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Current state and future education implication of enhanced recovery after surgery (ERAS) among Chinese anesthesiologists: national repeated cross-sectional surveys from 2019 to 2023

Yuelun Zhang[1], Zijia Liu[2*], Lulu Ma[2], Xu Li[2], Qianmei Zhu[2], Guonian Wang[3], Jing Cang[4], Yugang Diao[5], Tiezheng Zhang[5], Le Shen[2] and Yuguang Huang[2*]

Abstract

Background Enhanced recovery after surgery (ERAS) protocols have been widely adopted to improve surgical outcomes. In this study, we aimed to assess the current state of awareness and specific knowledge of ERAS among Chinese anesthesiologists, examine difficulties in implementation, and identify future priorities for ERAS education and training.

Methods A self-designed, repeated national survey regarding awareness and practice of the ERAS concept, specific knowledge, learning modalities, and difficulties in ERAS implementation was conducted in 2019, 2021, and 2023. Factors related to mastery of knowledge were analyzed via subgroup analysis and multivariable linear regression.

Results A total of 6385 participants were included; 96.2% were anesthesiologists. Approximately half of the participants reported implementing ERAS in more than 40% of patients. Compared with those in the 2019 survey, the overall proportion of participants who had heard about the concept of ERAS remained relatively stable across the three surveys ($P=0.078$). However, significant improvements were observed in participants reported good understanding (defined as responding "very familiar" or "quite familiar") of ERAS and implementing rate of ERAS in clinical practice ($P<0.001$). The mean score on the 15-question quiz was 8.5 ± 2.5. Significant differences in scores were observed across various geographic regions, levels of hospitals, education, professional titles, and age. Most anesthesiologists expressed a strong desire for additional education on ERAS in several ways. Feedback from the open-ended question in the survey indicated that multidisciplinary collaboration was a major challenge in implementing ERAS.

*Correspondence:
Zijia Liu
liu-zj02@126.com
Yuguang Huang
garypumch@163.com

Full list of author information is available at the end of the article

Conclusions This nationwide study indicates a notable enhancement in the comprehension and implementation of ERAS among Chinese anesthesiologists, although there is still room for improvement. Future efforts should focus on improving education and training to enhance ERAS knowledge and practice levels among health care providers.

Clinical trial number Not applicable.

Keywords Enhanced recovery after surgery, Medical education, Knowledge, Cross-sectional study, Survey, Anesthesiologist

Background

Enhanced recovery after surgery (ERAS) refers to multimodal evidence-based protocols that are applied to conventional perioperative care to reduce postoperative complications and expedite recovery following elective procedures. [1] High-quality systematic reviews have shown that practicing ERAS is associated with shorter lengths of postoperative hospital stays, reduced readmission rates and costs, and fewer postoperative complications. [2–4, 5] Therefore, clinical practice guidelines for various types of surgeries provide recommendations for optimal perioperative management. [6–9]

As interest in ERAS has grown in recent years, the education and training deficits have become more evident. [10] A common theory framework for understanding health-related behaviors is the knowledge, attitudes, and practices (KAP) model, in which practitioners first need to know about a particular issue, then change their attitudes toward the issue, and finally practice the new knowledge in health care settings. [11] Providing proper education and training to surgical health care providers could result in improved adherence to the ERAS protocol and better patient outcomes. [12]

Anesthesiologists play a crucial role in the perioperative management of patients and an indispensable role in implementing ERAS. However, previous surveys on ERAS implementation have often been conducted among surgeons, with only two small-scale studies in Europe, Africa, and India focusing on anesthesiologists' understanding, attitudes, and implementation of ERAS.[13,14] Over 80 million surgeries are performed in China each year, and there are more than 100,000 anesthesiologists nationwide. [15] Although national medical organizations, including the Chinese Society of Anesthesiology (CSA) and various academic institutions, have been making increasing efforts to promote the popularization and practice of ERAS, [16] large-scale surveys on Chinese anesthesiologists' understanding, attitudes, implementation, and education-related experiences of ERAS are lacking. In China, the implementation of ERAS involves a broad range of professionals, including licensed anesthesiologists, surgeons, nurses, and also residents and clinical fellows participating in perioperative care. While national guidelines and conference-based training promote ERAS concepts among healthcare providers, ERAS has not yet been uniformly integrated into the national core curriculum of anesthesiology or surgical residency programs. However, some academic institutions have started to incorporate dedicated ERAS courses and practical training into their postgraduate medical education. [17] Thus, we addressed this research gap by conducting this national repeated cross-sectional survey of Chinese anesthesiologists and relevant health care professionals. This survey was designed to address several important questions. First, we aimed to assess the current state of ERAS awareness and specific knowledge among Chinese anesthesiologists, including changes over time. Second, we sought to evaluate variation in ERAS knowledge and practice across geographic regions, hospital levels, and individual characteristics (such as education and professional experience). Third, we intended to explore the key difficulties in ERAS implementation and identify priorities for future educational strategies from the perspective of practicing anesthesiologists. These aims were guided by the increasing emphasis on ERAS in national guidelines and academic initiatives over recent years.

Methods

This manuscript follows the Consensus-Based Checklist for Reporting of Survey Studies (CROSS). [18] The study protocol was approved by the Peking Union Medical College Hospital Institutional Review Board (No. K5492). Written informed consent was obtained from all the surveyed participants. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration and its later amendments or comparable ethical standards.

Setting, participants, and sampling strategy

This nationwide survey was conducted among health care providers involved in perioperative care, with a primary focus on anesthesiologists. Eligible participants included licensed anesthesiologists, nurse anesthetists, anesthesiology residents and fellows, as well as other relevant professionals such as perioperative nurses and surgeons. There were no strict inclusion or exclusion criteria beyond involvement in perioperative clinical practice.

The study was designed as a repeated cross-sectional survey organized by the ERAS Study Group of the

Chinese Society of Anesthesiology (CSA), a branch of the Chinese Medical Association, from 2019 to 2023. The ERAS Study Group consists of experienced anesthesiologists and clinical researchers committed to promoting ERAS-related research and education in China.

A convenience sampling approach was used. Forty-one senior members of the ERAS Study Group acted as key coordinators, distributing the electronic questionnaire during and after CSA academic annual conferences through professional WeChat networks. These networks included departmental and institutional groups covering a wide range of hospitals across China. Participation was voluntary and anonymous. Due to the COVID-19 pandemic, the survey was conducted in 2019, 2021, and 2023, but not in 2020 or 2022.

Questionnaire development

The survey instrument was developed by the ERAS Study Group of the Chinese Society of Anesthesiology, following key principles from established survey design guidance, including the framework proposed by Gehlbach et al. [19] First, we clearly defined the study goals: to assess anesthesiologists' awareness, knowledge, implementation practices, and future educational needs regarding ERAS. Second, we constructed a conceptual framework based on the KAP (knowledge, attitudes, and practices) model to guide item development. Third, we reviewed relevant ERAS guidelines and previous surveys in perioperative medicine to identify key content domains. [16] Fourth, the initial draft of the questionnaire was developed by a senior anesthesiologist with over 20 years of clinical experience (Dr. Zijia Liu) and reviewed by another senior expert (Prof. Yuguang Huang). Fifth, we sought input from 10 anesthesiologists of varying seniority (residents, attendings, and chiefs) at Peking Union Medical College Hospital, who reviewed the questionnaire for clarity, relevance, and comprehensiveness. This process served as an expert validation to support the content validity of the instrument. Based on their feedback, we refined and finalized the instrument. Finally, the revised questionnaire was piloted in a small group for usability testing to ensure clarity and feasibility before national distribution.

The final version consisted of four parts:

1) Demographic information, including profession, hospital level, geographic region, education, title, age, and clinical experience.
2) Overall understanding and practice, including familiarity with ERAS concepts and self-reported implementation in clinical work.
3) Specific ERAS knowledge, assessed by 15 multiple-choice items with correct answers based on national guidelines.
4) Education and barriers, including willingness to receive further training, perceived progress in ERAS knowledge and practice, and main challenges encountered.

The survey was distributed electronically (via https://www.wjx.cn), with a single-entry limit per IP address to avoid duplicate responses. The original questionnaire was designed in Chinese, and the translated English version of the questionnaire can be found in the online-only Additional file 1.

Statistical analysis

Based on previous experience, at least 50 participants could be recruited by each of the 41 key coordinators every year. A repeated cross-sectional survey over 3 years would recruit approximately 6150 participants. This sample size could provide appropriately 200 participants for each question in our questionnaire with 31 items.

The basic characteristics of the participants were tabulated via descriptive analysis (Part 1 of the questionnaire). For overall understanding and practice of the ERAS concept (Part 2 of the questionnaire), we recategorized the answers and calculated the proportion of those with a good understanding, which was defined as "very familiar" or "quite familiar" with the relevant questions. The proportion of ERAS in daily clinical practice was categorized into "less than 40% patients" and "40% or more patients". This threshold was not pre-specified but was chosen based on the distribution of responses, ensuring a relatively balanced number of participants in each group for meaningful comparisons. The proportions by year of survey were plotted to show the general understanding and practice of ERAS and the potential temporal changes. Overall understanding and practice of the ERAS concept among different years were compared using chi-square test. For the specific knowledge of ERAS (Part 3 of the questionnaire, the quiz), the proportion of correct answers by year of survey in each domain was calculated and is shown in a bar plot. We also calculated the total score of the correct answer of each participant, which was the sum of the total number of correct answers in Part 3. The maximum total score for this part is 15 points. A higher score indicates better mastery of knowledge of ERAS. The mean score with 95% confidence interval (CI) of correct answers was calculated for participants from different years of the survey, levels of hospitals, geographic areas, education levels, ages, professional titles, and years of practice. Differences in the mean scores between subgroups were estimated via analysis of variance. The year-to-year comparison was a predefined analysis to assess temporal changes in ERAS knowledge and implementation. In addition to the univariable subgroup analysis exploring the difference in the mastery of

knowledge between participants with different characteristics, a multivariable linear regression model was also built to explore the factors correlated with the mastery of ERAS knowledge. The total score of correct answers was regressed against the year of survey and participant characteristics, including level of hospital, level of education, geographic area, age, professional title, and year of clinical practice, via a multivariable linear regression model. Multicollinearity among variables was assessed using the variance inflation factor. While most variables showed acceptable multicollinearity (variance inflation factor < 5), age demonstrated a variance inflation factor > 5, indicating substantial collinearity with year of clinical practice. To address this, age was removed from the final model, and the analysis was repeated with the remaining variables to ensure the stability and interpretability of the regression results. No variable selection was applied in the final model. Linear model assumptions were checked via visual inspection of residual plots. We narratively described the results in Part 4 of the questionnaire concerning past and future participation in ERAS training, learning, and teaching experiences, learning willingness, overall difficulties in ERAS practice, and progress in theory and practice. A sensitivity analysis was conducted by excluding non-anesthesiologist participants in the survey to check the robustness of the findings. Considering the exploratory nature of this survey, we did not use multiplicity adjustment in the statistical analyses, and the findings were interpreted qualitatively. A two-sided alpha of 0.05 was regarded as statistically significant. Data cleaning and analysis were completed in R (version 4.4.0, R Foundation, www.r-project.org, Vienna, Austria) with the "forestplot" package. [20] Bar plots were generated in Microsoft Excel.

Results

Participants

A total of 6385 participants completed the electronic questionnaire and were included in our survey. The number of participants in each year and their basic characteristics are shown in Table 1. The number of participants increased from 1563 in 2019 to 2439 in 2023. Most participants were anesthesiologists, constituting more than 95% of the total. Approximately two-thirds of the participants were working in Grade A tertiary hospitals, while the remaining one-third were from various other institutions, including Grade B tertiary hospitals, secondary hospitals, primary care facilities, and nongovernment medical institutions. The participants came from all geographic regions across China, covering all provincial-level administrative areas except the Macau Special Administrative Region, and a small number of overseas practitioners.

Approximately one-third of the participants held postgraduate degrees, and a similar proportion possessed senior professional titles. The mean age of the participants was 38.1 ± 8.5 years, with 39% having more than 16 years of professional experience. When participant characteristics across different years were compared, there were no significant differences in terms of profession, professional title, or age. However, variations existed in the regions represented by participants, possibly due to the changing locations of the annual academic conferences. Differences were also observed in educational background and years of professional experience.

Overall Understanding and implementation of ERAS

With respect to the overall understanding and practice of ERAS, we found that more than 90% of the participants had heard about the concept of ERAS, and this proportion remained relatively stable across the three surveys ($P = 0.078$). When asked if they personally understood the concept of ERAS, approximately 70% of the respondents believed that they had a good understanding (defined as responding "very familiar" or "quite familiar"), and this proportion slightly increased over the years ($P < 0.001$). When asked about the actual implementation of ERAS in terms of the percentage of patients, the proportion of participants engaging in ERAS in clinical practice increased over time ($P < 0.001$). However, only approximately half of the respondents reported practicing ERAS in more than 40% of their patients. Only 21.4% of the respondents had an ERAS implementation rate of over 60% (Fig. 1).

Specific understanding of ERAS elements

Figure 2 shows the annual correct answer rates for the 15 questions in Part 3 of the questionnaire, along with statistical comparisons between years (all P values ≤ 0.001). Overall, the correct answer rates for questions concerning the contents of preoperative admission education, antimicrobial prophylaxis, and choice of surgical approach were relatively high, all exceeding 80%. For other questions, including the content of ERAS, the recommended time of smoking cessation, the recommended time of fasting before surgery, the necessity of hypothermia protection, proper intraoperative temperature management, proper intraoperative fluid management, and the recommended time of early oral feeding and mobilization, the correct answer rates ranged from 40 to 70%.

A few questions, such as those concerning risk factors for PONV, proper prevention methods for PONV, and proper pain management, had correct answer rates below 40%. Statistically significant improvements over the years were observed for temperature management, PONV prevention, and prehabilitation-related contents. However,

Table 1 Basic characteristics of surveyed participants

Characteristics	All participants (*N* = 6385)	Survey in 2019 (*N* = 1563)	Survey in 2021 (*N* = 2383)	Survey in 2023 (*N* = 2439)
Profession				
Anesthesiologists	6145 (96.2%)	1526 (97.6%)	2271 (95.3%)	2348 (96.3%)
Nurse Anesthetists	221 (3.5%)	37 (2.4%)	93 (3.9%)	91 (3.7%)
Others*	19 (0.3%)	0 (0.0%)	19 (0.8%)	0 (0.0%)
Level of hospital				
Tertiary hospital, Grade A	4015 (62.9%)	854 (54.6%)	1336 (56.1%)	1825 (74.8%)
Other levels†	2370 (37.1%)	709 (45.4%)	1047 (43.9%)	614 (25.2%)
Geographic area				
Central China region	799 (12.5%)	178 (11.4%)	299 (12.5%)	322 (13.2%)
East China region	1234 (19.3%)	260 (16.6%)	361 (15.1%)	613 (25.1%)
North China region	1470 (23.0%)	258 (16.5%)	642 (26.9%)	570 (23.4%)
Northeast China region	339 (5.3%)	87 (5.6%)	31 (1.3%)	221 (9.1%)
Northwest China region	727 (11.4%)	230 (14.7%)	421 (17.7%)	76 (3.1%)
South China region	567 (8.9%)	230 (14.7%)	63 (2.6%)	274 (11.2%)
Southwest China region	1243 (19.5%)	316 (20.2%)	566 (23.8%)	361 (14.8%)
Oversea	6 (0.1%)	4 (0.3%)	0 (0.0%)	2 (0.1%)
Education level				
Postgraduate	2179 (34.1%)	461 (29.5%)	606 (25.4%)	112 (45.6%)
Bachelor's degree or lower	4206 (65.9%)	1102 (70.5%)	1777 (74.6%)	1327 (54.4%)
Professional title‡				
Senior professional titles	2335 (36.6%)	364 (23.3%)	527 (22.1%)	708 (29.0%)
Intermediate professional titles	2451 (38.4%)	621 (39.7%)	856 (34.7%)	1004 (41.2%)
Junior professional titles	1599 (25.0%)	578 (37.0%)	1030 (43.2%)	727 (29.8%)
Age	38.1 ± 8.5	38.8 ± 8.1	40.3 ± 9.0	35.6 ± 7.6
Years of practice				
21 years and above	1592 (24.9%)	455 (29.1%)	847 (35.5%)	290 (11.9%)
16 to 20 years	895 (14.0%)	268 (17.1%)	343 (14.4%)	284 (11.6%)
11 to 15 years	1436 (22.5%)	337 (21.6%)	471 (19.8%)	628 (25.7%)
6 to 10 years	1215 (19.0%)	250 (16.0%)	377 (15.8%)	588 (24.1%)
0 to 5 years	1247 (19.5%)	253 (16.2%)	345 (14.5%)	649 (26.6%)

*Including surgeons, medical professionals, and management personnel. Because the surveys were conducted during the annual academic conference of the Chinese Society of Anesthesiology (CSA), a small number of participants from other professions also completed this questionnaire

†Includes Grade B tertiary hospitals, secondary hospitals, primary care hospitals, and nongovernment medical institutions

‡Senior professional titles include chief and deputy chief physicians. Intermediate professional titles include attending physicians, nursing officers, and nurse practitioners. Junior professional titles include resident physicians, registered nurses, and intern physicians

despite these statistically significant changes, their practical relevance may vary. For instance, while some items, like temperature management, showed consistent improvement, others, such as proper pain management, demonstrated relatively limited progress. In contrast, the accuracy of some questions remained stable, and a few, such as recommended fasting times, even showed slight declines over time.

Improvements in and influence of ERAS knowledge

Each correct answer to the 15 questions was given a score of 1 point (maximum score of 15 points), and the mean score for all the subjects was 8.5 ± 2.5 points (median 9, IQR 7 to 10). The mean scores for each year were 7.9 (95% CI: 7.8 to 8.1) in 2019, 8.8 (95% CI: 8.7 to 8.9) in 2021, and 8.5 (95% CI: 8.4 to 8.6) in 2023. Figure 3 illustrates the scores of different subgroups. The correct scores of the subjects in 2021 and 2023 were statistically significantly higher than those in 2019. The participants from Grade A tertiary hospitals who held postgraduate degrees, were elderly in age, held senior professional titles, and had more working years gave significantly higher correct answer scores. There were large variations in correct scores among subjects from different regions, with those from Central China, East China, South China, and Southwest China scoring higher than the average level. The results of the multivariable linear regression model on factors influencing the correct answer scores were consistent with the results of the abovementioned univariable subgroup analyses after adjusting for other factors (Table 2). Inspection of the residual plots did not reveal potential violations of the assumptions of the multivariable linear regression model.

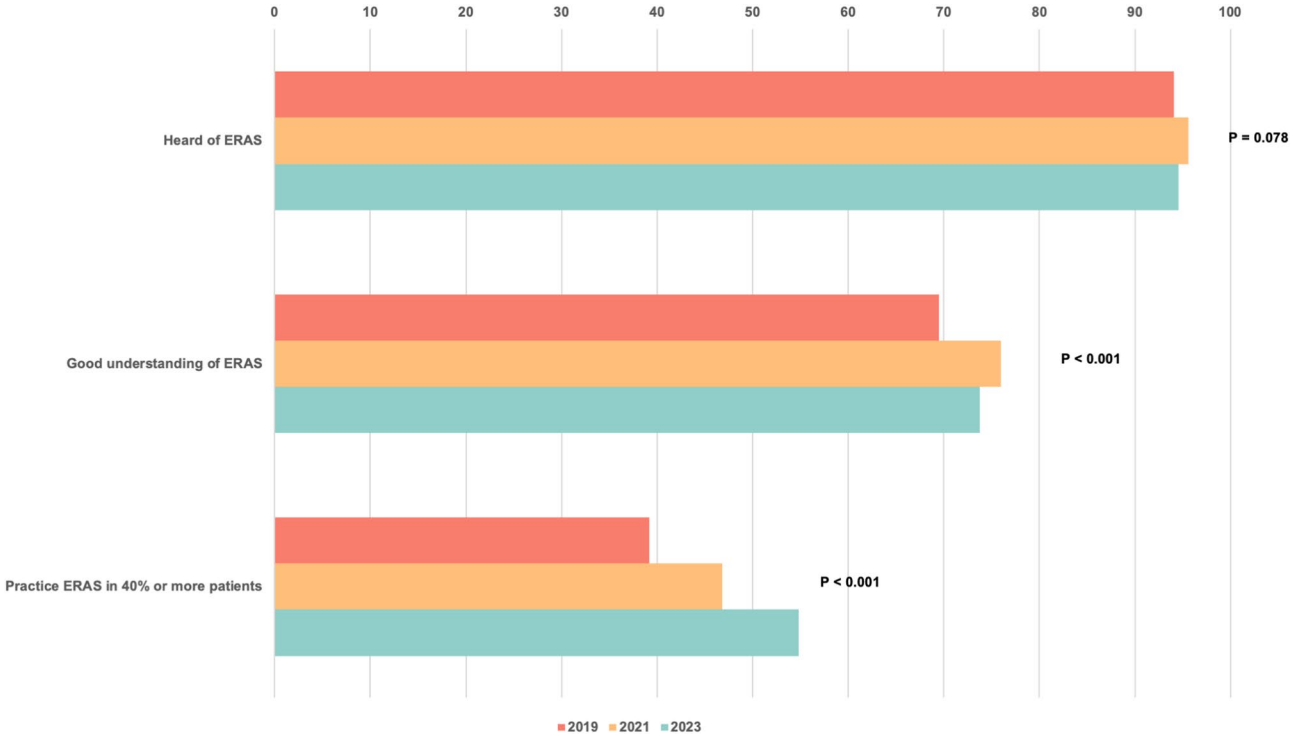

Fig. 1 Overall understanding and practice of the ERAS concept. The answers to each question in this domain were summarized and categorized. The figure illustrates the proportion of patients with a good understanding and who had had more practice with ERAS by the year of the survey. "Good understanding" was defined as "very familiar" or "quite familiar" options for relevant questions.

Educational intentions and difficulties implementing ERAS

For Part 4 of the questionnaire, nearly 90% of participants reported varying degrees of progress in ERAS-related theory, and 78.8% believed they had made progress in ERAS practice. Additionally, 87.4% of participants expressed that they were "very willing" or "quite willing" to receive further training in ERAS, with this proportion remaining stable across the survey years. Among the 4822 participants surveyed in 2021 and 2023, the primary methods for acquiring ERAS knowledge included online conference learning (reported by 84.4% in 2021 and 76.3% in 2023), books (71.9% in 2021 and 66.9% in 2023), and experiential learning from colleagues, including communication between anesthesiologists (60.2% in 2021 and 67.8% in 2023). Learning through mobile applications (APPs) also showed notable usage, with 61.3% of participants reporting this method in 2021 and 63.2% in 2023. Offline face-to-face seminars and training courses were less commonly mentioned, possibly due to the COVID-19 pandemic; but still contributed significantly to knowledge acquisition.

When asked about the difficulties encountered in implementing ERAS, 93.6% of participants acknowledged facing varying levels of challenges, with nearly 10% describing the practice of ERAS as "very difficult." The most commonly mentioned difficulties included the need for collaboration among various specialties (especially with surgeons), differences in understanding ERAS concepts within multidisciplinary teams, limited hospital support policies, patients' insufficient understanding of ERAS, and restrictive hospital management practices. Excluding non-anesthesiologist participants did not change the above-mentioned findings in the sensitivity analysis.

Discussion

This study was designed based on several expectations, including a possible increase in ERAS awareness and knowledge over time, variations in understanding and implementation across geographic regions and provider characteristics, and the presence of unmet educational needs. Our findings confirmed these expectations: knowledge scores and implementation rates significantly improved from 2019 to 2023; anesthesiologists from higher-tier hospitals and with greater educational attainment had better understanding of ERAS protocols; and most participants expressed a strong desire for further training. These results highlight critical areas for intervention and suggest directions for future curriculum design and health system planning.

This nationwide questionnaire surveyed Chinese anesthesiologists from nearly all provincial districts and demonstrated that they generally have a high level of awareness of the ERAS concept. From 2019 to 2023, the

Fig. 2 Specific knowledge of ERAS. Each question in this domain had the correct answer(s). The proportion of correct answers by year of survey in each domain is summarized in this figure

proportion of participants self-reported ERAS implementation in clinical practice and the scores of ERAS-related knowledge were statistically higher in 2023 compared to 2019. However, there is still considerable room for improvement. Most anesthesiologists are willing to receive further education on ERAS. Therefore, from this study, it is important to review previous teaching experiences and identify the future requirements for ERAS education.

Previous surveys on ERAS among anesthesiologists have reported similar findings. For example, a survey conducted in India in 2021 revealed that 89.4% of the 273 surveyed anesthesiologists were aware of the ERAS concept. [13] Another survey conducted during the International Congress 2012 Networks in Anesthesiology Symposium, which included 147 anesthesiologists from multiple countries, revealed that 76% of anesthesiologists believed in ERAS. However, only 19% of anesthesiologists stated that they implemented ERAS in their daily clinical practice. [14] In our survey, no formal definition of ERAS was provided to avoid influencing responses in the knowledge quiz section. Consequently, the reported implementation proportion reflect participants' self-perceived understanding of ERAS. Given the likely incomplete understanding of ERAS among anesthesiologists, the actual implementation proportion, when evaluated against standardized ERAS criteria, could be even lower. Although our survey was conducted later than the two studies mentioned above, only approximately half of the respondents reported practicing ERAS in more than 40% of their patients, highlighting the need for further efforts to improve implementation rates. Surveys of other specialties outside of anesthesiology, especially various surgical disciplines, revealed that the proportion of ERAS implementation in practice was 20.3%~37%.[21–26] Most of these previous surveys had limited sample sizes, with only a few hundred health care providers participating, and lacked repeated surveys over multiple years.

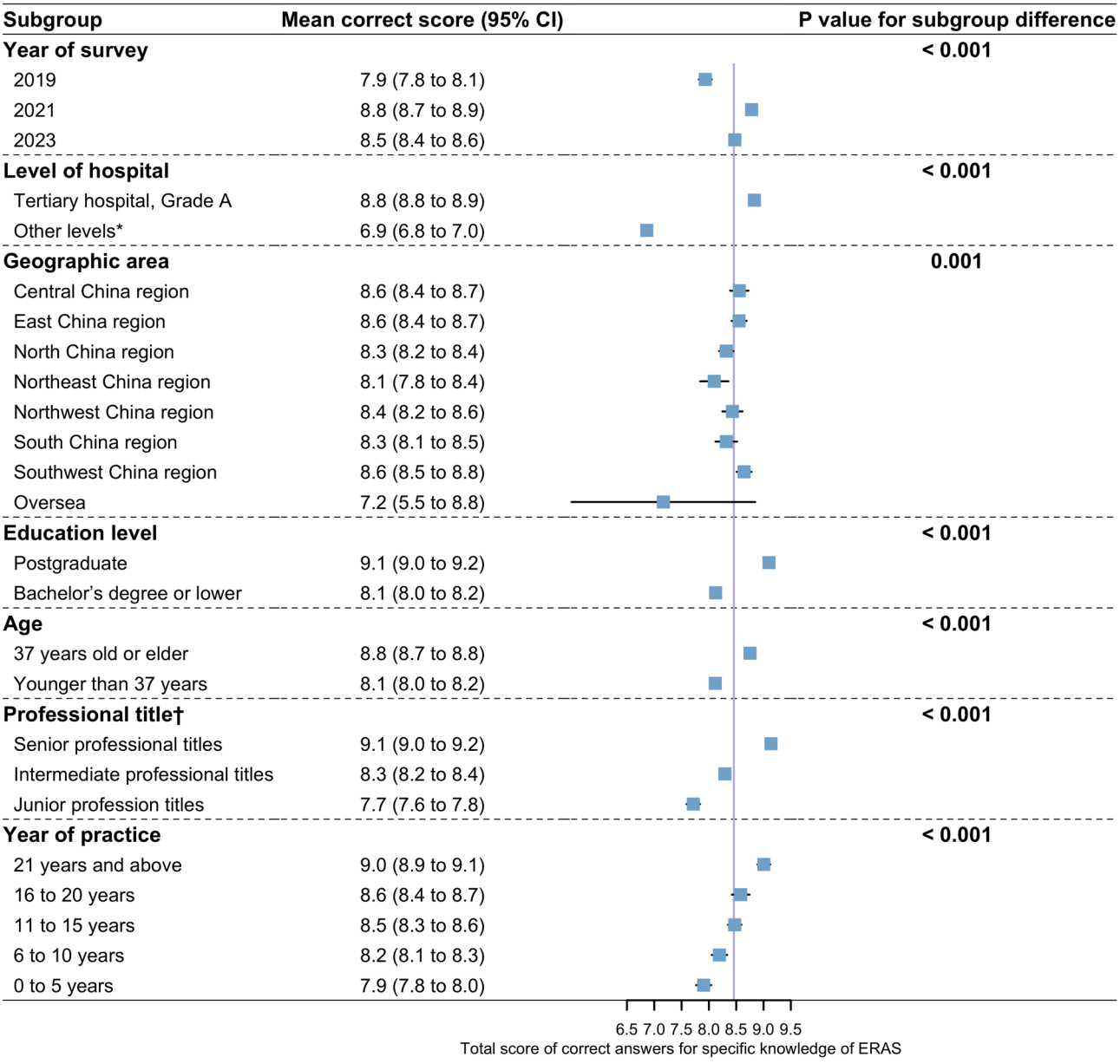

Fig. 3 Forest plot of the total score of correct answers for specific knowledge of ERAS in different subgroups. The blue squares in the figure represent the mean scores for correct answers to specific ERAS questions within each subgroup, and the error bars indicate 95% confidence intervals for the mean scores. The light purple line in the figure represents the overall mean score of 8.5 for all surveyed participants. The maximum total score is 15 points

An important aspect of our survey is that, in addition to assessing the overall understanding of the ERAS concept and practice of ERAS, we also examined specific knowledge elements. Previous studies did not investigate this aspect, perhaps because recommendations for specific implementation details vary across settings. As mentioned earlier, high-quality systematic reviews have demonstrated that interventions in various aspects of ERAS can enhance patient outcomes on the basis of evidence from randomized controlled trials (RCTs). However, most of this evidence comes from small-scale RCTs, leading to uncertainty about long-term prognosis and a reduction in severe complications. [2, 3, 4, 5] After systematically searching for relevant evidence, Chinese surgeons and anesthesiologists collaborated to publish clinical practice guidelines outlining recommendations for implementing various aspects of ERAS for surgical patients in China. [16] Our survey on ERAS knowledge points was based on these guidelines. Since this guideline was published between the 2019 and 2023 surveys, they may have contributed to the observed improvements in ERAS knowledge and implementation over time. However, our study was not specifically designed to evaluate the direct impact of their publication. Other factors, such

Table 2 Potentially correlated factors with correct answers regarding specific knowledge of ERAS. The total score of correct answers was regressed against the year of survey and participants' characteristics, including level of hospital, level of education, geographic area, professional title, and year of clinical practice, via a multivariable linear regression model. Age was not adjusted due to its strong correlation with year of clinical practice. The maximum total score is 15 points

Factors	Mean difference or coefficients (95% CI)	*P* value
Year of survey		
2019	Reference	-
2021	0.8 (0.6 to 0.9)	< 0.001
2023	0.4 (0.3 to 0.6)	< 0.001
Level of hospital		
Other levels*	Reference	-
Tertiary hospital, Grade A	0.8 (0.7 to 0.9)	< 0.001
Geographic area†		
Northeast China region	Reference	-
Central China region	0.7 (0.4 to 1.0)	< 0.001
East China region	0.8 (0.5 to 1.1)	< 0.001
North China region	0.4 (0.1 to 0.7)	0.007
Northwest China region	0.6 (0.3 to 0.9)	< 0.001
South China region	0.7 (0.4 to 1.0)	< 0.001
Southwest China region	1.0 (0.7 to 1.3)	< 0.001
Education level		
Bachelor's degree or lower	Reference	-
Postgraduate	0.8 (0.7 to 1.0)	< 0.001
Professional title‡		
Junior professional titles	Reference	-
Intermediate professional titles	0.6 (0.3 to 0.8)	< 0.001
Senior professional titles	1.2 (0.9 to 1.4)	< 0.001
Years of practice		
0 to 5 years	Reference	-
6 to 10 years	0.2 (-0.1 to 0.4)	0.136
11 to 15 years	0.3 (0.0 to 0.5)	0.033
16 to 20 years	0.2 (-0.1 to 0.5)	0.117
21 years and above	0.6 (0.3 to 0.8)	< 0.001

*Include Grade B tertiary hospitals, secondary hospitals, primary care hospitals, and nongovernment medical institutions

†Oversea participants were removed from this multivariable analysis because of the small sample size

‡Senior professional titles include chief and deputy chief physicians. Intermediate professional titles include attending physicians, nursing officers, and nurse practitioners. Junior professional titles include resident physicians, registered nurses, and intern physicians

Abbreviations: ERAS, enhanced recovery after surgery

as increasing clinical experience, continuing education efforts, and broader dissemination of ERAS concepts, may have also played a role. Future studies investigating the direct influence of guideline publication on ERAS adoption would be valuable. We believe that even if anesthesiologists believe in the principles of ERAS and are willing to implement them, a lack of knowledge of specific ERAS elements could impede optimal implementation and outcomes.

Improvements in knowledge were observed in several areas, including prehabilitation, [27] preoperative nutritional optimization, [28] temperature management strategies, [29] assessment and prevention of PONV. [30] These topics aligned closely with the current hotspots in anesthesia research and the academic priorities of CSA from 2019 to 2023, with a strong emphasis on teaching related knowledge. However, there were also specific issues where scores of ERAS knowledge remained unsatisfactory or even regressed, particularly concerning measures that differ from traditional management methods, such as preoperative fasting times [31] and complicated ERAS protocols integrating pathophysiological principles, including perioperative multimodal analgesia and fluid management strategies. [32]

In our research, anesthesiologists in Class A tertiary hospitals had significantly higher scores for ERAS knowledge. [33] Regional differences were also observed, with central, eastern, and southwest regions showing higher scores compared to other regions. These differences likely reflect the heterogeneity in hospital characteristics and clinical practices across regions. For instance, the eastern and central regions of China host a higher concentration of leading tertiary hospitals, which play a key role in perioperative care standardization, academic training, and ERAS protocol promotion. Many of these institutions have actively contributed to guideline development and training programs, which could influence regional adoption of ERAS practices and may explain the higher knowledge scores observed in these areas. Similarly, the southwest region showed relatively high knowledge scores, which may be partially influenced by the presence of leading institutions such as West China Hospital of Sichuan University. As one of the largest and most academically active medical centers in China, it has played a key role in perioperative research and education. Given that ERAS adoption can be influenced by institutional leadership and local training efforts, it is possible that the influence of such major hospitals extends beyond their immediate location and contributes to regional trends in ERAS awareness and practice. However, further studies would be needed to assess the direct impact of institutional initiatives on ERAS knowledge and implementation in different regions. Due to the complexity and variability of regional healthcare systems, we chose to focus on describing these differences rather than attributing them to specific regional factors. Future studies may benefit from a more detailed examination of regional disparities, potentially incorporating factors such as resource allocation, institutional policies, and regional training opportunities. In terms of individual characteristics, anesthesiologists with higher education

levels and professional titles had a better understanding of ERAS, which was consistent with the findings of previous studies. [34, 35] Therefore, to enhance the overall understanding of ERAS among anesthesiologists nationwide, it is essential to prioritize educational efforts for early-career anesthesiologists who may have had limited exposure to ERAS principles, particularly in regions with fewer training opportunities and resources.

The survey indicated that the majority of anesthesiologists strongly desired further education on ERAS. While education is foundational for improving ERAS knowledge and practice, it is not sufficient alone. Incorporating Human Factors Engineering (HFE) beyond education can further optimize ERAS implementation by improving system design and meeting the needs of both providers and patients. [36] Complementary strategies, such as multidisciplinary collaboration, institutional support, and standardized workflows, are critical to addressing systemic challenges. Additionally, integrating technology, such as mobile apps for reminders, electronic health records with embedded protocols, and patient education platforms, has the potential to enhance adherence to ERAS practices.

Although experiential learning represents one of the primary ways in which participants learn ERAS, imitating ERAS protocols from the literature or others without formal education is not helpful enough to connect the implementation and understanding principles of ERAS comprehensively. [37] Therefore, it is necessary to support systemic education of standardized ERAS courses to effectively compensate for the knowledge gaps and help the participants become real believers in ERAS. These courses could be designed to cover the essential elements of the ERAS protocol with a particular emphasis on providing in-depth knowledge and hands-on recommendations, especially the clinical details that deviate from traditional clinical procedures. Various techniques, such as case-based learning (CBL), problem-based learning (PBL), flipped classrooms, and team-based learning (TBL), should be incorporated into ERAS training. [38, 39] To start training from the early stages, anesthesiology resident education should be broadened beyond conventional core rotations to encompass the ERAS strategy. A recent report has already initiated the implementation of perioperative medicine as a distinctive curriculum for residents. [40].

Similar to the findings of previous studies, Chinese anesthesiologists identified collaboration and coordination among multiple disciplines as the most significant challenge in implementing ERAS. [41] Therefore, the multidisciplinary nature of ERAS should be fundamentally emphasized in education. Some studies have suggested that ERAS education and training should be conducted at the institutional level, with participants including personnel from various professions, such as surgery, anesthesiology, nursing, and management, and with support from the hospital in terms of policies and the environment. [42].

This study had several limitations. First, considering the feasibility of the survey, a strict probability sampling process was not designed or implemented when selecting the participants. All surveyed participants were recruited through a convenience sampling process. Potential selection bias in convenience sampling cannot be ruled out. Second, we did not rigorously examine the reliability and validity of the questionnaire. We believe it is necessary to develop standardized and reliable survey tools for ERAS in the future, which will greatly help researchers understand the status of ERAS education and practice and enhance the comparability of research results. Third, regarding the specific content of the survey in this study on whether the ERAS knowledge points were answered correctly, we cannot rule out the possibility that the participants searched for the correct answers on the internet or from clinical practice guidelines when answering the questions. However, we speculate that the participants did not have much motivation to search for the correct answers before completing the survey. Fourth, to protect the personal privacy of the participants, we did not collect any personal identifying information from the participants. Therefore, we cannot rule out the possibility that the same person participated in our survey multiple times over the years. However, since the three surveys in this study were conducted at least one year apart, even if some people did participate in the survey repeatedly, it is very likely that they would not remember the results of their questionnaire responses from at least one year ago and that their responses to the questions about ERAS-related issues provided were roughly independent. Finally, while we included an open-ended question to explore the primary challenges of ERAS implementation, the design of the survey was primarily quantitative and not intended to provide in-depth qualitative insights. The analysis of this open-ended question was limited to summarizing frequently mentioned keywords, and we did not perform a formal thematic or qualitative analysis. To comprehensively understand the barriers to ERAS implementation, future research should employ a dedicated mixed-methods design, incorporating in-depth interviews or focus groups to collect rich qualitative data. Such an approach would provide a deeper understanding of the challenges and enable the development of tailored strategies to address them.

Conclusions

The vast majority of Chinese anesthesiologists are aware of the ERAS concept. Between 2019 and 2023, their understanding of specific aspects of ERAS and its

implementation increased significantly but still needs improvement. Anesthesiologists with higher education, longer years of practice, higher professional titles, from Class A tertiary hospitals, and from the central, western, and southern regions mastered specific measures of ERAS better. In the future, strengthening medical education with multidisciplinary collaboration may be the key to promoting ERAS development. Tailored and standardized ERAS education programs, especially those targeting early-career anesthesiologists and practitioners from underrepresented regions, will be crucial in bridging the knowledge gap and improving implementation. These findings may also offer valuable insights for other countries seeking to improve ERAS education and implementation through large-scale, profession-specific surveys.

Abbreviations

ERAS	Enhanced recovery after surgery
KAP	Knowledge, attitudes, and practices
CROSS	A Consensus-Based Checklist for Reporting of Survey Studies (CROSS)
CSA	Chinese Society of Anesthesiology
PONV	Postoperative nausea and vomiting
CI	Confidence interval
IQR	Interquartile range
RCT	Randomized controlled trial
CBL	Case-based learning
PBL	Problem-based learning
TBL	Team-based learning

Supplementary Information

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Supplementary Material 1

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Author contributions

YG Huang and ZJ Liu conceived, designed, and supervised this study. ZJ Liu designed the overall sampling process, coordinated the recruitment of participants, and conducted data collection. YL Zhang and QM Zhu cleaned the original data and conducted statistical analysis. YL Zhang and ZJ Liu wrote the first draft of the manuscript. YG Huang, ZJ Liu, LL Ma, X Li, QM Zhu, GN Wang, J Cang, YG Diao, TZ Zhang, L Shen, and YL Zhang contributed data interpretation and revise the manuscript. All authors approved the final version of the manuscript. YG Huang and ZJ Liu are the guarantors of the manuscript, and all the authors have full access to the data.

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Data availability

The original data with variable dictionary and analysis code (in R language) will be publicly assessed 1 year after the manuscript is published. Relevant collaborative research requests should be sent to the corresponding author through email with a research proposal.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Peking Union Medical College Hospital Institutional Review Board (No. K5492). Written informed consent was obtained from all the surveyed participants. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration and its later amendments or comparable ethical standards.

Consent for publication

This study involves only aggregated data at the population level and does not include any identifiable personal information. All participants provided written informed consent prior to data collection, and the study was approved by the institutional ethics committee.

Competing interests

The authors declare no competing interests.

Author details

[1]Center for Prevention and Early Intervention, National Infrastructures for Translational Medicine, Institute of Clinical Medicine, Peking Union Medical College Hospital, Chinese Academy of Medical Science and Peking Union Medical College, Beijing 100730, China
[2]Department of Anesthesiology, Peking Union Medical College Hospital, Chinese Academy of Medical Science and Peking Union Medical College, Beijing 100730, China
[3]Department of Anesthesiology, Harbin Medical University Cancer Hospital, Harbin, Heilongjiang 150081, China
[4]Department of Anesthesiology, Zhongshan Hospital, Fudan University, Shanghai 200032, China
[5]Department of Anesthesia, General Hospital of Northern Theater Command, Shenyang, Liaoning 110016, China

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