*. 2018;31:431–438.
24. Sharma A, Minh Duc NT, Luu Lam Thang T, et al. A consensus-based Checklist for Reporting of Survey Studies (CROSS). *J Gen Intern Med*. 2021;36:3179–3187.
25. Scheetz J, Rothschild P, McGuinness M, et al. A survey of clinicians on the use of artificial intelligence in ophthalmology, dermatology, radiology, and radiation oncology. *Sci Rep*. 2021;11:1–10.
26. Wadhwa V, Alagappan M, Gonzalez A, et al. Physician sentiment toward artificial intelligence (AI) in colonoscopic practice: a survey of US gastroenterologists. *Endosc Int Open*. 2020;8:E1379–E1384.
27. Jungmann F, Jorg T, Hahn F, et al. Attitudes toward artificial intelligence among radiologists, IT specialists, and industry. *Acad Radiol*. 2021;28:834–840.
28. Laï MC, Brian M, Mamzer MF. Perceptions of artificial intelligence in healthcare: Findings from a qualitative survey study among actors in France. *J Transl Med*. 2020;18:1–13.
29. Davis FD, Bagozzi RP, Warshaw PR. User acceptance of computer technology: a comparison of two theoretical models. *Manag Sci*. 1989;35:982–1003.
30. Venkatesh M, Davis D. User acceptance of information technology: toward a unified view. *MIS Quarterly*. 2003;27:425.
31. Lipsey MW, Wilson DB. *Practical meta-analysis*. SAGE; 2001.
32. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. *Source Code Biol Med*. 2008;3:17.

33. Coppola F, Faggioni L, Regge D, et al. Artificial intelligence: radiologists' expectations and opinions gleaned from a nationwide online survey. *Radiol Med*. 2021;126:63–71.
34. Sarwar S, Dent A, Faust K, et al. Physician perspectives on integration of artificial intelligence into diagnostic pathology. *npj Digital Med*. 2019;2:28.
35. Kotrlik JW, Higgins CC. Organizational research: determining appropriate sample size in survey research. *Inf Technol Learn Perform J*. 2001;19:43.
36. Waymel Q, Badr S, Demondion X, Cotten A, Jacques T. Impact of the rise of artificial intelligence in radiology: what do radiologists think? *Diagn Interv Imaging*. 2019;100:327–336.
37. Sit C, Srinivasan R, Amlani A, et al. Attitudes and perceptions of UK medical students towards artificial intelligence and radiology: a multicentre survey. *Insights Imaging*. 2020;11:14.
38. Nelson CA, Pachauri S, Balk R, et al. Dermatologists' perspectives on artificial intelligence and augmented intelligence: a cross-sectional survey. *JAMA Dermatol*. 2021;157:871–874.
39. Wanat-Hawthorne A, Tanaka K, Angona R, Feng C, Eaton M. Survey of practice pattern in patients with heparin-induced thrombocytopenia requiring cardiopulmonary bypass. *Anesth Analg*. 2021;133:1180–1186.
40. Vigoda MM, Behrens V, Miljkovic N, Arheart KL, Lubarsky DA, Dutton RP. Perioperative cardiac evaluation of simulated patients by practicing anesthesiologists is not consistent with 2007 ACC/AHA guidelines. *J Clin Anesth*. 2012;24:446–455.