BMC Anesthesiology

RESEARCH

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Knowledge, attitude and practice toward to artificial intelligent patient-controlled analgesia among anesthesiologists: a cross-sectional study in east China's Jiangsu Province

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Abstract

Background Inadequate postoperative analgesia greatly affects the recovery of patients, can poses a substantial health and economic burden. Patient-controlled analgesia is the most commonly used method for postoperative pain relief. However, the situation of inadequate analgesia still exists. Artificial intelligent Patient-controlled analgesia (Ai-PCA) system can make it easier for medical staff to understand the pain level of patients in order to deal with it in time. So far, several studies have investigated anesthesiologists' knowledge and management of Ai-PCA.

Objective This study aimed to assess the degree of anesthesiologists' knowledge, attitude and their practice (KAP) towards Ai-PCA in east China's Jiangsu Province.

Methods This cross-sectional study was conducted among 396 anesthesiologists working in tertiary hospitals. The data were collected using a pretested, structured and self-administered KAP questionnaire. The data were analyzed using Independent t-test, analysis of variance, Pearson's correlation and multiple linear regression tests.

Results Five hundred twelve questionnaires were collected, 396 anesthesiologists (190 Male, and 206 Female) were included in our study for statistical analysis. The score of knowledge, attitude, practice was 5.49 ((SD = 1.65; range:0–8), 37.45 (SD = 4.46; range:9–45), and 26.41 (SD = 9.61; range:9–45), respectively. Among the participants, 309 (78%) and 264 (66.7%) had good knowledge and positive attitudes toward Ai-PCA, respectively. However, only 81 (20.5%) of the participants exhibited good practice regarding Ai-PCA. Participation in Ai-PCA training showed a significant correlation with knowledge, attitude and practice scores. Besides, age, years of experience and professional titles of anesthesiologists were correlated with knowledge scores. The title of the anesthesiologist was associated with attitude scores. And the marital status of anesthesiologists was correlated with practice scores.

Conclusion Our findings revealed the score of practice regarding Ai-PCA are very poor among anesthesiologists in east China's Jiangsu Province. The utilization of Ai-PCA was found to be impacted by whether the individual had

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received training. This calls for a comprehensive approach should be conducted for raising the level of knowledge, attitude, and practice of anesthesiologist on using Ai-PCA and more Ai-PCA training to be included in the daily learning.

Trial registration Chinese Clinical Trial Registry (www.chictr.org.cn; 27/10/2023; ChiCTR2300077070).

Keywords Ai-PCA, Knowledge, Attitude, Practice, Anesthesiologists

Introduction

Pain is an unpleasant sensation and emotional experience accompanied by substantial or potential tissue damage, and it is a multidimensional sense of perception, differs from individual to individual [1]. Acute pain after surgery is common, more than 93.7% of patients suffer from pain after surgery [2]. Several national surveys on postoperative pain have been conducted in the US, UK, Canada, Germany, and France, and all surveys reported a high incidence of moderate to severe pain in patients [3]. This situation is not optimistic in China, either. In a cross-sectional observational study of 1185 surgical patients from 17 hospitals in Southwest China showed that 56.19% and 29.73% of patients suffered from moderate/severe pain, respectively, during exercise and rest [4]. Severe unrelieved pain could lead to changes in many organ systems, like respiratory, circulatory, and immune systems, affecting patients' postoperative rehabilitation and quality of life of patients [5]. Moreover, patients with more severe acute pain are more likely to develop chronic pain, with 33% experiencing postoperative chronic pain [6], which may be associated with mental stresses [7].

Patient-controlled analgesia (PCA) technique can use a PCA pump continuous infusion analgesic medication to maintain a more stable effective plasma concentration to control pain and an on-demand bolus dose is allowed by the patient to self-management [8],. Although many randomized-controlled trials have demonstrated clinical advantages of PCA in easing the pain [9], the incidence of inadequate analgesia remains up to 45.5% [6]. Multiple factors can affect severe pain after surgery, such as female, history of mental illness, sleep difficulties, presence of preoperative pain, use of preoperative analgesia and so on [7]. Beyond that, inadequate assessment and management of pain may be another important factor [8]. Maitreyee et al. conducted a descriptive analysis of intravenous patient-controlled analgesia (IV-PCA) management errors, indicated that staff related factors such as staff inexperience, distractions, increased workload and insufficient staffs were the leading factors [10]. PCA equipment is scattered in patient wards without direct or instant connection with medical personnel. If no immediate response is made by medical staff when mechanical error occur or when a patient's analgesia requires adjustments, the analgesia efficiency will be compromised [11].

Ai-PCA system may overcome the shortcomings of the traditional PCA, which connects electronic PCA pumps and other mobile terminals with a central computer [11]. It could record the operation data, including the number of infusion doses and times to realizes continuous dynamic management and quality control of the analgesic medical process. When abnormal data occurs, the staff can evaluate the patient's pain score and related adverse reactions at the first time, record and upload the corresponding data, which is conducive for healthcare workers to receive and processes the feedback information. A recent study from Hu et al. reported that the application of Ai-PCA could significantly reduce analgesic adverse reactions and increase the satisfaction degree of analgesia [12].

For several years, the expert consensus for Ai-PCA have stressed on the importance of management as a critical component of postoperative analgesia. The management of the Ai-PCA can have a direct impact on patient satisfaction with analgesia, which motivated us to conduct this study on anesthesiologists in order to assess the current situation. This study assessed anesthesiologists', knowledge, attitude as well as practice towards Ai-PCA. aiming to pinpoint areas for improvement and enhance postoperative patient care and satisfaction.

Methods and materials

Study design and setting

This cross-sectional study was conducted from 15th December 2023 to 25th December 2023 among anesthesiologists, who currently work in Nanjing, east China's Jiangsu Province. Only tertiary hospitals were included.

Inclusion and exclusion criteria

All participants met the following inclusion criteria:(a) currently employed in the Anesthesiology department ≥ 1 year; (b) obtaining a Physician Practice Certificate issued by the Ministry of Health of China; (c) voluntarily consenting to take part in the study. Anesthesiologists who declined to participate were excluded.

Sample size

The required sample size was determined by a single population proportion formula [13]. The proportion was taken at 50%, and the sample size calculation was made

as the following proportion of the study with 95% of confidence intervals (CI) and 5% of margin error.

$$n = z^2 p(1-p)/w^2$$

where n = sample size, p = proportion (50%), w = margin error (5%), z = 1.96 confidence level, The calculated minimum sample size was 384 [14].

Data collection tools

An anonymous self-administrated questionnaire was used to assess anesthesiologists' KAP (knowledge, attitude, and practice) towards Ai-PCA system management. This questionnaire was designed using standardized methodology, including literature review, expert discussions, and pilot studies. Before the final investigation, a pilot study involving 30 anesthesiologists was conducted to evaluate questionnaire's language clarity, organization, and accuracy..Minor adjustments were made based on the feedback received. The Cronbach's value for Internal consistency reliability of individual subscales of the questionnaire was 0.91, 0.78 and 0.92 for knowledge, attitude and practice, respectively, indicating good internal consistency (> 0.70) [15].

The questionnaire comprised four parts. The first part (7 questions) focused on demographic information covering gender, age, educational background, marital status, year of work, the title of a professional post, whether have participated in Ai-PCA related training. Subsequent sections addressed anesthesiologists' knowledge, attitude, and practice through 10, 9 and 9 questions, respectively. In the "knowledge" section, two additional questions were included to identify careless responses. Participants providing incorrect answers to these questions were excluded from the study. Furthermore, the order of answers for certain questions was strategically modified to enhance result credibility.

The second part focused on the anesthesiologist's knowledge of Ai-PCA, comprising 10 questions organized into four themes: definition, components, use process and management system. The responses were presented with "yes", "no" or "no idea", with correct answers receiving 1 point and incorrect or unclear answers receiving no points. The maximum achievable score was 10 points, with the lowest being 0 points.

The third part examined anesthesiologists' attitude regard to Ai-PCA. The questionnaire consists of 9 questions addressing various aspects: attitude towards to participation in Ai-PCA related training, attitude towards to Ai-PCA analgesic management, attitude towards to analgesia-related adverse events and attitude towards to Ai-PCA recognition. Results were assessed using the 5-point Likert scale(1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree), the answer was scored 1 ~ 5, respectively. The higher score indicate a more positive attitude.

The fourth part explored the practical application of Ai-PCA among anesthesiologists. This section includes nine questions covering aspects such as frequency of participation in knowledge update and training, frequency of Ai-PCA management based on the collected data, frequency of attention to adverse events, frequency of summarizing and discussing the use of Ai-PCA, and frequency of asking patients about their satisfaction with Ai-PCA. The response section uses a 5-point Likert scale, ranging from 5 (Always) to 1 (Never).

The score of each question was calculated, and ranged up to a maximum of 10, 45 and 45 points for the knowledge, attitude and practice, respectively. The total KAP score were calculated by summing the points from each part. Overall scores were categorized as "good" and "bad" using Modified Bloom's cut-off point(80%). Scores above this range are considered as a high level of knowledge, positive attitude, and a good level of practice. In contrast, scores below this range are defined as low knowledge, negative attitude, and poor practice [11].

Dissemination of survey questionnaire

After screening the inclusion and exclusion criteria, this questionnaire was conveniently distributed to 600 anesthesiologists working in tertiary hospital via the sojump software. Our study used the method of convenience sampling for the advantage of simplicity, easiness, and for rapid collection of data in a costeffective way.

Data analysis

The collected data was extracted to an Excel spreadsheet and appropriately coded in order to make it applicable to statistical tests. After data collection completed, which was checked to find out errors or incomplete information, and it could be excluded from the entry. Finally, the collected data were exported to SPSS version 26.0 for analysis. Categorical date were described as proportions. Descriptive statistics were summarized using tables, figures, and textual representation. Frequency, mean and standard deviation was calculated. Student's t-test and analysis of variance test to assess the association between each continuous independent variable (KAP scores) and the sociodemographic variables. Scheffe's test was adopted as post-test of one-way ANOVA. Then we performed multiple linear regression tests, aiming to identify factors associated with perceived knowledge, attitude, and practice levels. The association between the knowledge, attitude, and practices was assessed using the Pearson's correlation coefficient (r). $P < 0.05$ was considered as statistically significant. The internal consistency

and reliability of the KPA scale were assessed using Cronbach's alpha coefficient.

Ethics approval and consent

The ethical clearance of this study was approved by Institutional Review Board of the Affiliated Cancer Hospital of Nanjing Medical University and carried out in tertiary medical centers in Nanjing, East China's Jiangsu province. The study was performed using self-administered questionnaires. The written informed consent was obtained from all participants before the study, and they have the right to withdraw from the study at any phase. All further study was conducted under guidance of the Helsinki declaration of 1964 (revised 2013).

Results

Sociodemographic characteristics

Five hundred twelve questionnaires we collected via the sojump software, 5 participants were excluded due to they take less than 60 s to complete the survey. Moreover, 111 anesthesiologists were excluded due to the inattentive responses, particularly poor performance on the questions "Is Ai-PCA no different from traditional PCA?" and "Is Ai-PCA very safe and free from adverse reactions?". Finally, 396 anesthesiologists (190 Male and 206 Female) were included in our study and used for statistical analysis.

Of the surveyed participants, 52.0% were female and 48.0% were male. The age range were 23–66 years, with a mean age of 39.4 years (SD: 10.137), median 38yrs (IQR: 30yrs– 48yrs). Majority of the participants were married (75%), while 25% were single. More than a half of the participants reported having a postgraduate diploma($n=50.5\%$), while 38.4% had received undergraduate education, and 11.1% held a doctorate. Regarding years of practice experience, 34.6% had more than 20 years, 20.5% had 11–20 years, and 30.6% had less than 5 years. Only 14.4% had 6–10 years of experience. Less than a third had attended the training of Ai-PCA(33.1%), more than two-thirds (66.9%) had never received such training. The participants' demographic details are summarized in Table 1.

Knowledge

The mean knowledge score was 7.60 (SD = 2.63; range:0–10). When dividing the score into two categories, the results revealed that 309(78.0%) had good knowledge (scores of 8 and above), While 87(22%) had poor knowledge (scores < 8) (Fig. 1).

The majority of the participants understood the concept (87.6%) and the components (85.6%) of AI-PCA. Most anesthesiologists (83.8%) supported that Ai-PCA is smarter and more efficient than traditional analgesia pumps. Approximately 83.8% of the respondents correctly answered the process of using Ai-PCA, including evaluation, developing a analgesia plan and prescribing. However, nearly two-thirds (65.4%) of the participants mistakenly believed that the Ai-PCA system could design drug dose and prescribe medication. Moreover, more than a fifth of participants (22.5%) had no understanding of this aspect. About 86.4% of participants agreed that Ai-PCA should be checked and obtain the patient's signature before implementation. In regard to the make the rounds of the wards, a half of the anesthesiologists (51.3%) hold the wrong idea that once a week is enough. Most participants (88.1%) approved that the patient's physical condition and the operation of Ai-PCA should be be closely monitored during using Ai-PCA (Fig. 2).

The results of one-way ANOVA indicated a significant relationship between age and knowledge ($P=0.007$). Post-hoc analysis using Scheffe's test revealed a notable difference in knowledge scores between individuals aged 36 to 45 years and ≥ 46 years ($P=0.008$). Anesthesiologists exhibited higher levels of knowledge compared to those aged 36–45. Regarding work experience, the one-way ANOVA demonstrated a significant correlation between knowledge score and years of experience. Scheffe's test showed that participants with 21 or more years of experience had greater knowledge compared to those with ≤ 5 years ($P=0.005$) and 11 to 20 years of experience($P=0.022$). Moreover, there was a noticeable differences between knowledge and technical title of the anesthesiologists ($P=0.049$). Knowledge about Ai-PCA among senior professionals was significantly higher than primary. The results of Independent t-test also showed that a significant difference in knowledge scores between participants who had received training on AI-PCA and those who hadn't ($P=0.000$). Participants who had undergone training exhibited higher levels of knowledge (Table 1).

Attitude

The mean attitude score was 37.45 (SD = 4.46; range:9–45). When dividing the score into two categories, the results showed that 132(33.3%) had poor attitude (scores < 36), while 264(66.6%) had good attitude (scores of 36 and above) (Fig. 1).

Most participants (91.2%) considered Ai-PCA training to be vital important for clinical tasks and patient outcomes, and over 94.4% (374) of them were willing to discuss problems encountered in the clinical practice of Ai-PCA with other healthcare workers and try to find solutions. Nearly two-thirds of the anesthesiologists (64.3%) disagreed with the statement that learning Ai-PCA expert consensus and updating knowledge is not very important. About 92.9% (368) of the respondents

Table 1 Sociodemographic characteristic of the study participants ($n=396$)

		Knowledge		Attitude		Practice	
Variable	**Frequency (%)**	**Mean ± SD**	**Test results**	**Mean ± SD**	**Test results**	**Mean ± SD**	**Test results**
Gender							
Male	190(48%)	7.84(2.41)	t = 1.82	37.76(4.47)	t = 1.43	26.37(9.04)	t = -0.08
Female	206(52%)	7.35(2.82)	$p=0.07$	37.12(4.45)	$p=0.15$	26.45(10.22)	$p=0.935$
Age							
≤ 35	174(43.9%)	7.23(2.99)	F = 4.957	36.89(4.53)	F = 2.498	25.56(10.17)	F = 1.234
36–45	97(24.5%)	7.53(2.63)	$p=0.007^{**}$	37.92(4.65)	$p=0.084$	26.99(9.01)	$p=0.292$
≥ 46	125(31.6%)	8.18(1.89)		37.88(4.15)		27.15(9.23)	
Marital status							
Single	99(25%)	7.11 ± 3.11	t = -1.917	36.83(4.9)	t = -1.616	24.4(9.63)	t = -2.401
Married	297(75%)	7.77 ± 2.43	$p=0.057$	37.66(4.3)	$p=0.107$	27.08(9.53)	$p=0.017^{*}$
Education							
Bachelor	152(38.4%)	7.61 ± 2.59	F = 0.323	37.46(4.42)	F = 0.01	26.68(9.39)	F = 0.179
Postgraduate	200(50.5%)	7.54 ± 2.67	$p=0.724$	37.47(4.56)	$p=0.99$	26.37(9.84)	$p=0.836$
Ph.D	44(11.1%)	7.89 ± 2.6		37.36(4.28)		25.7(9.53)	
Work experiences							
≤ 5	121(30.6%)	7.1 ± 3.04	F = 5.467	36.7(4.77)	F = 1.829	24.71(10.15)	F = 2.296
6–10	57(14.4%)	7.75 ± 2.57	$p=0.001^{**}$	37.49(4.29)	$p=0.141$	27.61(10.25)	$p=0.077$
11–20	81(20.5%)	7.14 ± 3.05		37.69(4.56)		26.11(8.91)	
≥ 21	137(34.6%)	8.26 ± 1.69		37.96(4.14)		27.59(9.11)	
Technical title							
primary	129(32.6%)	7.12 ± 2.96	F = 2.649	36.65(4.53)	F = 3.498	24.88(9.99)	F = 1.706
middle	79(19.9%)	7.78 ± 2.59	$p=0.049^{*}$	38.11(4.23)	$p=0.016^{*}$	27.56(9.8)	$p=0.165$
Vice-senior	76(19.2%)	7.58 ± 2.62		38.49(4.82)		27.08(9.41)	
senior	112(28.3%)	8.04 ± 2.15		37.21(4.14)		26.92(9.07)	
Have you ever participated in the training of Ai-PCA							
no	265(66.9%)	7.13(2.97)	t = 6.709	36.89(4.45)	t = 3.657	23.92(9.24)	t = 7.893
yes	131(33.1%)	8.56(1.28)	$p=0.000^{**}$	38.6(4.27)	$p=0.000^{**}$	31.46(8.31)	$p=0.000^{**}$

* $P<0.05$

** $p<0.01$

recognized the advantages of Ai-PCA for data feedback and recording, 87.4% of them believed that using Ai-PCA can reduce the incidence of analgesia-related adverse events and greatly improve patient satisfaction. However, 22% (87) of the participants thought that adverse events such as drowsiness, nausea and vomiting should not be paid too much attention. More than 90% of the respondents agreed or strongly agreed that improving the quality of Ai-PCA clinical application requires all medical staff are an important part of the process, and believe that Ai-PCA has broad prospects and will help to enhance analgesia effects and medical quality (Fig. 3).

As showed in Table 1, the results of One-way ANOVA demonstrated that there was an statistically significant relationship between technical title and the score of attitude. The Scheffe's test reported that those with vice-senior titles scored higher than those with junior titles. Besides, independent t-test also illustrated that there was an obvious difference in attitude between participants who had been trained with those had not ($P=0.000$).

Practice score

The mean practice score was 26.41 ± 9.61 (SD = 9.61; range:9–45). When dividing the score into two categories, the results showed that 315(79.5%) had poor practice (scores < 36), 81(20.5%) had good practice (scores of 36 and above) (Fig. 1).

34.3% of participants actively acquired the relative knowledge of Ai-PCA through various channels (e.g. training, reading literature or expert consensus, communicating with other healthcare workers, etc.) one to two times in the last two months. About 36.8% of the participants often carried out education to patients, such as avoiding patients' wrong perception of drugs. However, nearly a third of participants (33.8%) never adjusted the number of making the rounds in the wards

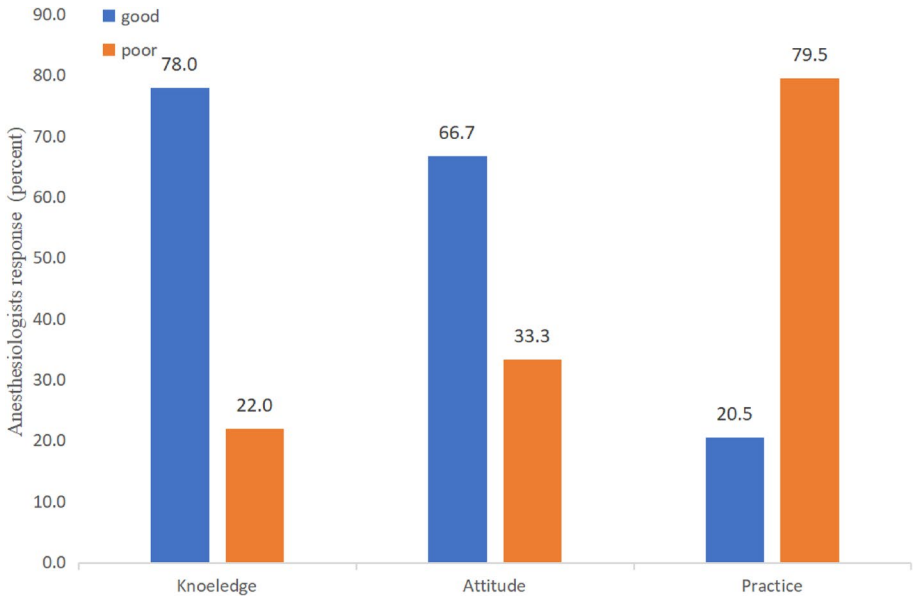

Fig. 1 Mean knowledge, attitude and practice scores of anesthesiologist. Knowledge score < 8 = poor knowledge, and ≥ 8 = good knowledge; Attitude score < 36 = poor attitude, and ≥ 36 = good attitude; Practice score < 36 = poor practice, and ≥ 36 = good practice

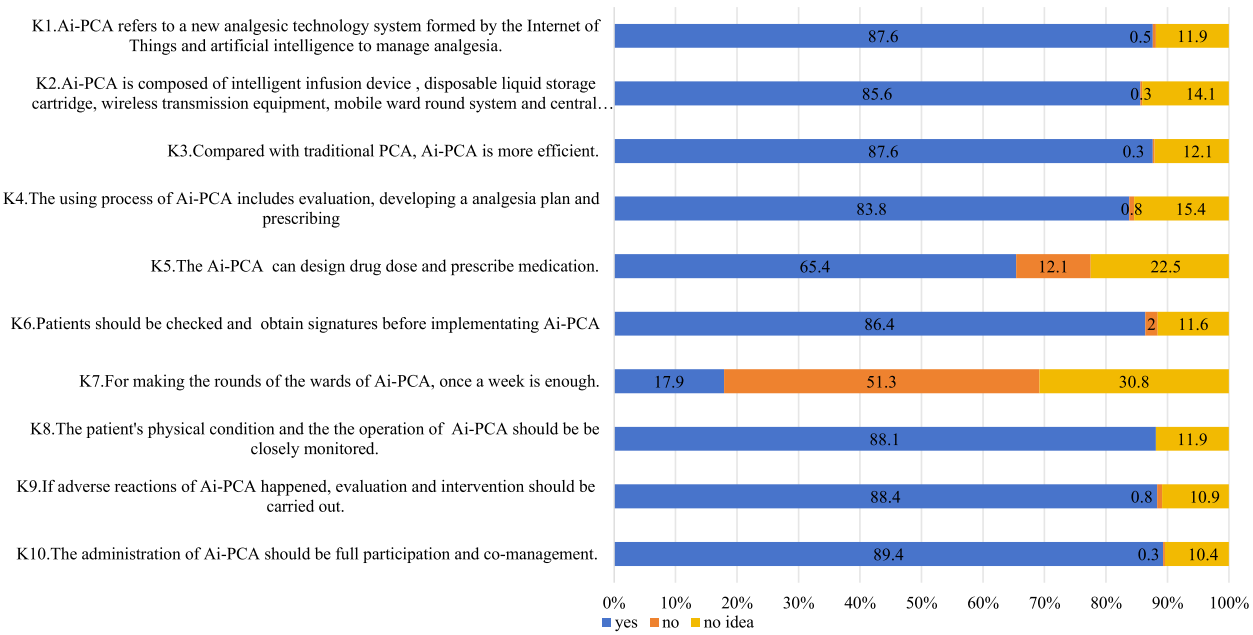

Fig. 2 Response of anesthesiologist' knowledge towards to Ai-PCA

based on Ai-PCA. There were 179 participants (45.2%) who often asked patients about their pain management during ward rounds. But there were 124 anesthesiologists who never adjusted the method of analgesia and the dose of drug based on Ai-PCA background data. About 247(62.4%) anesthesiologists frequently concerned patients with adverse events such as hypotension, nausea and vomiting. More than a third of participants (36.6%) never reported the situation of the patients using Ai-PCA at the morning meeting. More than 60% of the participants regularly asked patients about satisfaction about pain management. There were 46.8% of participants reported to willing to summarize the experience of using Ai-PCA and apply it to their next practice (Fig. 4).

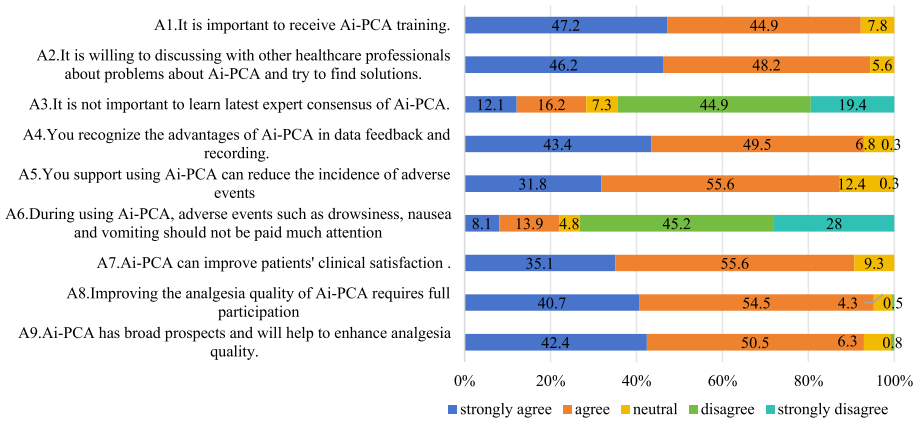

Fig. 3 Response of anesthesiologist's attitude towards Ai-PCA

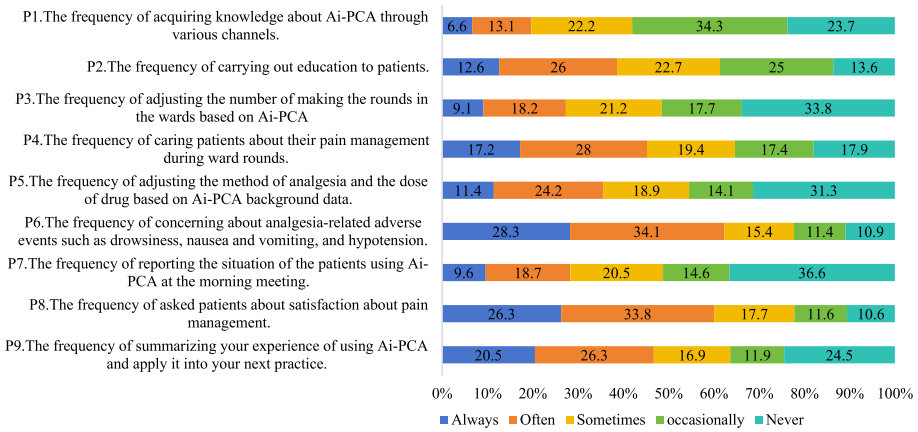

Fig. 4 Response of anesthesiologist' practice towards to Ai-PCA

What is more, the results of independent t-test (Table 1) demonstrated that there was an obvious difference between marital status and the score of practice of participants ($P=0$ 0.017), and who were married scored higher than single. Similarly, Trained anesthesiologists who had been trained score higher than untrained ($P=0$ 0.000).

Association and Correlation of KAP on Ai-PCA

As shown in Table 2, there was a significant and positive relationship between knowledge and attitude of the respondents about Ai-PCA ($r=0.049$, $P<0.001$). As knowledge scores increased, so did the score of attitude. Additionally, a noticeable modest positive correlation was illustrated between the knowledge and practice scores of Ai-PCA ($r=0.298$, $p=0.048$). An increase in knowledge scores was associated with higher attitude scores. Moreover, attitude and practice had an modest positive correlation relationship ($r=0.253$, $P<0.001$), indicating that higher attitude scores were linked with higher practice scores.

As shown in the results of linear regression analysis (Tables 3, 4 and 5), the variables of scores of knowledge, attitude and practice were associated with each other. Furthermore, the variable of whether have been trained of Ai-PCA was associated with anesthesiologists' knowledge, attitude and practice. The participants who have been trained, the score of knowledge and attitude was both increased by 0.623 units. What's important, the score of practice increased by 6.094 units.

Discussion

Despite the availability of many methods of analgesia, acute postoperative pain remains a common occurrence. Approximately 20 percent of patients experience severe pain within the first 24 h after surgery, a statistic that has remained largely unchanged over the past 30 years [1]. It's evident that there is no perfect analgesic drug. Therefore,

advocating for postoperative pain management should extend beyond pharmacological therapies [1].

Ai-PCA represents a novel approach to analgesic management, integrating traditional PCA with the Internet of Things (IoT) and artificial intelligence (Ai) to dynamically manage postoperative analgesia through remote monitoring. The system can store PCA real-time operating parameters, provide intelligent alarm feedback, and maintain comprehensive information. The Ai-PCA system can realize the integration of patient participation, real-time monitoring, electronic record-keeping, and active service [13]. Guo et al. found the application of Ai-PCA in elderly patients with hip fractures can achieve better analgesia, reduced the incidence of neuro-cognitive impairment and decreased inflammatory response during perioperative period, and enhanced patient satisfaction [12]. Since it's introduced into market in 2018, Ai-PCA has has gained widespread popularity in China and is gradually supplanting traditional PCA pumps. The Expert Consensus on Intelligent Patient-Controlled Analgesia Management guideine underscores the importance of adhering to proper processes and management protocols [16]. However, the effective utilization of Ai-PCA relies heavily on anesthesiologists' knowledge, attitudes,

Table 2 Correlation between knowledge, attitude, and practices

		Scores of knowledge	Scores of attitude	Scores of practice
Scores of knowledge	Pearson's correlation	1	0.449**	0.298**
	Sig		0.000	0.000
	N	396	396	396
Scores of attitude	Pearson's correlation	0.449**	1	0.253**
	Sig	0.000		0.000
	N	396	396	396
Scores of practice	Pearson's correlation	0.298**	0.253**	1
	Sig	0.000	0.000	
	N	396	396	396

** $p < 0.01$

Table 3 Linear regression analysis of demographic characteristics on anesthesiologist' knowledge towards to Ai-PCA

Independent variables	B coefficient	Standard coefficient	β-value	Statistics	*P*-value
Age	0.273	0.354	0.089	0.771	0.441
Work experiences	0.031	0.252	0.015	0.123	0.902
Technical title	-0.073	0.23	-0.033	-0.316	0.752
Whether have been trained of Ai-PCA	0.623	0.274	0.112	2.271	0.024*
Scores of attitude	0.224	0.027	0.381	8.334	0.000**
Scores of practice	0.042	0.013	0.155	3.215	0.001**

*$p < 0.05$

** $p < 0.01$

Table 4 The results of linear regression analysis to investigate the effect of demographic characteristics on anesthesiologist' attitude towards to Ai-PCA

Independent variables	B coefficient	Standard coefficient	β-value	Statistics	*P*-value
Age	0.273	0.354	0.089	0.771	0.441
Work experiences	0.031	0.252	0.015	0.123	0.902
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Whether have been trained of Ai-PCA	0.623	0.274	0.112	2.271	0.024*
Scores of attitude	0.224	0.027	0.381	8.334	0.000**
Scores of practice	0.042	0.013	0.155	3.215	0.001**

* $p < 0.05$

** $p < 0.01$

Table 5 The results of linear regression analysis to investigate the effect of demographic characteristics on anesthesiologist' attitude towards to Ai-PCA

Independent variables	B coefficient	Standard coefficient	β-value	Statistics	*P*-value
Marital status	1.105	1.02	0.05	1.084	0.279
Whether have been trained of Ai-PCA	6.094	0.968	0.299	6.295	0.000**
Scores of knowledge	0.588	0.19	0.161	3.096	0.002**
Scores of attitude	0.264	0.11	0.123	2.409	0.016*

* $p < 0.05$

** $p < 0.01$

and practices regarding Ai-PCA management in accordance with current guidelines.

Therefore, this study aimed to investigate anesthesiologists' knowledge, attitudes and practices towards Ai-PCA management in accordance with current management guidelines.

The current study revealed that a majority of the anesthesiologists (78.0%) had good knowledge of Ai-PCA, reflected in a high knowledge score (7.60 ± 2.63). Most of them demonstrated a solid understanding of the components of Ai-PCA and acknowledged its superior efficiency compared to traditional PCA pumps. Supporting Ai-PCA requires full participation and co-management. However, a notable proportion of anesthesiologists displayed limited familiarity with the process of dispensing analgesic drugs for Ai-PCA, as indicated by significantly lower scores in this aspect. Presently, manual operation still prevails in configuring s PCA pumps, and more intelligent analgesic pumps may appear in the future [17]. In clinical practice, anesthesiologists primarily engage in prescribing analgesic drugs, while the dispensing process for Ai-PCA pumps is handled by nurses. Anesthesiologists oversee the installation of analgesic pumps but may not be involved in the entire configuration process [18]. Regarding Ai-PCA management,, many anesthesiologists believe that ward rounds need only occur once a week. However, guidelines recommend daily ward rounds by acute pain service (APS) members for three days postsurgery, with adjustments as necessary. Currently, a dedicated APS team manages Ai-PCA pumps during ward rounds and provides feedback. [19]. Although Ai-PCA pumps have streamlined the management workload, anesthesiologist involvement throughout the entire process is crucial for ensuring higher-quality analgesia higher quality analgesia.

Only two thirds of anesthesiologists in this study exhibited positive attitude towards Ai-PCA (66.7%). While many valued participation in Ai-PCA training and were willing to address work-related issues collaboratively, attitudes towards updating knowledge and learning the latest expert consensus were less proactive. This finding aligns with reports from pain management guidelines indicating fewer advanced strategies employed in patient treatment in China [20]. Insufficient attention is directed towards the prevention and treatment of adverse events. A recent study in China reported that 22.9% of patients discontinued PCA use on the first postoperative day, primarily due to the side effects (60.0%) and concerns regarding these effects. Enhancing knowledge acquisition can improve anesthesiologists' awareness and attitudes towards adverse event management, while specific protocols are needed to address various adverse events that may arise during analgesic processes.

In the current study, only one-fifth of the anesthesiologists have good practice level toward Ai-PCA. This result falls below the guideline recommended in 2018. In addition, a significant number of anesthesiologists have not fully embraced the flexibility offered by the mobile round system to adjust the number of rounds or the central management system to modify analgesic regimens and administration frequencies. Ai-PCA offers significant advantages in real-time recording and transmission of patient analgesia and related information. For instance, when the patient experience mild pain due to decreasing regional blocking effects or declining analgesic blood concentrations, the pain can be relieved by pressing the automatic control button. The system can detect inadequate analgesia through analysis of button-pressing frequencies. In cases of severe pain, such as during sudden movements or coughing fits, repeated button presses trigger alerts for insufficient analgesia, prompting APS members to adjust single dose, promptly to prevent moderate and severe pain. Furthermore, the system can identify adverse reactions like postoperative nausea and vomiting (PONV), dizziness,or itching, allowing patients to mitigate drug infusion by clamping PCA pipelines. APS members can promptly address such issues through through "blockage" alarm and ascertainthe specific causes of adverse reactions. In addition, attention should be paid to patients who have not used the automatic control button for over 8 h, and necessitating potential reductions in analgesic infusion or more

comprehensive education and guidance by APS members [21].

Inadequate knowledge and insufficient assessment and administration of analgesic interventions pose challenges in the field of pain management [22]. Our study revealed a positive and significant correlation between knowledge、attitude and practice. And good knowledge, attitude and practice level are positively correlated with whether attend to training. Therefore, it is important to attend training of Ai-PCA. A study by Ladan et al. at indicated that after training and implementing a pain management improved [23].

Our study still has its limitations, such as a small sample size and a localized focus, it represents the first exploration of this topic. We ensured a targeted examination by exclusively studying anesthesiologists. However, this focus limits the generalizability to other healthcare professionals. The cross-sectional design provided a snapshot of attitudes and practices but lacked longitudinal insight. Despite efforts to mitigate response bias, honesty remains a concern. Nevertheless, our study underscores the importance of Ai-PCA training for improving anesthesiologists' knowledge and attitudes, potentially leading to enhanced clinical practice. Moving forward, research should include broader samples and employ dynamic methodologies to track changes over time. Despite its limitations, our study initiates vital discussions on optimizing pain management practices through Ai-PCA implementation.

Conclusion and recommendation

In summary, while 78.0% of anesthesiologists exhibit good knowledge and two-thirds hold a positive attitude towards Ai-PCA, only one-fifth demonstrate adequate practice adherence to current guidelines. Thus, it is recommended to implement various forms of Ai-PCA training programs for anesthesiologists to enhance pain management levels and capitalize on Ai-PCA's strengths.

Abbreviations

Ai-PCA	Artificial intelligent Patient-controlled analgesia
KAP	Knowledge, Attitude and Practice
PCA	Patient-controlled analgesia
IV-PCA	Intravenous patient-controlled analgesia
ANOVA	Analysis of variance
IoT	Internet of Things
APS	Acute pain service
PONV	Postoperative nausea and vomiting

Acknowledgements

All the authors would like to sincerely acknowledge experts who provide advice on questionnaire designation. A deep appreciation to all the participants who provided their valuable information to us by responding to their survey questionnaire.

Authors' contributions

All the authors made significant contributions to this manuscript. J.C. and S.H. involved in designing the study, data analysis and interpretation, as well as manuscript writing and revision. Y.J. , Y.Z. and L.Z. helped collect the data and revise the manuscript for important intellectual content. L.G. and J.T. helped conceive and design the study, interpret the data, write the manuscript, critically revise the manuscript for important intellectual content. All authors read and approved the final manuscript.

Funding

This work was supported by grants from Jiangsu Provincial Health Commission (Z2020029).

Availability of data and materials

The datasets used and/or analyzed in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This cross-sectional study got ethical approval from the Ethics Committee of Jiangsu Cancer Hospital, China. Verbal consent was obtained from Anesthesiology department leaders in each hospital. Written informed consent was obtained from all study participants. All methods were performed in accordance with the relevant and performed in accordance with the Declaration of Helsinki guidelines.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 26 March 2024 Accepted: 10 September 2024
Published online: 20 September 2024

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