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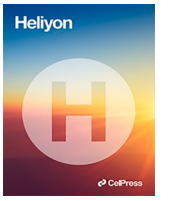

Research article

Efficacy and safety of patient-controlled intravenous analgesia after APS team standardized postoperative pain management: A 6-year experience of an acute pain service in 107802 Chinese patients

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ABSTRACT

There are few studies on the impact of postoperative pain management (such as Acute Pain Service, APS) on the prognosis of patients, especially the research on large samples, even less data on Chinese patients. It is reported that only 25.12 % of hospitals in China have established APS or similar teams, and less than 10 % of them are responsible for the whole process of postoperative analgesia services. Tongji Hospital affiliated to Tongji Medical College of Huazhong University of Science and Technology has established a professional APS team led by anesthesiologists (TJ-APS), and has a standardized workflow and management system. Based on the TJ-APS standardized postoperative pain management, the incidence and adverse effects of postoperative pain in different types of surgical patients were analyzed. In total, 107,802 patients receiving intravenous PCA from the Tongji Hospital affiliated to Tongji Medical College of Huazhong University of Science and Technology were selected between January 2016 and December 2021, which were under TJ-APS standardized postoperative analgesia process, postoperative analgesia strategy based on the principle of "low opioid, multimodal, specialization and individualization", as well as regular ward rounds and 24-h on call on-duty system. We assessed the incidence and adverse effects of postoperative pain in different types of surgical patients. Based on the TJ-APS standardized postoperative pain management, the incidence of poor postoperative analgesia in patients with intravenous PCA is significantly lower than that reported in the current literature (20 %), and mainly occurs in biliary-pancreatic surgery, extrahepatic surgery and gastrointestinal surgery. The overall incidence of adverse effects was 5.52 %, of which nausea and vomiting was the highest, especially among gynecological tumors and gynecological patients, which were 10.75 % and 8.68 % respectively, but both were lower than the level reported in the current literature (20 %). This APS multimodal management and analgesia process can provide reference and guidance for PCA management of postoperative acute pain.

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1. Introduction

More than 310 million people worldwide receive surgical treatment every year [1], and the annual number of surgeries in China has exceeded 66 million [2]. According to statistics, more than 80 % patients receiving surgical treatment experience acute post-operative pain, only 50 % of patients have postoperative pain relief [3], and approximately 20%–40 % of patients experience moderate-to-severe postoperative pain [4,5]. Poor postoperative analgesia will increase the wound healing time, lead to delayed rehabilitation and chronic postoperative pain, which will seriously affect the quality of life of patients and cause an unnecessary medical burden. Therefore, effective control and management of postoperative pain is one of the most concerning problems of patients and clinical doctors, and also one of the core ethical responsibilities of medicine [6–11]. In recent years, although the technology and management awareness of doctors and nurses on postoperative pain have improved, such as the promotion of pain as the fifth vital sign, the improvement of surgical methods, the introduction of new drugs, new surgical techniques and new analgesic techniques, 20 % of patients still experience severe postoperative pain within 24 h after surgery [12–14]. Clinicians should actively find and summarize the causes and improve postoperative analgesia management.

APS is an important management mode to improve postoperative acute pain, and it has been widely used in hospitals around the world for many years [15–18]. According to a survey, more than 60 % of hospitals in Europe and America have APS teams [16,19,20]. Most of the information on postoperative pain management is mainly based on the research performed in United States, Germany and other European countries [8,21–23]. Moreover, the current clinical research on postoperative analgesia is mainly focused on improving analgesia technology and drugs, while there are few studies on the impact of postoperative pain management (such as APS) on the prognosis of patients, especially the research on large samples [10,12]. Considering that China's population accounts for about 21.5 % of the world's population, the United States accounts for about 4.3 % of the world's population, and Germany accounts for about 1 %, China has a significant proportion of the world's population [24]. Therefore, it is necessary to study the current situation of analgesia in China, especially the poor postoperative analgesia and adverse effects after different types of surgery in Chinese patients. The 27th National Anesthesia Academic Annual Meeting in 2019 reported that only 25.12 % of hospitals in China have established APS or similar groups, and only 23.48 % provided pain treatment education before surgery, and less than 10 % of them are responsible for the whole process of postoperative analgesia services [25,26].

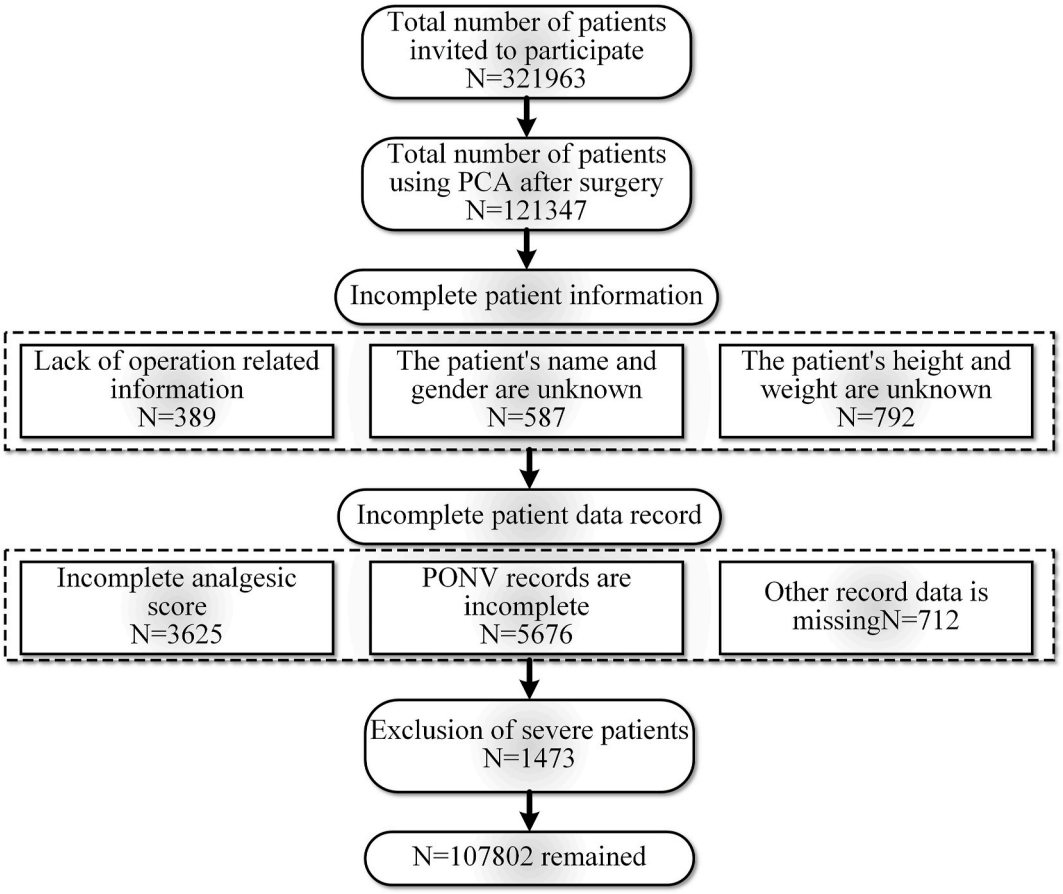

Fig. 1. Exclusion criteria.

In the Anesthesiology Department of our hospital, standardized postoperative analgesia began in 1997, and TJ-APS group has been established since 2010. The TJ-APS team has established a complete work system, work manual, and surgery process (see the method section for details). The APS team, together with various operating departments, adopts multimodal postoperative analgesia to provide patients with specialized and individualized postoperative analgesia. As of December 2021, more than 170,000 surgical patients have been served successfully. Patient controlled analgesia (PCA) is the main technology used by Tongji APS (TJ-APS) team. Due to its advantages of wide indications, convenient operation and nursing, rapid drug onset and reliable effect, intravenous PCA is the most widely used in clinical practice, and is also the most widely used analgesic drug delivery method in our hospital. This is a retrospective study, based on the analysis of patients who used intravenous PCA after surgery from 2016 to 2021 in our hospital. This study focused on the analysis of the incidence of poor postoperative analgesia and adverse effects of patients with different types of surgery after standardized postoperative pain management of TJ-APS team, which can provide reference for improving the quality of postoperative acute pain management. In addition, it supplements the Chinese data on the incidence of poor postoperative analgesia and adverse effects of patients under the APS standardized postoperative analgesia process.

2. Methods

2.1. Informed consent

The study was approved by the Ethics Review Committee of our hospital (Clinical Research Committee, Protocol No. TJ-IRB20221286), which waived the requirement for informed consent.

2.2. Study population

In this study, we analyzed surgical cases at our hospital from January 2016 to December 2021. Cases with incomplete patient information records and incomplete patient follow-up data records due to human factors were excluded. Finally, 107,802 patients were included in this study. The exclusion criteria are presented in Fig. 1.

2.3. TJ-APS team

The TJ-APS team mainly consists of a pain specialist leader (chief physician of the anesthesia department), a senior attending physician, three residents and an anesthesia nurse. Senior attending physicians rotate every six months, and residents and anesthesia nurses rotate every three months. Training on relevant work systems and work processes should be done prior to the rotation. The APS team regularly carries out in-hospital pain education and multi-disciplinary communication to understand the postoperative analgesia needs of patients undergoing surgery, the preparation of postoperative analgesia pump, and the postoperative analgesia rounds of patients. APS teams are on duty 24/7 to provide on-call pain services. The on-duty APS doctor decides the multimodal analgesia, PCA drugs, and parameters of the analgesia pump according to the patient's conditions; takes the postoperative analgesia records after the daily ward rounds; and gives feedback to the superior. Postoperative analgesia in Tongji is jointly completed by all the staff in the anesthesia department under the leadership of the department director. The anesthesiologist, who assists in education, signs the consent form for postoperative analgesia and completes necessary anesthesia surgeries, such as ultrasound-guided nerve block, connection of postoperative analgesia devices, and so on.

2.4. Intravenous PCA analgesia process

Before surgery. The APS team first collected basic patient information, such as the patient's hospitalization number, name, sex, age, height, weight, medical history, planned surgery, and other information. The patient was then evaluated for pain relief, focusing on chronic pain history, drug abuse, previous postoperative treatment plans and reactions, medical and psychiatric complications, and postoperative pain risk assessment. Finally, the patients were taught about pain relief so that they could understand the treatment plan for postoperative Pain and guide pain assessment methods.

During-surgery. During surgery and before skin incision, nonselective nonsteroidal anti-inflammatory and analgesic drugs (flurbiprofen axetil) or selective COX-2 inhibitor (parecoxib sodium) were used for preanalgesia in patients without contraindications. According to the type of surgery, nerve block procedure dominated by local anesthetics was selected for pre-analgesia. For example, for thoracic surgery, paravertebral nerve block or intercostal nerve block procedure is used, and for orthopedic surgery, peripheral nerve block procedure is used. For patients undergoing thoracic, gastrointestinal, extrahepatic, and other visceral surgeries, oxycodone (0.1 mg kg^{-1}) was used half an hour before the end of the surgery to reduce visceral pain. Based on the unique postoperative pain and clinical characteristics of different types of surgery, different PCA formulas were used for specialized postoperative analgesia, and PCA parameters were adjusted according to the patient's age, weight, etc. Specialized analgesia: For obstetric, gynecological, and gynecological tumor surgery, hydromorphone 0.1 mg ml^{-1} is primarily used for postoperative analgesia. For gastrointestinal surgery, Sufentanil 0.5 μg.ml^{-1}+Dizocine 0.16 mg ml^{-1} is primarily used for postoperative analgesia. For orthopedics and trauma surgery, hydromorphone 0.1 mg ml^{-1} or sufentanil 0.7 μg ml^{-1}+tramadol 4 mg ml^{-1} are primarily used for postoperative analgesia. For biliary and pancreatic surgery, urology surgery and liver surgery, sufentanil 0.7 μg ml^{-1}+ tramadol 4 mg ml^{-1} is primarily used for postoperative analgesia. For extrathoracic, cardiac and major vascular surgery, Butorphanol tartrate 1 mg ml^{-1}+ oxycodone 0.12 mg ml^{-1} is primarily used for postoperative analgesia. Pumps for children are generally prepared according to hydromorphone 0.2 mg kg^{-1},

and the specific formula will be changed according to the dosage. The lock-out interval between bolus doses was st at 10min, while the maximum infusion rate was limited to 15 mL per hour. The PCA was administered for a duration of 24 h following obstetric, gynecological tumor, and gynecological surgeries, while for other surgeries, the PCA was administered for a duration of 48 h (Table 1).

After-surgery. After the surgery, the patient was sent to the anesthesia recovery room (PACU) and connected to the analgesia pump. Following surgery, postoperative patients were continuously monitored for vitals signs in the ward using monitors for a duration of 24 h. And vital signs were recorded at regular intervals, specifically 6 h, 12 h and 24 h after surgery. The APS team conducted two postoperative rounds for patients approximately 6 h and 24 h after surgery. The contents of the ward round include pain assessment, adverse effects inspection, the PCA pump operation, on site treatment and records. The doctor on duty of APS on that day was on call 24 h a day to deal with the possible emergencies and accidents of patients. The specific process is illustrated in Fig. 2.

Definition of poor postoperative analgesia. The VAS (0–100) score was used to evaluate the degree of postoperative pain. Postoperative rest or exercise VAS $\geq$40 indicated that the patients had poor postoperative analgesia, and postoperative rest or exercise VAS$<$40 indicated that the patients did not have poor postoperative analgesia.

Definition of adverse effects. (1) PONV indicates if patients had nausea during rest, or exercise, the severity of the side effect, and whether it was intermittent or continuous. The patients without the above conditions were reported as having no nausea or vomiting. (2) Respiratory depression: If the patient's respiratory rate was less than 10 times/minute or the pulse oxygen saturation was less than 90 % under the oxygen inhalation state, the condition is recorded as respiratory depression. (3) Uroschesis: If a patient was still unable to urinate autonomously 6 h after the catheter was pulled out, and the swollen bladder could be palpated, then the patient had urinary retention. (4) Other adverse reactions: Through communication with the patient, we confirmed if the patient experienced any skin itching, abdominal distension, dizziness, or any other adverse effects.

Treatment process for patients with poor postoperative analgesia and adverse effects. In the case of poor analgesia, we press the PCA handle, increase PCA parameters. If pain cannot be relieved, non-steroidal anti-inflammatory and analgesic drugs or opioids are administered according to the pain situation. If respiratory depression is found, we immediately instruct the patient to breathe, inhale oxygen with a mask, reduce the PCA parameters or suspend the PCA pump, give 0.1–0.4 mg naloxone intravenously, assist in breathing if necessary, and call the superior doctor. In case of nausea and vomiting, the first thing to do is to treat the cause (electrolyte disorder, gastrointestinal decompression stimulation and other surgeries or fat emulsion preparations used), and metoclopramide 10 mg can be given intramuscularly or intravenously; In the case of urinary retention, the reasons should be analyze. If urinary retention is determined to be caused by PCA, it is recommended that patients engage in early mobility, urinate in a habitual position, and apply warm compress to the lower abdominal bladder area to promote urination. If the patient still cannot urinate successfully through the above measures, it can be considered to reduce or pause the PCA. In instances of more severe urinary retention, catheterization measures may be warranted; In case of itching, if other causes are excluded, Phenergan 25 mg intramuscular injection or naloxone 0.1–0.2 mg intravenous injection and dexamethasone 5–10 mg intravenous injection can be given.

2.5. Data analysis

This study first used Microsoft Excel 2013 to generate statistics and a summary of patient data from 2016 to 2021, and then used Origin Lab 2018 to analyze and plot the data. In this study, more than 20 representative surgeries were selected. To facilitate data analysis, we classify ophthalmic surgery, neurosurgery, otorhinolaryngology surgery, cardiovascular surgery, plastic surgery, and cosmetic surgery as "others." The reason for this classification is that the proportion of PCA administered after these surgeries were very low. Finally, we divided the types of surgery at our hospital into 15 types. Under the current medical insurance policy in Chinese mainland, PCA is relatively expensive and cannot be fully reimbursed; therefore, the use of PCA is entirely based on personal will. Some people may not use PCA due to economic considerations; although they actually need it, the impact of this part of the reason does not belong to the research content of this paper.

3. Results

3.1. Comparison of administration rate of intravenous PCA in different types of surgery

The average intravenous PCA administration rate was 33.57 % (Fig. 3A). Compared with the proportion of patients receiving intravenous PCA after other types of surgery, that after extrathoracic, obstetric, gastrointestinal, and extrahepatic surgery was higher, $>$60 % (80.93 %, 76.76 %, 68.69 %, and 62.34 %, respectively; Fig. 3A). The proportion of postoperative intravenous PCA

Table 1
Formula of postoperative analgesia pump.

Type of surgery	Formula
Obstetric, Gynecological, and Gynecological tumor surgery	Hydromorphone 0.1 mg ml^{-1}
Gastrointestinal surgery	Sufentanil 0.5 μg.ml^{-1}+Dizocine 0.16 mg ml^{-1}
Orthopedics and Trauma surgery	Hydromorphone 0.1 mg ml^{-1} or Sufentanil 0.7 μg ml^{-1}+Tramadol 4 mg ml^{-1}
Biliary and Pancreatic surgery, Urology surgery and Liver surgery	Sufentanil 0.7 μ g.ml^{-1}+ Tramadol 4 mg ml^{-1}
Cardiac and major Vascular surgery	Butorphanol tartrate 0.1 mg ml^{-1} + Oxycodone 0.12 mg ml^{-1}
Pediatric surgery	Hydromorphone 0.2 mg kg^{-1}

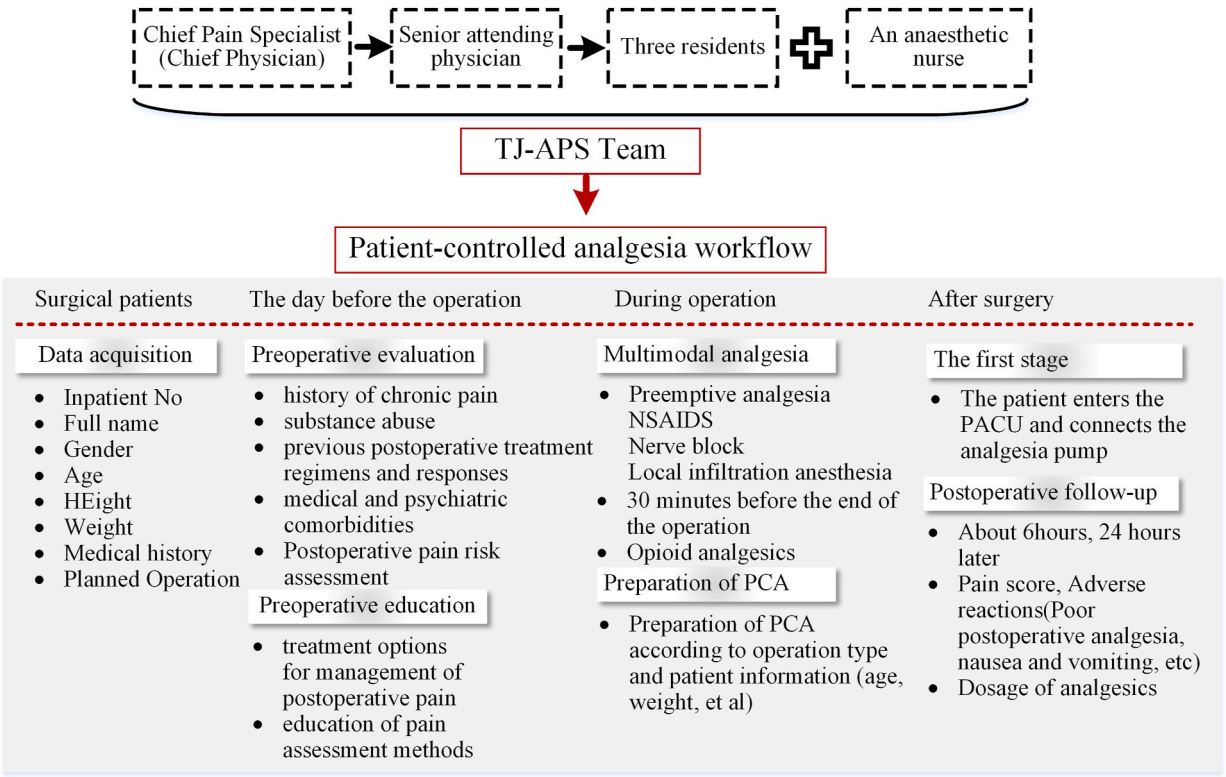

Fig. 2. Patient-controlled analgesia workflow.

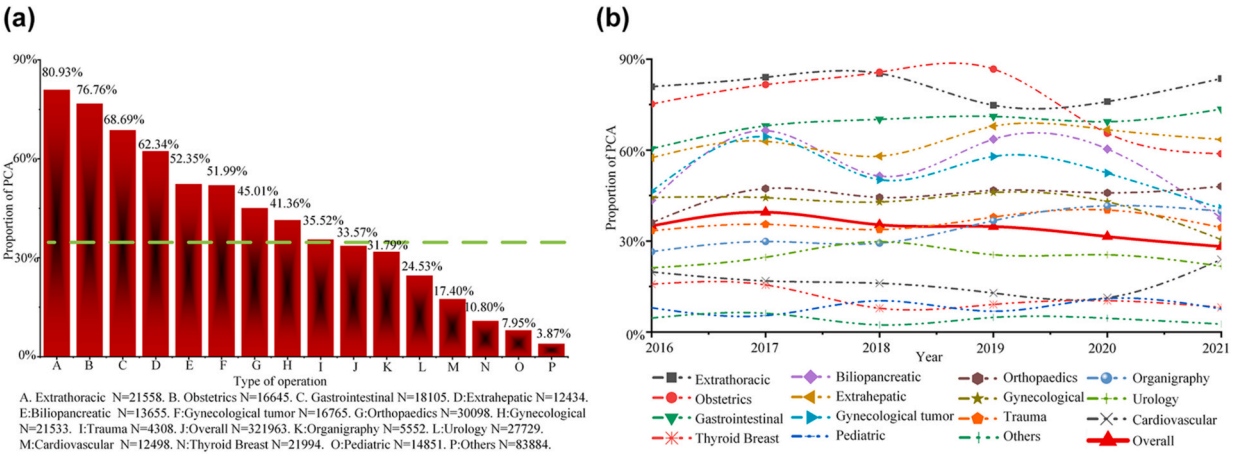

Fig. 3. A Comparison of the proportion of patient-controlled analgesia administered after different types of surgery from 2016 to 2021. Fig. 3 B Proportion of patient-controlled analgesia administered after different types of surgery from 2016 to 2021 varies with years.

administered to patients undergoing biliary-pancreatic, gynecological tumor, orthopedic, gynecological, and trauma surgery was higher than the average, 53.35 %, 51.99 %, 45.01 %, 41.36 %, and 35.52 %, respectively (Fig. 3A). The proportion of intravenous PCA administered in organ transplantation, urological, and cardiovascular surgeries was lower than the average, 31.79 %, 24.53 %, and 17.4 %, respectively. However, the rate of intravenous PCA administration in these types of surgeries was more than 15 % (Fig. 3A). The rate of intravenous PCA administration in thyroid-breast surgery, pediatric surgery, and other types of surgery was relatively low (10.80 %, 7.95 %, and 3.87 % respectively; Fig. 3A).

Further, we calculated the proportion of intravenous PCA administered after different types of surgery in our hospital from 2016 to 2021 (Fig. 3B). Overall, the proportion of patients with different types of surgery using intravenous PCA after surgery shows a fluctuating increase, reaching a high level in 2017, 2018 and 2019, showing a significant downward trend in 2020, and rising in 2021,

which is mainly related to COVID-19 leading to downward trends in other types of treatment, especially the changes in obstetric surgery, as shown in Fig. 3B. In the six years from 2016 to 2021, the proportion of patients receiving intravenous PCA after thoracic surgery was more than 80 %, reaching the highest (84.02 %) in 2017 and the lowest (74.82 %) in 2019. The proportion of patients receiving intravenous PCA after gastrointestinal and extrahepatic surgeries showed an increasing trend annually. For orthopedic, thyroid-breast, pediatric, and gynecological surgeries, the proportion of patients receiving intravenous PCA after surgery has been relatively stable over the past 6 years. For other types of surgery, the proportion of patients receiving intravenous PCA after surgery fluctuated over time, and there was no obvious trend (Fig. 3B).

3.2. Analysis of poor postoperative analgesia

The total proportion of patients with poor analgesia in our hospital approximately 6 h after surgery was 3.33 % (Fig. 4). The types of surgery with poor analgesia of more than 5 % that occurred approximately 6 h after surgery were biliary-pancreatic surgery, extra-heptic surgery, and gastrointestinal surgery, which were 6.74 %, 5.34 %, and 5.18 %, respectively (Fig. 4). For the four types of surgery, namely obstetrics surgery, trauma surgery, urological surgery, and orthopedic surgery, the proportion of patients with poor analgesia 6 h after surgery was higher than the average of 3.91 %, 3.79 %, 3.54 %, and 3.51 %, respectively. Among the four types of surgery, cardiac-vascular surgery, organ transplantation, thoracic surgery, and gynecological surgery, the proportion of patients with poor analgesia to about 6 h after surgery was 2.94 %, 2.21 %, 1.80 %, and 1.73 %, respectively (Fig. 4). Less than 1.5 % of the surgeries with poor analgesia occurring approximately 6 h after the surgery were pediatric surgery, gynecological tumor surgery, and thyroid and breast surgery (Fig. 4).

Approximately 24 h after the surgery, the incidence of poor analgesia in cardiac and vascular surgery, organ transplantation surgery, gynecological surgery, other types of surgery, pediatric surgery, gynecological tumor surgery, and thyroid and breast surgery was 0.92 %, 0.51 %, 0.74 %, 0.43 %, 0.68 %, 0.28 %, and 0.29 %, respectively (Fig. 4). The proportion of poor postoperative analgesia in biliary and pancreatic surgery, extrahepatic surgery, and trauma surgery was 3.78 %, 3.20 %, and 3.73 % respectively (Fig. 4).

3.3. Analysis of adverse effects after intravenous PCA

According to the statistical analysis of clinical data in the past six years, the main types of adverse effects are postoperative nausea and vomiting (PONV), respiratory depression, skin itching, abdominal distension, urinary retention, dizziness. The results showed that the overall incidence of adverse effects was 5.52 % (N = 107,802). Among all the adverse effects, postoperative nausea and vomiting (PONV) accounted for 76.52 % (N = 5953), dizziness accounted for 17.05 % (N = 5953), and other adverse effects, respiratory depression, skin itching, abdominal distention, and urinary retention, accounted for only 3.07 % (N = 5953), 1.43 % (N = 5953), 1.09 % (N = 5953) and 0.84 % (N = 5953) respectively (Fig. 5).

3.4. Analysis of PONV

According to a statistical analysis of 6 years of clinical data, the proportion of PONV in patients undergoing gynecological tumor surgery and gynecological surgery 6 h after surgery was 10.75 % (n = 8716) and 8.68 % (n = 8906), respectively. The data decreased to 7.49 % and 5.00 % 24 h later (Fig. 6A and B). The proportion of PONV occurring 6 h after surgery in patients undergoing biliary-pancreatic, urological, and obstetric surgeries were 5.87 % (n = 7149), 4.50 % (n = 6803), and 4.77 % (n = 12,777), respectively.

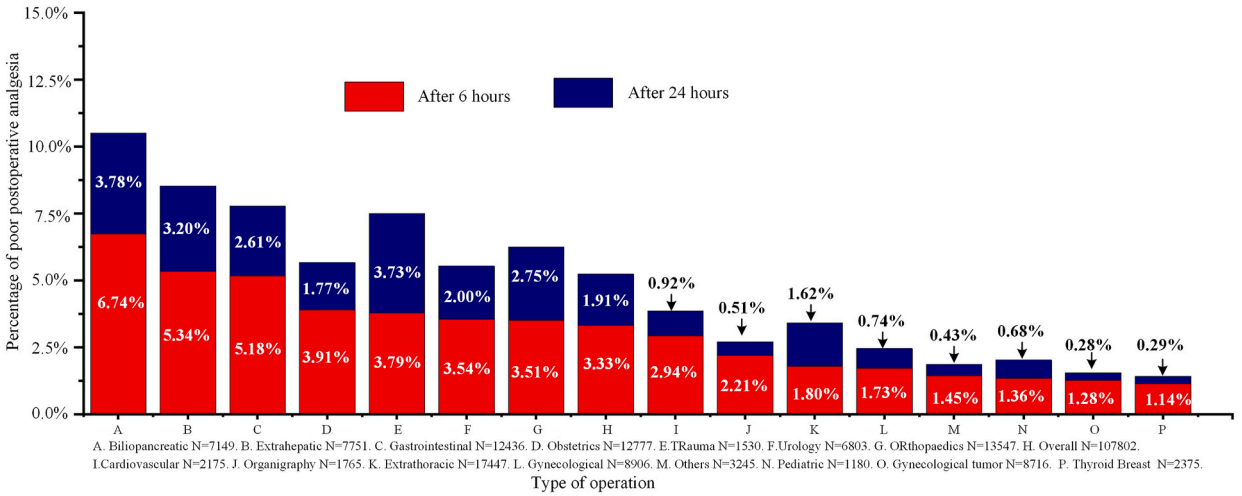

Fig. 4. Proportion of postoperative patient-controlled analgesia administered among the total patient-controlled analgesia administered from 2016 to 2021.

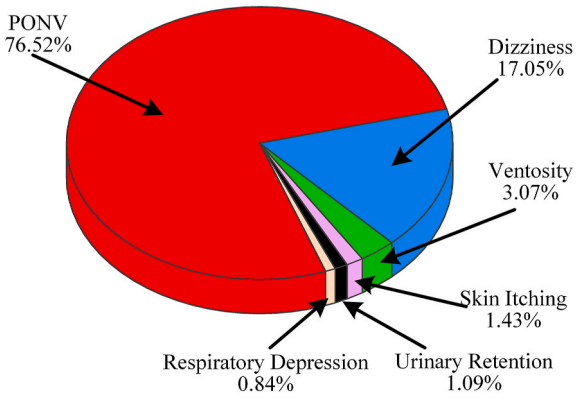

Fig. 5. Proportion of adverse effects among patients using PCA after surgery from 2016 to 2021.

After 24 h, the proportion decreased to 4.11 %, 3.70 %, and 1.51 %, respectively (Fig. 6C–E). In trauma, gastrointestinal, orthopedic, pediatric, cardiovascular, and liver surgeries, the proportion of PONV occurring 6 h after surgery was lower than the overall proportion, 3.79 % (n = 1530), 3.35 % (n = 12,436), 3.10 % (n = 13,547), 2.80 % (n = 1180), 2.48 % (n = 2175), 2.54 % (n = 7751), respectively. After 24 h, the proportion decreased to 1.89 %, 2.20 %, 2.51 %, 3.56 %, 4.50 %, 1.35 %, respectively (Fig. 6F–K). The incidence of PONV 6 h after surgery in patients undergoing other types of surgery, thyroid and breast surgery, organ transplantation surgery, and thoracic surgery was generally low: 1.94 % (n = 3245), 1.77 % (n = 2375), 1.36 % (n = 1765), and 1.18 % (n = 17,447), respectively. The incidence decreased 24 h later to 1.29 %, 1.39 %, 0.23 %, and 1.13 %, respectively (Fig. 6L–O). An analysis of the overall proportion of PONV occurring among patients at our hospital in the past 6 years showed that the overall proportion of PONV occurring approximately 6 and 24 h after surgery was 4.23 % and 2.72 %, respectively (Fig. 6P).

In general, among the 15 types of surgery, the proportion of postoperative PONV decreased gradually over time. The incidence of PONV 24 h after surgery decreased by 35.74 %. In particular, the proportion of organ transplantations decreased by 83.33 % within 24 h, followed by obstetrics, cardiovascular surgery, liver surgery, and gynecology, 68.31 %, 53.70 %, 46.70 %, and 42.43 %, respectively, which decreased by more than 40 %.

4. Discussion

At present, the classic and recommended APS team in the world is based on anesthesiologists and consists of anesthesiologists and anesthesia nurses [15,16]. The advantage of this is that anesthesiologists have a better understanding of the pharmacology and physiology of pain management, and also have comparative advantages in terms of analgesia technology [15,16]. The TJ-APS team of Tongji hospital affiliated to Tongji Medical College of Huazhong University of Science and Technology (TJ-APS) is led by the Chief Physician of the Anesthesiology Department (Professor Zhang), plus a senior attending physician, three residents and an anesthesia nurse. The TJ-APS standardized postoperative analgesia process, postoperative analgesia strategy based on the principle of “low opioid, multimodal, specialization and individualization”, as well as regular ward rounds and 24-h on call on-duty system, can timely detect and deal with poor postoperative analgesia and adverse effects. In particular, the team has been implementing continuous quality improvement (CQI) of PCA formula and management processes.

Under this APS multimodal management, the average use rate of intraveous PCA in this large Class III hospital in central China was 33.57 %, among which, the proportion of patients who used intraveous PCA after surgery for extrathoracic, obstetric, gastrointestinal and extrahepatic surgery was more than 60 %, 80.93 %, 76.76 %, 68.69 % and 62.34 % respectively. Based on the TJ-APS standardized postoperative pain management, the incidence of poor postoperative analgesia in patients with intravenous PCA is significantly lower than that reported in the current literature (20 %), and mainly occurs in biliary-pancreatic surgery, extrahepatic surgery and gastrointestinal surgery. The overall incidence of adverse effects was 5.52 %, of which nausea and vomiting was the highest, especially among gynecological tumors and gynecological patients, which were 10.75 % and 8.68 % respectively, but both were lower than the level reported in the current literature (20 %).

In general, TJ-APS team has formulated the standard postoperative analgesia and adverse reaction treatment processes based on the ERAS concept and postoperative pain management guidelines and has more advantages in the selection of specialized analgesics and the implementation of the analgesia process. This reduced the incidence of poor postoperative analgesia and adverse effects in patients.

4.1. Postoperative use of intravenous PCA in different types of surgery

The rate of intravenous PCA administration in patients generally shows a yearly rising trend. Owing to the COVID-19 pandemic in 2020, the proportion of PCA administration declined. Later, with the recovery of medical care, the proportion of PCA administration rebounded, especially in obstetrics. Among the four types of surgery, extrathoracic, extrahepatic, obstetric, and gastrointestinal, the proportion of patients using postoperative PCA is more than 60 %. This is mainly related to the following factors: (1) patients’

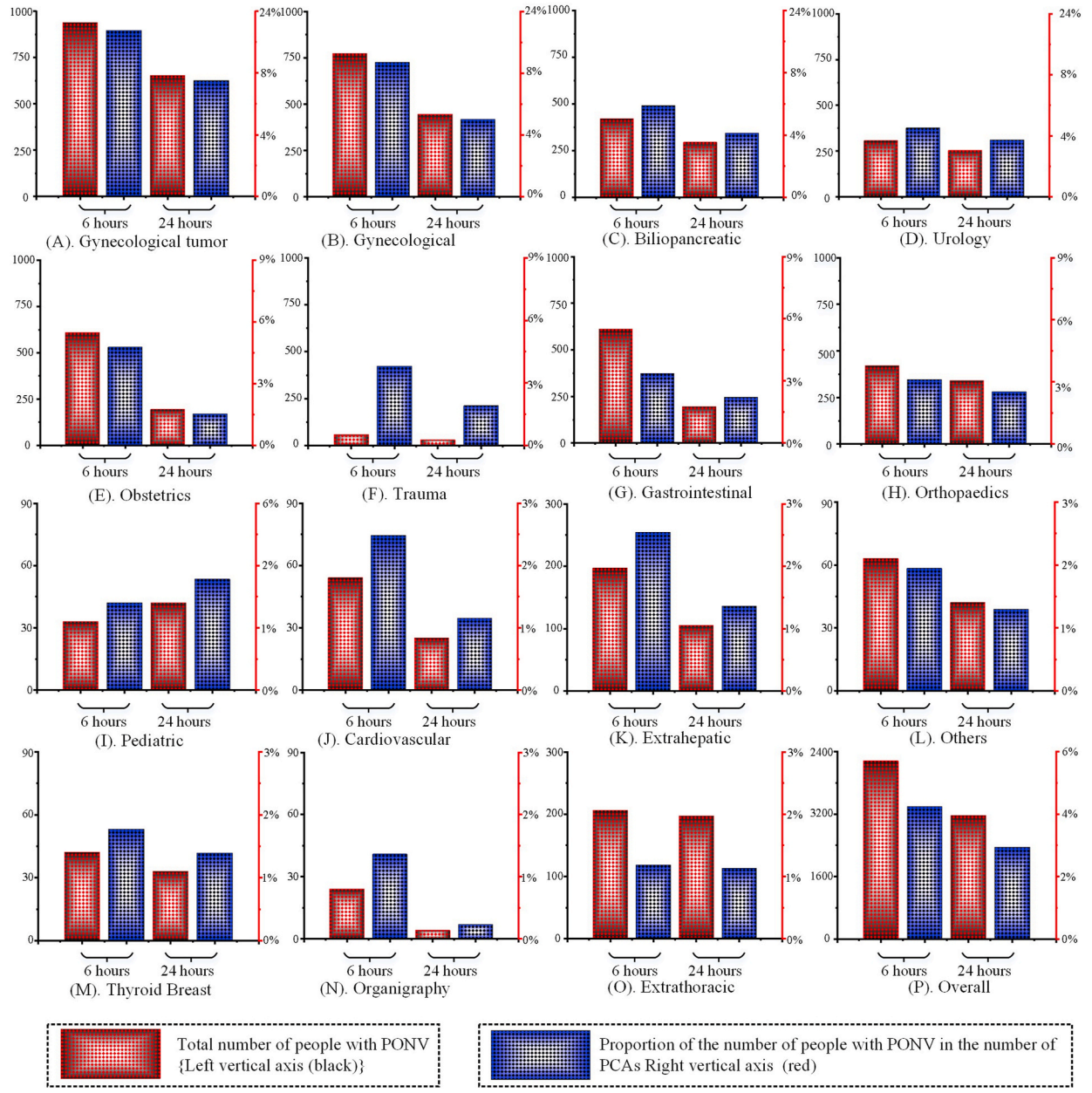

Fig. 6. Proportion and number of postoperative nausea and vomiting adverse reactions associated with postoperative patient-controlled analgesia administration after different types of surgery from 2016 to 2021.

awareness of pain management has gradually increased, and people increasingly pursue a high postoperative quality of life [8,27]. (2) Effective relief of postoperative pain is a key component of postoperative rehabilitation surgery (Enhanced Recovery after Surgery, ERAS) [10,17], this concept is accepted by doctors, nurses and patients. (3) The standardized analgesic treatment with PCA under APS management has won a good reputation among patients, surgeons and nurses. In addition, to some extent, it suggests that the degree of pain in extrahepatic, obstetric and gastrointestinal surgeries is higher than other types of surgery, because it is difficult to obtain opioids in the wards; the intravenous PCA formula is dominated by medium and strong opioids [28]. These conclusions can provide a very helpful reference for us to decide whether to prepare patients for PCA in clinical surgery. The use rate of intravenous PCA in obstetrics decreased in 2020, mainly because we tried to use epidural PCA for postoperative analgesia in some patients.

Although the use rate of venous PCA after pediatric surgery has increased to a certain extent over the years, compared with the other 14 types of surgery, the proportion of venous PCA after pediatric surgery remained the lowest in 6 years. In consideration of safety issues, we only administer intravenous PCA to children weighing more than 10 kg, so the overall use rate of PCA in pediatric surgery is not high. However, it is worth noting that children's postoperative pain still deserves attention, and the measures for

children's postoperative pain relief also need to be gradually improved in the future.

Although cardiovascular surgery is a surgery with extremely high life risk, it is particularly demanding for anesthesiologists, with high postoperative pain intensity and wide distribution [29]. However, the proportion of patients receiving PCA after this surgery was 17.40 % (6-year average). The main reason is that the tracheal catheter was pulled out late in patients undergoing cardiac and macrovascular surgery at our hospital, resulting in a low proportion of patients receiving PCA after surgery. The other surgeries include ophthalmic surgery, neurosurgery, otorhinolaryngology surgery, cardiovascular surgery, plastic and cosmetic surgery, and very few specialized surgeries. This proportion is the lowest among all 15 categories from the average point of view, which is an important reason why these surgeries are classified as "others".

4.2. Characteristics of poor postoperative analgesia

Through retrospective statistical analysis of clinical data, we found that the overall incidence of poor postoperative analgesia in patients with intravenous PCA was less than 4 % within 6 h after surgery based on the specialized optimization of PCA drug compatibility and the application of multimodal analgesia, which is significantly lower than that reported in the published literature (20 %) [30,31], and mainly occurs in biliary-pancreatic surgery, extrahepatic surgery and gastrointestinal surgery. The main reasons are: (1) A standardized APS workflow has been established. (2) Multi-modal analgesia was used in the perioperative period. Prior to skin incision, parecoxib sodium, flurbiprofen axetil, or digoxin was administered for pre analgesia. For patients undergoing thoracic, gastrointestinal, extrahepatic and other visceral surgeries, oxycodone (0.1 mg kg^{-1}) was used half an hour before the end of the surgery to reduce visceral pain. Paravertebral nerve block or intercostal nerve block was used for thoracic surgery. For orthopedic surgery, nerve block based on local anesthetics was adopted. (3) Specialized postoperative analgesia. According to the unique postoperative pain characteristics and clinical characteristics of different types of surgery, different PCA formulas were used for specialized postoperative analgesia.

Compared with other types of surgery, the incidence of poor postoperative analgesia in gastrointestinal surgery, extrahepatic surgery, biliary-pancreatic surgery, and obstetrics is still high. We need to ensure that, in biliary-pancreatic surgery, extrahepatic surgery, and gastrointestinal surgery, minimally invasive surgery was carried out, and the proportion of endoscopic surgery increased. Although the pain intensity of endoscopic surgery is lower than that of open surgery [32], the postoperative pain cannot be underestimated [12]. The proportion of poor postoperative analgesia in biliary-pancreatic and gastrointestinal departments is still high. Postoperative analgesia is still a challenge for clinicians. Postoperative pain management still needs to be further improved [17]. Identifying the risk of poor postoperative analgesia will help to improve the effectiveness and safety of analgesic treatment.

Extrathoracic surgery is considered one of the most painful surgeries for patients [33]. Postoperative pain can lead to adverse outcomes, such as respiratory complications, prolonged hospitalization, poor quality of life, and chronic post-thoracotomy pain syndrome. It is gratifying to note that postoperative analgesia based on TJ-APS reduces the incidence of poor postoperative analgesia in thoracic patients.

5. Analysis of adverse effects of intravenous PCA

There was no medical accident among patients who used intravenous PCA during the six-year period under the guidance of standardized postoperative analgesia treatment by TJ-APS. The overall incidence of adverse effects was 5.52 % (N = 107,802). Among all the adverse effects, postoperative nausea and vomiting (PONV) accounted for 76.52 % (N = 5953), dizziness accounted for 17.05 % (N = 5953), and other adverse effects (respiratory depression, skin itching, abdominal distention, and urinary retention, etc) accounted for only 6.43 % (N = 5953). The above adverse effects were far lower than those reported in the published literature. Furthermore, it is important to highlight that none of the patients included in our study has been harmed in going to Intensive Care. This is mainly due to the standardized APS management and unique postoperative analgesia process led by anesthesiologists in our hospital.

In practice, opioids with small respiratory inhibition should be selected as much as possible, and multimodal analgesia should be adopted to reduce the incidence of postoperative respiratory inhibition. Opioid pruritus is mainly related to opioid type, administration mode and dosage [31,34]. TJ-APS did not choose morphine as postoperative analgesia because of its high incidence of pruritus, and intravenous PCA was chosen as the administration mode, which is lower than epidural and intrathecal administration [31,35]. Multi-modal analgesia was adopted, which reduced the dosage of opioid drugs, in order to reduce the incidence of pruritus.

Characteristics of PONV. The overall proportion of PONV occurring about 6 h after surgery was 4.23 %, and mainly occurred in gynecological tumor surgery, gynecological surgery, and biliary-pancreatic surgery, 10.75 % 8.68 % and 5.87 % respectively. However, which is lower than that reported in published literature. PONV occurred in less than 2.0 % of patients approximately 6 h after thyroid and breast surgery, organ transplantation, and thoracic surgery. The overall incidence of PONV in patients about 24 h after surgery (2.72 %) was generally lower than that in patients 6 h after surgery. PONV are closely associated with opioid use [36]. Previous studies found that after the use of morphine for postoperative analgesia, the proportion of PONV was as high as 20%–40 % [37,38] and that female sex was one of the high-risk factors for PONV [39]. Our research results show that although the proportion of PONV in gynecological tumor surgery and gynecological surgery was highest (10.75 % and 8.68 %, respectively), the overall proportion has been significantly reduced compared to that previously reported (20 %) [37,38]. Our team targeted prevention against high-risk factors for nausea and vomiting, such as dexamethasone + tropisetron/palonosetron before surgery, dexamethasone and tropisetron can prevent nausea and vomiting [40,41], and tropisetron (antiemetic) or low-dose naloxone added to the postoperative analgesia pump. It should be noted that obstetric patients did not take preventive measures against nausea and vomiting, however, the incidence

of nausea and vomiting was only 4.77 % (6 h) and 1.51 % (24 h). Reviewing the literature, we found that PONV after cesarean section are mainly seen in epidural analgesia, which may be related to the mode of administration or hypotension [42,43]. Our data suggests that the incidence of PONV after cesarean section using intravenous PCA is very low. Although the mechanism is unclear, it suggests that compared with epidural PCA, this may be one of the advantages of intravenous PCA in obstetrics.

Based on 12 years of practice and 170,000 clinical cases, this paper confirms that this multimodal management is helpful to continuously improve the quality of postoperative analgesia management, reduce the incidence of adverse analgesia and adverse reactions, and improve the quality of life of patients after surgery through the analysis and research of the data collected from 2016 to 2021.

5.1. Limitations of the study

This study is a retrospective study and does not evaluate the psychology of patients. In addition, postoperative pain management based on APS may reduce perioperative complications of patients and have a positive impact on hospital stay and hospitalization costs [44], but no relevant data has been collected in this study.

Ethics declarations

This study underwent a thorough review and obtained approval from the Medical Ethics Committee of Tongji Hospital Affiliated to Tongji Medical College of Huazhong University of Science and Technology. The approval number assigned to this study is No. TJ-IRB20221286. Given that this is a retrospective study, and the subjects involved cannot be identified, informed consent was deemed unnecessary. Furthermore, the study project does not encompass matters of personal privacy or commercial interests.

Data availability statement

The data pertaining to our study has not been made accessible in a publicly available repository due the authors' lack of authorization to share the data.

CRediT authorship contribution statement

Jiaoli Sun: Writing – original draft, Methodology, Formal analysis, Data curation. **Ningbo Li:** Visualization. **Baowen Liu:** Software. **Guangyou Duan:** Methodology. **Hua Zheng:** Data curation. **Xueqin Cao:** Data curation. **Mao Wang:** Formal analysis, Data curation. **Zhifa Zhang:** Methodology. **Xianwei Zhang:** Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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