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Original Article

Application of novel automated anesthesia cart to improve medication management in a large tertiary hospital

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Abstract: Objective: This study was designed to evaluate the effect of application of novel automated anesthesia cart upon the efficacy and quality of medication management in the largest tertiary referral hospital in China. Methods: A total of 60 anesthesiologists were required to alternately locate the items during two independent simulated anesthesia scenarios using either a traditional cart (control; Cart 1) or an automated anesthesia cart (A-med; Cart 2). Trial completion time, auditing time and questionnaire response were recorded and statistically compared between two groups. Results: By using an automated anesthesia cart, the trial completion time and auditing time were considerably shortened compared to that of application of a conventional anesthesia cart (both $P<0.001$). The questionnaire results demonstrated that the performance of the automated anesthesia cart was significantly better than that of the traditional anesthesia cart ($P<0.001$). Conclusion: Application of novel automated anesthesia cart could significantly improve the efficacy and quality of medication management in the largest tertiary referral hospital in China. The performance of this automated anesthesia cart is widely accepted by clinical anesthesiologists.

Keywords: Medication management, anesthesia, anesthesiologist, automated anesthesia cart

Introduction

The management of medications in the operation room is a complex task which integrates diverse functions and roles of the anesthesiologists. Anesthesiologists are mainly responsible for maintaining the storage and safety of multiple types of medications during the time of surgery and preoperative anesthesia. Convenient availability to vital medication and operation efficiency has been considered as the main tasks of the anesthesiologists. However, the charge procedures of the medications are constantly time-consuming and have a high risk of errors. It is highly necessary to standardize the workflow of the charge process to enhance the simplicity, convenience and accuracy in tertiary hospitals.

In a majority of developing countries, for instance, in China, the management and charge procedures of the surgery medications are still being handled and processed in the traditional manual methods. Anesthesiologists have to search and identify the required medications in an artificial manner from a traditional medication cart, and then verify the category and quantity and write them down on paper for the accounting staff. These procedures are extremely time-consuming, inaccurate and distractive. Moreover, the handwritten records are constantly misunderstood by the pharmacists who probably generate accounting errors.

Due to the widespread of information technology in high-level hospitals in China, the management of anesthesia medications is being altered and modernized in terms of both efficacy and quality using the automated anesthesia carts. The new-generation automated anesthesia cart consists of intelligent computer system and intelligent management carts which mainly function to store the anesthesia medicines. The anesthesiologists can open the drawer, obtain the storage of medications and record the medication information by simply using the intelligent computer system equipped with the cart, which is mainly supported by the system server

Handwritten account note of the First Affiliated Hospital of Zhengzhou University

Name Hospitalization No Department

Clinical examination		Medicine	
Topical anesthesia		Sodium lime	
General anesthesia		Metoprolol	
Unilateral laryngeal mask		Urapidil hydrochloride	
Bilateral laryngeal mask		Sodium potassium magnesium calcium and glucose	
Endobranchial anesthesia		Voluven	
Epidural anesthesia		Changyuan	
Critical anesthesia		:Invert sugar and electrolytes injection	
Specific intubation		Ropivacaine	
CPR		Dexamethasone	
Controlled hypotension		Tropisetron hydrochloride and sodium chloride	
Postoperative analgesia		Dexmedetomidine	
Central venous puncture		Penehyclidine hydrochloride	
Deep venous catheter package		Midazolam	
Single-lumen central vein catheter (adult)		Etomidate	
Double--lumen central vein catheter (adult)		Diprivan	
Single-lumen central vein catheter (pediatrics)		Propofol	
Double--lumen central vein catheter (pediatrics)		Rocuronium	
Three-lumen central vein catheter (adult)		Hengrui	
Arterial puncture		Dezocine	
Arterial pressure monitoring/h		Flurbiprofen acetate	
Filter		Propacetamol	
Blood-gas analysis		Propofol	
Glucose level detection		Nimbexon	
Postopertive EEG			
Medical occluder			

Signature: Date:

Figure 1. Picture of traditional cart (A) and handwritten account note (B).

and the runtime system. In the United States and Canada, the novel automated anesthesia cart has been successfully applied in large hospitals the efficacy and quality of medicine management [xxx]. However, it has not been attempted in the tertiary hospitals in China.

The novel automated anesthesia carts were applied in the operation room of the First Affiliated Hospital of Zhengzhou University, which is currently the largest tertiary hospital in China, aiming to strengthen the medication management and mitigate the workload of anesthesiologists during surgery. The effect of this automated anesthesia cart upon the efficacy and quality of medicine management is evaluated in this investigation.

Materials and methods

Study design

A randomized, controlled, crossover trial was carried out. Two simulated anesthesia scenarios were established, in which the anesthesiologists were required to search and identify the medicines, charge and audit with the pharmacists. In the first scenario, the anesthesiologists were assigned to identify the medicines by using a traditional and an automated anesthesia cart (DIH Technology Company, China), respectively. In the second scenario, the anesthesiologists were switched to the other anesthesia cart.

Study subject

Sixty anesthesiologists were recruited in this investigation, which was conducted at the First Affiliated Hospital of Zhengzhou University. The study procedures were approved by the ethics committee of the First Affiliated Hospital of Zhengzhou University. Written informed consents were obtained from all participants prior to this study.

Illustration of anesthesia carts

Traditional anesthesia cart: Traditional anesthesia cart was used for medicine storage except narcotic drugs in the operating room of the First Affiliated Hospital of Zhengzhou University (**Figure 1A**). In the morning daily, the anesthesiologists had to collect the keys of each anesthesia cart from the pharmacists who worked in the satellite pharmacy of operating area and excluded the restricted substances. Subsequently, the anesthesiologists were responsible for selecting the medicines for anesthesia from the carts, recording the category and quantity of medicines on a note intraoperatively, as illustrated in **Figure 1B**. Postoperatively, the pharmacists had to audit the handwritten note to verify the accuracy.

Automated anesthesia cart: The automated anesthesia carts were equipped with intelligent computer system, which could display the medications stored in the trolley drawers on the electronic screen. Each type of medicine was

Figure 2. Picture of automated anesthesia cart.

Questionnaire

Participant __

Cart used __

Please circle the number that is most appropriate as an answer to the given comment.

	Disagree	Neutral	Agree
1. The medications in this cart were easily visible	1	2	3
2. The medications in this cart were easily found	1	2	3
3. The medications in this cart are well organized	1	2	3

Figure 3. The 3-point Likert-type scale questionnaire used in this study.

Table 1. Comparison of medicine use and dosage between two scenarios

No.	Scenario 1	No.	Scenario 2
1	Propofol (20 ml:200 mg)	1	Dexamethasone (1 ml:5 mg)
2	Lidocaine (5 ml:100 mg)	2	Adrenaline (1 ml:1 mg)
3	Midazolam (2 ml:10 mg)	3	Atropine (1 ml:0.5 mg)
4	Atropine (1 ml:0.5 mg)	4	Midazolam (2 ml:10 mg)
5	Etomidate (10 ml:20 mg)	5	Dopamine (2 ml:20 mg)
6	Phenylephrine (1 ml:10 mg)	6	Neostigmine (2 ml:1 mg)
7	Neostigmine (2 ml:1 mg)	7	Propofol (20 ml:200 mg)
8	Adrenaline (1 ml:1 mg)	8	Phenylephrine (1 ml:10 mg)
9	Dopamine (2 ml:20 mg)	9	Lidocaine (5 ml:100 mg)
10	Dexamethasone (1 ml:5 mg)	10	Etomidate (10 ml:20 mg)

stored in a separate box with a transparent cover. The automated anesthesia carts shared the similar structure and layout with the traditional carts, which could be easily familiarized by the anesthesiologists. In addition, each medicine was stored in separate and marked with explicit labels, as shown in **Figure 2**. Finally, the medicine record can be automatically compiled on the electronic screen simultaneously and printed on the note at the end of the anesthesia procedures.

Likert-type scale questionnaire: Likert-type scale questionnaire was chosen and completed by the 60 anesthesiologists during two scenarios. A 3-point Likert-type scale, consisting of content, usability and organization, was used to evaluate the performance of the automated anesthesia cart (**Figure 3**). Eventually, the questionnaire responses were obtained from all anesthesiologists.

Study design: Prior to the study, each anesthesiologist received training courses by the technicians from DIH Technology Company to familiarize the use and operation of the automated anesthesia cart. Traditional and automated anesthesia carts were applied in two different simulated anesthesia scenarios, respectively. The simulated scenarios were timed and randomly ordered (**Table 1**), and the 10 common anesthesia medicines were chosen for two scenarios. Half of the anesthesiologists utilized the traditional anesthesia cart in the first scenario by using a random number generator, and they were switched to the automated anesthesia cart during the second simulated scenario.

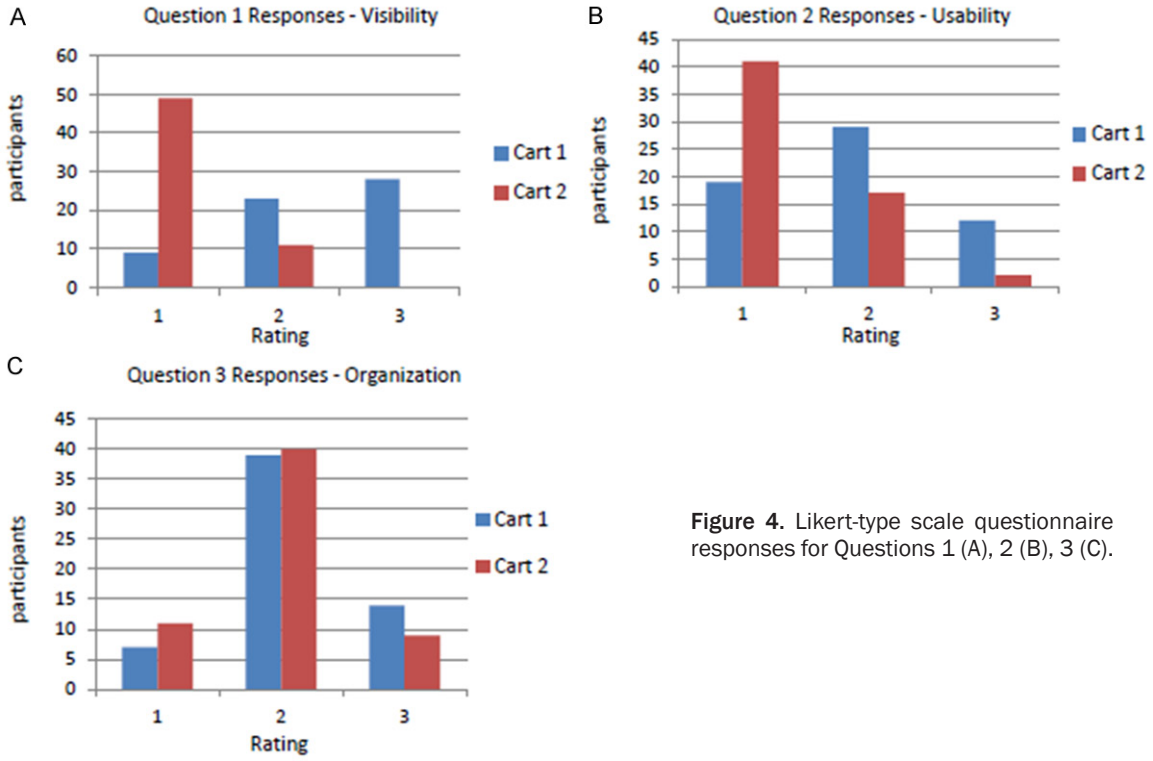

Figure 4. Likert-type scale questionnaire responses for Questions 1 (A), 2 (B), 3 (C).

Study procedures: In the first scenario, the anesthesiologists were required to review the medicine list prior to the study. Then, the time of selecting the 10 medicines and the time of accounting were recorded. Five-minute break was given to the anesthesiologists between the first and second scenarios. During the 5-minute break, the anesthesiologists should complete the 3-point Likert-type scale questionnaire (**Figure 3**) to express their evaluation upon the medicine cart performance. After the break, the second scenario was initiated, identical to the first scenario except the design of the medicine cart. Likert-type scale questionnaire was completed after the second scenario. Finally, the anesthesiologists should answer the question of "Which medication cart would you prefer to use in anesthesia and please deliver your suggestions". At the end of each scenario, the pharmacists audited the accounts with the medications and the auditing time was equally recorded. Subsequently, all parameters were statistically compared between two groups.

Statistical analysis

SPSS statistical software was utilized for data analysis. Multiple parameters were statistically analyzed and compared by using the repeated measures analysis of variance (ANOVA), the paired-sample Wilcoxon signed rank test, and McNemar's chi-square test. A *P* value of less than 0.05 was considered as statistical significance.

Results

Completion time

In the automated anesthesia cart group, the anesthesiologists completed the first scenario with a mean time of (59.2±3.1) s, significantly faster compared with (68.9±2.5) s in the traditional anesthesia cart group (P<0.001). In the second scenario, the completion time in the automated anesthesia cart group was (62.5±6.1) s, considerably less than (65.6±4.7) s in the traditional anesthesia cart group (P<0.001). ANOVA test demonstrated a potential medicine learning curve from the first to the second scenarios for the anesthesiologists, suggesting that the anesthesiologists could complete the second scenario (56.9±2.3) s using the automated anesthesia cart faster compared with the first scenario (61.5±1.8) s (P<0.001). The anesthesiologists can master the operation of automated anesthesia cart and accurately select the 10 medicines significantly 4.4 s fast-

er compared with their counterparts using the traditional anesthesia cart.

Auditing time

The mean auditing time in the automated anesthesia cart group was (31.9±3.1) s, significantly less compared with (39.4±1.0) s in the traditional anesthesia cart group (P<0.001).

Likert-type scale responses

The 3-point Likert-type scale questionnaire was completed by the anesthesiologists following each round of scenario, as illustrated in **Figure 4**. The grading scores of three questions related to the visibility, usability and of the automated anesthesia cart were all significantly higher compared with those of the traditional anesthesia cart (all P<0.001).

Evaluation on cart performance

After completing two scenarios, 95% (57/60) of the anesthesiologists preferred to utilize the automated anesthesia cart, significantly higher compared with 5% (3/60) who chose to use the traditional anesthesia cart in clinical practice (P<0.001). Meantime, a majority of anesthesiologists expressed to receive operation training for automated anesthesia cart and handle the emergency situation of power shortage.

Discussion

The First Affiliated Hospital of Zhengzhou University, as a licensed tertiary referral hospital, is the largest hospital in China with a total of 8000-licensed beds [1], 99 surgical suites and 152 anesthesiologists. Over 500 operations are being performed daily, up to 100000 surgical cases each yearly. The conventional management mode cannot fulfill the expansion of the surgeries. Thus, a new-generation medicine management is urgently required to enhance both the efficacy and quality of medicine management.

Appropriate medication use is a key ring throughout the surgical procedures. How to enhance the workflow of medicine management has become a top priority. In this study, 60 anesthesiologists were instructed to utilize the automated anesthesia carts for the first time. Almost all anesthesiologists recommended the application of automated anesthesia cart in our hospital. First, the anesthesiologists can complete the task significantly faster by using the automated anesthesia cart, mainly due to automated medicine charge, easily-recognizable electronic records and shorter auditing time. In addition, application of the automated anesthesia cart considerably reduces the workload of both the anesthesiologists and pharmacists, especially in the circumstances of a large quantity of prescribed medicines.

During emergency situations, the electronic records will be more explicit and accurate than the manual notes. In addition, application of the automated anesthesia cart dramatically shortens the retrieval time, which is supported by the findings in this investigation. Through technician instructions prior to use, the anesthesiologists can master the operation of automated anesthesia cart and accurately select the 10 medicines significantly faster compared with their counterparts using the traditional anesthesia cart, indicating that if the anesthesiologists are familiar with the operation of the automated anesthesia cart, they will complete the task significantly faster. The time saved by automated anesthesia cart is of significance especially for patients with cardiac or respiratory arrest during emergency settings [2].

The medicine visibility is the main limitation of the traditional anesthesia cart. When one of the drawers is opened, it is extremely to rapidly distinguish the medicine you need in a short time, which is not clearly labeled. Multiple modifications have been made in the automated anesthesia cart in which independent boxes with transparent covers are supplemented to store various medicines. More importantly, the covers of each box are marked with labels of different colors. The main task of the anesthesiologists is to ensure the accuracy and safety of medicines and any slight error during medicine management procedures should be cautiously avoided [3]. Several interventions have been delivered to promote safe administration of medications to patients in many countries. The legible drug labels are the emphasis of both ampoules and syringe management [4, 5]. By using the automated anesthesia cart, the colorful labels allow for the anesthesiologists to identify the medicines rapidly and accurately, which is one of the cues used to select ampoules [6], especially for the Chinese anesthesiologists who have to select the medicines

Figure 5. Picture of certain types of medicines with labels that are difficult to distinguish. From left to right in the 1st line: prostigmine methylsulfate, furosemide, isoprenaline hydrochloride, hydrochloric acid dopamine,chlorination succinic acid and droperidol. From left to right in the 2nd line: noradrenaline bitartrate, hydrochloric acid deoxidation epinephrine, adrenalin hydrochloride, methoxamine hydrochloride, nitroglycerin, atropine sulfate, dexamethasone sodium phosphate and metoclopramide.

with undistinguishable labels with a shortage of prefilled syringes (**Figure 5**). Moreover, the medicines kept in each drawer can be explicitly displayed on the electronic screen, which assists the anesthesiologists to identify the required medicines rapidly and accurately.

The better performance of the automated anesthesia cart is subsequently validated by the questionnaire response given by the anesthesiologists, who deliver higher rating scores for the automated anesthesia cart during two rounds of scenario tests. In addition, the structure and layout of the automated anesthesia cart is almost identical to the traditional anesthesia cart, which is easily accepted by the anesthesiologists. The answers of Question 1 and 2 indicate that the anesthesiologists recommend the application of the automated anesthesia cart compared with traditional anesthesia cart. The response of Question 3 suggests that the anesthesiologists consider the contents of automated anesthesia cart are organized. Meantime, the anesthesiologists also emphasize the importance of training courses prior to application of the automated anesthesia cart because wrong operation is likely to induce apparent errors. Previous studies also indicate that use of automated dispensing cabinet could improve the efficiency of drug administration in hospitals [7-13]. Nevertheless, in event of power outage, traditional anesthesia cart should be prepared in the operation room to replace the function of the automated anesthesia cart.

Next, the automated anesthesia cart will be applied in 60 surgical suites of the First Affiliated Hospital of Zhengzhou University except the cardiovascular and organ transplant operations. Meantime, the traditional anesthesia cart will be prepared in case of emergency. In the upcoming investigations, we will re-evaluate the performance of the automated anesthesia cart when it is applied in a wider array of scenarios. Moreover, the suggestions and advice will be collected from more anesthesiologists and pharmacists, aiming to enhance the efficacy and quality of medicine administration and management in clinical settings.

Conclusion

Taken together, application of automated anesthesia cart can enhance the efficiency and replace the handwritten accounts with electronic recording in the largest tertiary hospital in China. Likert-type scale questionnaire reveals that automated anesthesia cart with explicit labels is widely accepted by the anesthesiologists, which complies with international standards, which deserves wider application to more hospitals of different levels in developing countries, such as China.

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Disclosure of conflict of interest

None.

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References

[1] Wang S, Rao KQ. The developing of beds in Chinese hospitals: from an international point of view (chinese). Chinese Hospitals 2012; 16: 13-16.

[2] Travers AH, Rea TD, Bobrow BJ, Edelson DP, Berg RA, Sayre MR, Berg MD, Chameides L, O'Connor RE, Swor RA. Part 4: CPR overview: 2010 American heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2010; 122: S676-S684.

[3] Wheeler SJ, Wheeler DW. Medication errors in anaesthesia and critical care. Anaesthesia 2005; 60: 257-73.

[4] Hanna GM, Levine WC. Medication safety in the perioperative setting. Anesthesiol Clin 2011; 29: 135-144.

[5] Orser BA, Hyland S, David U, Sheppard I, Wilson CR. Review article: improving drug safety for patients undergoing anesthesia and surgery. Can J Anaesth 2013; 60: 127-135.

[6] The Australian Incident Monitoring Study. Currie M, Mackay P, Morgan C, Runciman WB, Russell WJ, Sellen A, Webb RK, Williamson JA. The "wrong drug" problem in anaesthesia: an analysis of 2000 incident reports. Anaesth Intensive Care 1993; 21: 596-601.

[7] Shu W, Towne P, So A. Transition to new automated dispensing cabinets at two tertiary care hospitals. Am J Health Syst Pharm 2011; 68: 1200-1202.

[8] Hyland S, Koczmara C, Salsman B, Lap E, Musing S, Greenall J. Optimizing the use of automated dispensing cabinets. Canadian Journal of Hospital Pharmacy 2007; 60.

[9] Grissinger M. Safeguards for using and designing automated dispensing cabinets. P T 2012; 37: 490-530.

[10] Quick AK, Macario A, Brock-Utne JG, Jaffe RA, Kadry B. A case illustrating the costs of quality improvement: nine months to move needles and syringes on the anesthesia cart. A A Case Rep 2015; 5: 88-90.

[11] Gallagher TQ, Setlur J, Maturo S, Hartnick CJ. Percutaneous transtracheal needle insufflation: a useful emergency airway adjunct simply constructed from common items found on your anesthesia cart. Laryngoscope 2012; 122: 1178-80.

[12] Shultz J, Davies JM, Caird J, Chisholm S, Ruggles K, Puls R. Standardizing anesthesia medication drawers using human factors and quality assurance methods. Can J Anaesth 2010; 57: 490-9.

[13] Holst D, Rudolph P, Wendt M. Practical realization of a patient-accompanying concept in anesthesia and intensive care. Anasthesiol Intensivmed Notfallmed Schmerzther 2000; 35: 25-9.