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Review Article

New Advances in the Clinical Application of Postoperative Analgesia and Pain Assessment Scales in China

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Abstract

Postoperative pain management is a cornerstone of perioperative medicine, and the accuracy of pain assessment directly determines analgesic efficacy. For decades, Chinese clinical practice has relied heavily on translated versions of foreign pain assessment scales, which often suffer from inadequate cultural adaptation, strong subjectivity, and a unidimensional focus on pain intensity. In 1993, the concept of patient-controlled analgesia (PCA) was introduced in China, followed by widespread clinical adoption by 1998. In 2011, China developed the world's first artificial intelligence PCA (Ai-PCA) pump, with subsequent expert consensus documents published in 2018 and 2024. Leveraging accumulated experience with Ai-PCA, a Chinese research team developed the Smart Patient-Controlled Analgesia Outcome Chinese Pain Assessment Scale (S-CPAS) in 2025. This innovative, intelligent assessment system marks a paradigm shift from subjective, experience-based evaluation to data-driven, multidimensional assessment. The S-CPAS integrates the Pain Comprehensive Index (PCI) – covering pain intensity, functional impacts, adverse reactions, pump operational quality, sedation, and muscle strength – with patient satisfaction scores. It has demonstrated good reliability and validity in multicenter studies. This review systematically examines the past, present, and future of clinical applications of postoperative pain assessment scales in China. We discuss the historical evolution of postoperative analgesia, the limitations of traditional tools, and the core innovations of the S-CPAS in individualization, precision, and intelligence. Future directions include the integration of S-CPAS with the Virtual Pain Unit (VPU) and Acute Pain Service (APS) collaborative management model to enable precision multimodal analgesia (PMA). Other emerging trends are the use of wearable sensors, multimodal physiological monitoring, machine learning-based pain trajectory prediction, and out-of-hospital remote analgesia management. We call for widespread adoption of the S-CPAS-based intelligent assessment platform to promote standardized, high-quality postoperative pain management in China and to contribute to the "Healthy China" strategy.

Keywords

Postoperative Pain, Pain Assessment Scale, Intelligent Patient-controlled Analgesia, Precision Multimodal Analgesia, S-CPAS

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1. Background

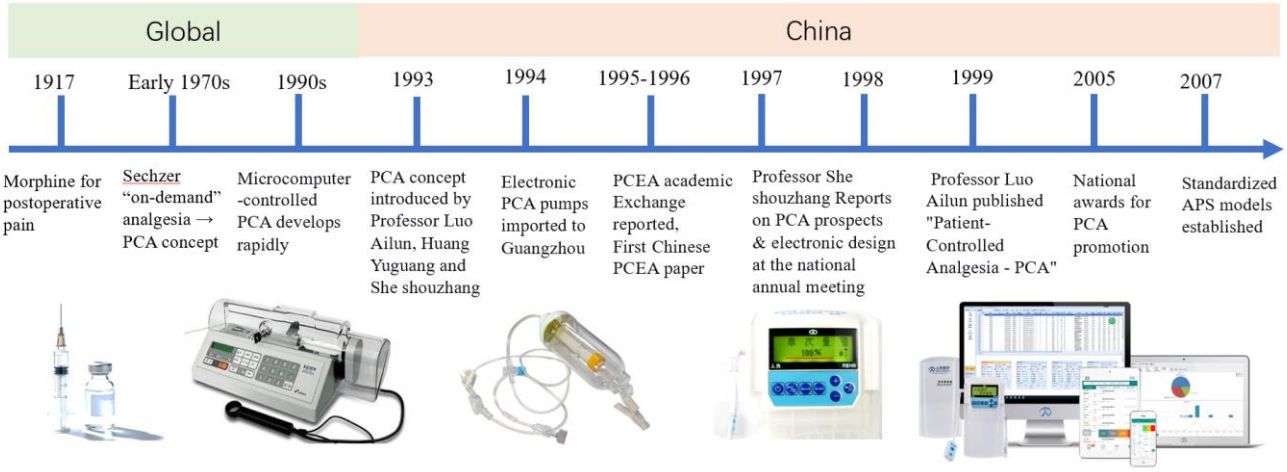
The history of human efforts to combat pain is long and profound. Starting from the time of Hua Tuo, the development of anesthesia and analgesia in China has spanned more than 1,800 years. In the West, on October 16, 1846, Dr. Morton successfully demonstrated ether anesthesia publicly in the circular amphitheater of Massachusetts General Hospital, marking over 180 years of development of clinical anesthesia and analgesia. Although the discipline of anesthesiology has achieved rapid and stable high-quality development, the progress of pain treatment has been relatively slow, and the quantitative assessment of pain remains an urgent problem to be solved. In 2020, the International Association for the Study of Pain revised the definition of pain to "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" [1]. Pain is not only an important physiological defense mechanism and alarm system of the body, but also a core medical problem that needs to be addressed in clinical practice. The WHO has listed pain as the fifth vital sign, making it a focus of widespread social concern. Due to surgical tissue damage and inflammatory reactions, patients often experience acute postoperative pain [2]. Postoperative pain is a complex multidimensional problem involving physiological, psychological, cognitive, social, and environmental factors. Precise postoperative analgesia depends not only on rich clinical experience but, more critically, on the use of appropriate, specifically constructed assessment tools before treatment. However, at present, postoperative pain is mostly assessed with unidimensional tools, which often leads to inadequate pain management [3]. Based on this, a Chinese research team recently created the Smart Patient-Controlled Analgesia Outcome Chinese Pain Assessment Scale (S-CPAS) [4]. This article reviews the past, present, and future development directions of the clinical application of postoperative pain assessment scales in China, with the aim of promoting high-quality development of intelligent and precise multimodal analgesia in clinical practice.

2. Historical Evolution of Postoperative Analgesia and Pain Assessment in China

2.1. Development of Postoperative Analgesia Techniques

Postoperative analgesia has evolved from empirical medication to individualized patient control, and from mechanical infusion to intelligent integration. In 1917, morphine began to be used for postoperative analgesia; in 1939, intramuscular pethidine became mainstream. In the early 1970s, Sechzer proposed the concept of "on-demand" analgesia and put it into practice, laying the theoretical foundation for patient-controlled analgesia (PCA) [5]. In 1988, Professor Zhang Lisheng from the Fourth Affiliated Hospital of Hebei Medical University organized the first National Academic Conference on Pain of the Chinese Society of Anesthesiology (Chengde), calling for strengthening research on postoperative analgesia [6]. During the 1990s, the close integration of electronic technology with modern medicine drove the rapid advancement of microcomputer-controlled PCA. Standard PCA allows patients to self-administer analgesic boluses on demand, within the limits set by the physician [7]. Their core parameters include loading dose, continuous infusion rate, bolus dose, lockout time, and safe dose limit per unit time, effectively solving the problem of large inter-individual differences in pain threshold. In 1993, the PCA concept was first introduced in China by Professor Luo Ailun and Professor Huang Yuguang from Peking Union Medical College Hospital and Professor She Shouzhang from Guangzhou. In 1994, electronic analgesic pumps (Grasby-3100 and Grasby-9300 from the UK) were introduced in Guangzhou, and a large amount of clinical research was carried out. For three consecutive years, lectures on acute or chronic pain treatment were held, inviting professors such as Huang Yuguang, Martin Mok, and Tang Fuling to teach in Guangzhou, popularizing the clinical application of different PCA modes and routes of administration, greatly improving the level of PCA analgesia. Hospitals adopted PCA as a new technology and project, providing new policies to encourage physicians to actively promote it. In 1995, at the Beijing International Anesthesia Academic Exchange, She Shouzhang reported on "Clinical Application Research of Epidural PCA," which was widely acclaimed. In 1996, the "Epidural Patient-Controlled Analgesia and Acute Pain Service (APS) Management Series" received government science and technology funding from Guangdong Province. In the same year, China's first epidural PCA application paper was published in the Chinese Journal of Pain Medicine [8]. In 1997, She Shouzhang gave a special report at the National Anesthesia Annual Conference in Shenyang—"Prospects for PCA Application in China"; in 1998, he gave a special report at the National Pain Annual Conference in Zhengzhou—"Design and Clinical Application of PCA Electronic Pumps." In 1999, Professor Luo Ailun from Beijing edited and published the monograph PCA. During the same period (1997-2004), Guangzhou First People's Hospital pioneered the investigation of the feasibility and safety of patient-controlled epidural analgesia (PCEA) with a retained epidural catheter after combined spinal-epidural anesthesia [9]. From a pharmacokinetic perspective, they also demonstrated that epidural analgesia with local anesthetics is safe and reliable [10] and established the optimal dosage [11]. Furthermore, they reported that continuous epidural infusion of low-concentration local anesthetics combined with opioids enhances analgesic efficacy, reduces opioid consumption, and improves patient satisfaction with pain relief [12, 13]. This approach also helps improve postoperative pulmonary function and decrease abdominal

complications [14]. From 2005 to 2007, three hospitals represented by Professors Luo Ailun, Huang Yuguang, She Shouzhang, and Yao Shanglong jointly won the Second Prize of the Ministry of Education's Science and Technology Progress Award and the Third Prize of the Chinese Medical Association for the project "Postoperative Analgesia and Promotion of PCA." In the dissemination of PCA analgesia techniques, efforts to enhance pain management quality have been accompanied by the concurrent standardization of the acute pain treatment system, focusing on both analgesic regimens and pain management protocols. Regimen standardization involves drug selection, compatibility, administration routes, analgesic modalities, and equipment; management standardization comprises organizational structures, institutional protocols, and pain monitoring and treatment evaluation [15]. The concept of the APS has gained traction, and a standardized APS model featuring anesthesiologist-directed, nurse-administered scheduled rounds and on-call physician handling of emergencies has proven effective in improving acute pain outcomes [16, 17].



PCA: patient-controlled analgesia; PCEA: patient-controlled epidural analgesia; APS: acute pain service

Figure 1. *Timeline of major milestones in the development of postoperative analgesia and PCA.*

2.2. Introduction and Limitations of Postoperative Pain Assessment Tools

Pain assessment is the core of pain management, and its accuracy directly affects etiological diagnosis, severity judgment, and efficacy evaluation. There are more than 20 English original versions of pain assessment scales internationally. Those commonly used in Chinese clinical practice and research are mostly Chinese translated versions, including unidimensional tools such as the Verbal Rating Scale, Numerical Rating Scale, Visual Analog Scale (VAS), and Faces Pain Scale; as well as multidimensional comprehensive tools such as the Brief Pain Inventory, McGill Pain Questionnaire, American Pain Society Patient Outcome Questionnaire-Revised, Houston Pain Outcome Instrument, Quality Improvement in Postoperative Pain Management Questionnaire, International Pain Outcome Questionnaire, and Defense and Veterans Pain Rating Scale [18]. However, traditional assessment tools have obvious limitations, most notably their heavy reliance on patients' subjective reports. Because pain is inherently a subjective experience, individual variations in pain perception and expression mean that self-report pain scales may not always accurately capture a patient's true pain experience. Studies have shown that patients may exaggerate their pain on numerical rating scales to receive more attentive medical responses, or alternatively, underreport it due to fear of future pain. Such subjectivity and variability in reporting can introduce bias into clinical assessments, thereby compromising the effectiveness of pain management [19]. Furthermore, a patient's cultural background, language differences, age, and educational level can all influence assessment outcomes. More research is therefore needed to determine the applicability of different scales across various populations and to identify strategies for improving their utility in clinical practice [20]. Specific influencing factors include: (1) Patients may intentionally or unintentionally exaggerate pain to gain more attention or medical resources; (2) Some patients downplay their pain to please medical staff or avoid being seen as weak; (3) Medical staff may be influenced by cultural customs and racial biases during assessment; (4) Patients recovering from general anesthesia, children, and those with cognitive impairment have difficulty accurately expressing pain; (5) In forensic disability evaluations, the compensating party often questions the credibility of subjective pain reports [21]. Therefore, achieving a balance between subjective experience and objective indicators has become a core challenge in the development of pain assessment tools.

3. Current Status of Postoperative Analgesia and Assessment in China

3.1. Current Challenges and Progress in Postoperative Analgesia Management

With the introduction of the enhanced recovery after surgery (ERAS) concept, effective postoperative analgesia has become a key step and core element of ERAS, receiving increasing attention [22]. Nevertheless, a considerable proportion of patients still do not achieve effective relief of postoperative pain [23]. Dolin et al. performed a retrospective analysis of 20,000 surgical patients published on the Internet, showing that the incidence of moderate-to-severe pain at rest was 29.7%, during activity 32.2%, and severe pain 10.9% [24]. Surveys by Gan and by Bockel showed that 50%-70% of patients experience moderate-to-severe postoperative pain [25, 26]. A 2016 survey involving 12 tertiary hospitals in Guangdong Province with 4,370 patients showed that the incidence of moderate-to-severe pain at rest (VAS ≥4) on postoperative day 1 and day 2 was 10.6% and 3.8%, respectively; during activity, the incidence was 33.6% and 16.3%; and the incidence of the most severe pain was 41.4% and 18.8%. The proportion of anesthesia physicians involved in management was 32.6%, which was lower than that in a similar survey in 2010 (36.7%) [27]. Reasons for inadequate analgesia include unbalanced development of hospitals in China, shortage of anesthesia personnel, insufficient investment in PCA quality control, dispersed patient hospitalization locations, incomplete feedback from PCA pump information, high callback rates, high incidence of inadequate analgesia, and ineffective management, leading to low satisfaction of clinicians and patients. In addition, uneven quality of equipment and non-standard market competition are also important factors. Inadequate analgesia can lead to a series of physiological and psychological problems, delay postoperative recovery, increase the risk of transition from acute to chronic pain, prolong hospital stay, and increase medical costs [28, 29].

3.2. Creation and Core Innovations of the S-CPAS

Based on the above difficulties, a Chinese research team created the S-CPAS with independent intellectual property rights. This scale breaks through the unidimensional limitation of traditional tools and constructs a comprehensive assessment system covering the Pain Comprehensive Index (PCI) and analgesia satisfaction, comprising ten dimensions [4].

Individualization advantage

The S-CPAS not only integrates unidimensional and multidimensional assessment elements but also achieves individualized assessment through more than 60 indicators. The system can automatically collect operational data from the Ai-PCA pump, patients' on-demand bolus information, and medical staff treatment records. With the help of the "Quality Control Intelligent Assessment Tablet Recorder," ward round data can be entered paperlessly. After the data are automatically transferred to the "Quality Control Intelligent Assessment Management Platform," the system intelligently generates curves and bar charts of pain control effects, summarizing the PCI and analgesia satisfaction scores, and intuitively displays the analgesic effect and satisfaction with a low blue curve and a high red curve [30]. This design makes follow-up individualized, information-based, and intelligent.

Precision advantage

The PCI dimensions of the S-CPAS include: postoperative pain assessment (covering resting pain, movement pain, functional exercise pain, and their impact on seven functions: breathing, eating, sleep, walking, communication, and emotion), quantification of common adverse reactions to postoperative self-controlled analgesia (nausea, vomiting, respiratory depression, dizziness, drowsiness, etc.), sedation score, and muscle strength assessment. The analgesia satisfaction dimension covers patients' satisfaction with the precision and use of the PCA pump, satisfaction with the rescue analgesic effect after pain occurs, satisfaction with the timeliness of medical staff response and treatment, satisfaction with the entire process of medical staff services, and satisfaction with the overall postoperative analgesic effect [4]. In addition, the system uses the Analgesia Quality Index (AQI, also known as the comfort index) to perform real-time intelligent quality control on PCA pump operation status, alarm handling, patient usage, and ward round evaluations. Both healthcare providers and patients can provide dual assessments of analgesic efficacy, satisfaction, and adverse reactions, thereby addressing the longstanding issue that outcomes and side effects during PCA therapy cannot be collected or fed back in a timely manner [31]. By enabling real-time tracking of analgesic efficacy and pump performance, standardizing data collection, digitizing information storage, implementing intelligent quality control, and ensuring precise analgesic dosing, the system contributes significantly to improving the quality of postoperative pain management [32].

Intelligence advantage

The integration of artificial intelligence (AI) technology enables the S-CPAS to achieve full-process automation from data collection to intelligent analysis, thereby supporting individualized, paperless, information-driven, and intelligent follow-up, while also improving data comparability [33]. Leveraging the 5V (volume, velocity, variety, veracity, and value) characteristics of big data processing models, the system can wirelessly monitor PCA operation, patient self-control processes, and fault alarms in real time. This allows for individualized drug delivery regulation and provides healthcare professionals with a standardized, information-rich management platform. When using the S-CPAS to assess a patient's postoperative analgesic effect, clinicians can access objective, real-world data via the intelligent Ai-PCA system—such as

pump operational status and time-stamped pain intensity scores—to better understand patient satisfaction. For issues arising during PCA therapy, such as inadequate analgesia, complications like nausea and vomiting, or pump malfunctions, anesthesiologists can directly intervene based on the Ai-PCA analgesia records and S-CPAS assessment results, thereby reducing patient waiting times and improving both analgesic efficacy and patient satisfaction [30]. Through machine learning and big data analysis, it is expected to further optimize PCA operation quality assessment in the future, achieving the "three early" goals of early prediction, early judgment, and early intervention.

Table 1. *Summary of key components, scoring features, and clinical functions of the S-CPAS.*

Component / Dimension	Number of items	Scoring method	Clinical function / Remarks
Part 1: Pain Comprehensive Index (PCI)			
A. Postoperative pain assessment	10	0–10 linear analog scale (0 = no pain/no impact; 10 = worst pain/complete impact)	Covers resting pain, activity pain, functional exercise pain, and impact on breathing, eating, sleep, walking, communication, depression, anxity.
B. Postoperative adverse reaction assessment	8 (after deletion of low-incidence items: headache, urinary retention)	0–10 linear analog scale (0 = none; 10 = most severe)	Quantifies nausea, vomiting, repiratory depression, drowsiness, dizziness, pruritus, constipation, agitation. Monitors opioid-related side effects.
C. PCA pump operational quality evaluation	6 (after deletion of "staff follow-up")	0–10 linear analog scale (0 = worst; 10 = best)	Assesses patient understanding, analgesic need satisfaction, relief after single/multiple presses, frquency of device failures, impact of failures on analgesia.
R. Ramsay Sedation Score	1	Ordinal scale (1–6: 1 = anxious/agitated; 6 = deep sleep, no response)	Prevents excessive sedation; targets moderate sedation (score 3) to rduce stress and improve comfort.
J. Muscle strength assessment	1	Ordinal scale (0–5: 0 = no contraction; 5 = normal strength against full resistance)	Guides early mobilization and functional exercise; monitors pain-related limitation of movment.
Part 2: Analgesia satisfaction	5	0–10 linear analog scale (0 = extremely dissatisfied; 10 = very satisfied); average of 5 items = final satisfaction score	Patient-centered outcome: satisfaction with pump use, rescue effect, staff response time, whole-process service, overall analgesic effect.
Integrated intelligent functions			
Automatic data collection	–	Real-time capture of Ai-PCA pump parameters (press frequency, alarms, drug usage, etc.)	Eliminates recall bias; ensures objectivity.
Quality Control Platform	–	Generates PCI and satisfaction curves (blue low curve = pain control; red high curve = satisfaction)	Enables paperless, information-driven, intelligent follow-up.
Analgesia Quality Index (AQI)	–	Real-time intelligent scoring (0–100) based on multiple parameters;	Reflects quality control awareness, technical level, management standardization.

S-CPAS: smart patient-controlled analgesia outcome Chinese pain assessment scale; PCA: patient-controlled analgesia; Ai-PCA: artificial intelligence patient-controlled analgesia

4. Future Directions of Postoperative Analgesia and Assessment in China

4.1. From Anesthesiology to Perioperative Medicine: Reshaping the Role of Analgesia

The transition from anesthesiology to perioperative medicine cannot be achieved without the rapid development of pain treatment. Without perfect analgesia, comfort-oriented medical care would be empty talk. The current rapid development of ERAS and minimally invasive surgery places higher demands on PCA: how to position it, how to improve it, and how to achieve precision? Future analgesic strategies should adhere to the principle of multimodal analgesia, including the combination of drugs with different mechanisms of action and the integration of different technical methods. Ideal analgesia should transition patients from "bearing pain" to "enjoying pain-free" experiences. The development goal of acute pain treatment is to formulate perioperative optimized analgesic protocols, prevent inadequate analgesia, and prevent the chronification of acute pain. The information-based patient-controlled analgesia system solution (PCASS) can significantly improve ERAS analgesia quality [34]. Combining big data, artificial intelligence technologies, and preventive analgesia will be essential for the future improvement of Ai-PCA [35].

4.2. Education and Popularization of Pain Knowledge

Changing the public's outdated concepts about pain, informing them that moderate-to-severe pain can be controlled, and highlighting the benefits of pain relief for rehabilitation are important links in improving the level of pain management. Professional pain treatment teams should be established, and the APS management model should be optimized to provide efficient and economical services for patients.

4.3. Wireless Intelligence and Promotion of PCASS

The state advocates the "Internet +" strategy. Under the ERAS concept, integrating the wireless analgesia management system (WAMS) with intelligence, informatization, and cloud data analysis, and optimizing PCA drug combinations and parameter settings, can achieve precise analgesic medical effects. PCASS has the following advantages: wireless real-time monitoring of PCA operation, self-control process, and fault alarms; real-time monitoring of patient condition to prevent complications; individualized drug delivery regulation, supporting new modes (such as transdermal patches and intranasal administration); standardized, information-based, and efficient management; big data storage and cloud analysis [36]. Currently, intelligent PCASS approved by the state (such as the Renxian wireless analgesic pump system) has achieved good results in China.

4.4. Implementation of the Precision Multimodal Analgesia Concept

In 2024, Professor Wang Tianlong from Xuanwu Hospital, Capital Medical University, proposed the new concept of "Precision Multimodal Analgesia (PMA)," which has been included by the National Committee for the Approval of Scientific and Technical Terms as a Chinese-originated anesthesiology term [37]. PMA uses a combination of local anesthetics, opioids, nerve blocks, and non-steroidal anti-inflammatory drugs according to the source and location of surgical trauma and rehabilitation needs, constructing a three-dimensional prevention and treatment system for incisional pain, visceral pain, and inflammatory pain. Traditional multimodal analgesia has defects such as unclear analgesic targets, lack of targeted protocols, high incidence of moderate-to-severe pain, and delayed rehabilitation. Although the ERAS strategy has been widely recognized, perioperative analgesic effects are still unsatisfactory. Professor Zhang Lisheng once again called for strengthening the development of pain research in China toward clinical, basic, and original directions. [38]. The introduction of the S-CPAS helps medical staff assess the individual characteristics and intensity of incisional pain, visceral pain, and inflammatory pain, thereby improving PMA interventions and reflecting the clinical value of intelligent management in the virtual pain unit (VPU) [39].

4.5. Integration of the 6P Medical Strategy and Intelligent Assessment Systems

Future pain treatment should follow the 6P medical strategy of Predictive, Preventive, Personalized, Participatory, Precision, and Public Health Trajectories [40]. Deep integration of the S-CPAS with the VPU+APS collaborative management scheme is expected to promote high-quality development of intelligent PMA clinical practice. With the advancement of artificial intelligence technology, through big data analysis and machine learning, postoperative pain assessment scales will present three major trends: "objectification, personalization, and intelligence." Technological innovation must be combined with ethical norms to give full play to the advantages of new-era analgesic assessment technologies, achieving a leap from research to application, allowing patients to obtain timely, comfortable, and safe individualized analgesic experiences, and promoting high-quality development of digital-intelligent medical innovation analgesic systems.

5. Conclusion

Postoperative analgesia and pain assessment in China have undergone a historic leap from imitation to independent innovation. The development and validation of the S-CPAS mark

that China now has a comprehensive assessment tool that conforms to its local cultural background and integrates intelligent technology. This scale not only compensates for the multidimensional deficiencies of traditional unidimensional tools but also, through deep integration with the Ai-PCA system and the VPU+APS management model, achieves closed-loop management from data collection and intelligent analysis to outcome presentation. Looking to the future, with the gradual maturation of multimodal physiological signal monitoring, wearable devices, machine learning prediction models, and clinical decision support systems, the S-CPAS is expected to be extended to special populations (e.g., sedated patients, those with cognitive impairment) and remote out-of-hospital analgesia management. The Chinese anesthesiology and pain disciplines should continue to uphold the spirit of innovation, promote PCA technology towards digital-intelligent, standardized, and high-level development, and contribute to the realization of the "Healthy China" strategy.

Abbreviations

AI	Artificial Intelligence
APS	Acute Pain Service
AQI	Analgesia Quality Index
ERAS	Enhanced Recovery After Surgery
PCA	Patient-controlled Analgesia
PCEA	Patient-controlled Epidural Analgesia
PMA	Precision Multimodal Analgesia
PCI	Pain Comprehensive Index
PCASS	Patient-controlled Analgesia System Solution
S-CPAS	Smart Patient-controlled Analgesia Outcome Chinese Pain Assessment Scale
VPU	Virtual Pain Unit
VAS	Visual Analog Scale

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Hanzhong Cao: Resources

Qinjun Chu: Investigation, Validation

Tianlong Wang: Investigation, Validation

Weifeng Yu: Conceptualization, Project administration, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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