Benefits of ultra-fast-track anesthesia for children with congenital heart disease undergoing cardiac surgery

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Abstract
Background: To compare the outcomes of ultra-fast-track anesthesia (UFTA) and conventional anesthesia in cardiac surgery for children with congenital heart disease (CHD) and low birth weight.

Methods: One hundred and ninety-four CHD children, aged 6 months to 2 years, weighting 5 to 10 kg, were selected for this study. The 94 boys and 100 girls with the American Society of Anesthesiologists (ASA) physical status III and IV were randomly divided into two groups each consisting of 97 patients, and were subjected to ultra-fast-track and conventional anesthesia for cardiac surgery. For children in UFTA group, sevoflurane was stopped when cardiopulmonary bypass (CPB) started and cis-atracurium was stopped at the beginning of rewarming, and remifentanil (0.3 μg/kg/min) was then infused. Propofol and remifentanil were discontinued at skin closure. 10 min after surgery, extubation was performed in operating room. For children in conventional anesthesia group, anesthesia was given routinely and they were directly sent to ICU with a tracheal tube. Extubation time, ICU stay and hospital stay after operation were recorded. Sedation-agitation scores (SAS) were assessed and adverse reactions as well as other anesthesia-related events were recorded.

Results: The extubation time, ICU stay and hospital stay were significantly shorter in UFTA group (P < 0.05) and SAS at extubation was lower in UFTA group than in conventional anesthesia group, but similar in other time points. For both groups, no airway obstruction and other serious complications occurred, and incidence of other anesthesia-related events were low.

Conclusions: UFTA shortens extubation time, ICU stay and hospital stay for children with CHD and does not increase SAS and incidence of adverse reactions.

Keywords: Ultra-fast anesthesia, Congenital heart disease, Low weight children, Extubation time

Background
Fast-track anesthesia (FTA) is a procedure that enables extubation in intensive care unit (ICU) within 6 h after surgery to facilitate the recovery of consciousness and autonomous breathing. It has been safely applied to cardiac surgery since the 1990s [1, 2]. FTA is feasible and safe and reduces the occurrence of ventilator-induced complications, thereby decreasing ICU stay, resource use and cost [3–5]. Ultra-fast track anesthesia (UFTA) was developed after fast-track anesthesia to further optimize the use of medical resource. With UFTA, extubation is performed immediately or within 1 h after surgery in the operating room [6]. The benefits of UFTA include lower incidence of postoperative complications, better hemodynamic performance, shorter ICU stay [7–9].

Congenital heart disease (CHD) is the most common type of congenital anomaly, occurring in up to 1% of all live births. Children with CHD often have abnormalities in brain maturation and brain injury [10, 11]. Surgery is one of the most common options for treatment [12, 13]. Anesthesia procedures are ideal for medical and cardiac surgical management. The risks of the procedures include cardiovascular and respiratory complications from anesthesia and sedation and a potentially under-appreciated risk of neurocognitive dysfunction [14] and improvement in anesthesia management would...
reduce the risk. In this study, we aimed to investigate the outcomes of UFTA in CHD children in cardiac surgery and to assess the effect of UFTA in reducing postoperative complication.

Methods

Subjects
This was a prospective study. CHD children, aged 6 months to 2 years and admitted to our hospital, were selected for this study. They weighted 5 to 10 kg with the American Society of Anesthesiologists (ASA) physical status III and IV. Children were excluded if they had respiratory tract infection within 2 weeks of surgery and organ complications. Children were also excluded if they could not interrupt ventilation during cardiopulmonary bypass (CPB) and had severe pulmonary hypertension before operation. The study protocols were approved by Ethics Committee of China Emergency General Hospital and informed consent was obtained from every guardian of child participated in the study.

Grouping and treatment
The patients (94 boys and 100 girls) were randomly divided into two groups each consisting of 97 patients, and were subjected to UFTA and conventional anesthesia before surgeries. The surgeries were performed by the same team of surgeons, anesthesiologists, and post-operative physicians. For children in UFTA group, cis-atracurium was stopped and remifentanil (0.3 μg/kg/min) was infused at rewarming. At the onset of skin closure, propofol (3 μg/kg/h), cis-atracurium (0.1 μg/kg/h) and dexmedetomidine (1 μg/kg/h) throughout the surgery. The concentration of sevoflurane was adjusted based on hemodynamics. Additional midazolam (0.05 mg/kg) and sufentanil (1 μg/kg) were given before skin incision. Sevoflurane was discontinued when CPB started.

Postoperative pain was assessed using visual analogue scale (VAS) as reported [16], and morphine (10 μg/kg/h) was infused if VAS was > 4 and stopped if VAS was < 2. The Riker Sedation–Agitation Scale (SAS) was used to assess the sedation-agitation status after surgery [17], and dexmedetomidine (0.2 μg/kg/h) was infused if SAS was > 5.

Assessment
MAP, HR and CVP were recorded before anesthesia induction (T0), after intubation (T1), at incision (T2), before and during CPB (T3 and T4), before and after extubation (T5 and T6). Extubation time (the interval between the end of operation and extubation), ICU stay and post-operative hospitalization stay were also recorded. SAS at extubation, and 6, 12 and 24 h after operation were assessed. Adverse reactions (airway obstruction) as well as other relevant events after operation were recorded.

Statistical analysis
The data were analysed by SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). The normality of distribution of continuous variables was tested by one-sample Kolmogorov-Smirnov test. Continuous variables with normal distribution were presented as mean ± s.d. (standard derivation); non-normal variables were reported as median (interquartile range [IQR]). Means of 2 continuous normally distributed variables were compared by independent samples Student’s t test. The frequencies of categorical variables were compared using Pearson $\chi^2$ or Fisher’s exact test, when appropriate. A value of $P < 0.05$ was considered significant.

Results
A total of 194 children were enrolled in this study, 97 in each group. Two groups of patients had no difference in gender, age, body weight, CHA classification, ASA grade, surgical methods, anesthesia time, CPB time and block time (Table 1).
Furthermore, no difference in MAP, HR and CVP was observed between the two groups at different time points (Table 2). However, extubation time, ICU stay and hospital stay were significantly shorter in the UFTA group than in conventional group ($P < 0.05$, Table 3).

The SAS score of UFTA group was significantly lower than that of traditional anesthesia group at extubation ($P < 0.05$), but the scores were similar 6, 12 and 24 h after operation (Table 3). Other anesthesia-related parameters such as the incidence of continuous positive airway pressure (CPAP) use and reintubation rate were similar between the two groups, but the number of patients with ventilator-associated pneumonia was less in UFTA group than in conventional group ($P < 0.05$, Table 4), although the numbers were small in both groups. The incidence of adverse events were low and similar in both group and no airway obstruction was not observed in either group (Table 5).

**Discussion**

Our results show that the extubation time is significantly shorter in the UFTA group than in conventional group. Furthermore, the ICU stay and hospitalization stay are also shorter. No serious hemodynamic changes, nor serious complications are observed in neither groups, confirming that UFTA is safe for anesthesia management in CHD operation.

UFTA was developed to optimize perioperative anesthesia operations and management to shorten intubation time after operation for fast recovery of patients. A Meta-analysis of randomized controlled trials with large sample size showed that compared with conventional

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**Table 1** Baseline comparison of children underwent ultra-fast track anesthesia and conventional anesthesia

| Parameters                        | Ultra-fast track anesthesia (n = 97) | Conventional anesthesia (n = 97) | $P$ value |
|-----------------------------------|-------------------------------------|----------------------------------|-----------|
| Male/female (no.)                 | 45/52                               | 49/48                            | 0.231     |
| Age (year)                        | 1.2 ± 0.5                           | 1.1 ± 0.5                        | 0.331     |
| Body weight (kg)                  | 9.1 ± 1.1                           | 9.2 ± 1.1                        | 0.829     |
| No. pre-term patients             | 46                                  | 44                               | 0.782     |
| Birth weight (kg)                 | 2.3 ± 0.46                          | 2.2 ± 0.38                       | 0.389     |
| ASA III / VI (no.)                | 52 / 45                             | 46 / 51                          | 0.254     |
| CHD classification                 |                                     |                                  |           |
| Atrial septal defect (no.)        | 48                                  | 52                               | 0.612     |
| Ventricular septal defect (no.)   | 30                                  | 30                               | 0.452     |
| Atrioventricular septal defect    | 2                                   | 3                                | 0.652     |
| D-transposition of the great arteries | 4                                 | 3                                | 0.978     |
| Tetralogy of fallot (no.)         | 19                                  | 15                               | 0.334     |
| Coarctation of the aorta          | 2                                   | 3                                | 0.778     |
| Interruption arterial arch        | 1                                   | 1                                | 0.978     |
| Pulmonary stenosis                | 5                                   | 4                                | 0.878     |
| Ventricular outflow tract obstruction | 6                                 | 8                                | 0.478     |
| Anesthesia time (h)               | 3.4 ± 1.1                           | 3.3 ± 1.0                        | 0.342     |
| Surgery time (min)                | 297.1 ± 22.8                        | 289.0 ± 20.5                     | 0.551     |
| CPB time (min)                    | 47.4 ± 11.8                         | 46.3 ± 10.7                      | 0.234     |
| Block time (min)                  | 30.2 ± 8.9                          | 31.4 ± 9.1                       | 0.331     |

**Table 2** Comparison of MAP, HR and CVP between children undergoing ultra-fast track anesthesia and conventional anesthesia

| Parameters  | Anesthesia          | No. case | $T_0$       | $T_1$       | $T_2$       | $T_3$       | $T_4$       | $T_5$       | $T_6$       |
|-------------|---------------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| MAP (mmHg)  | UFTA                | 97       | 60.9 ± 5.6  | 56.9 ± 4.2  | 56.6 ± 4.1  | 50.2 ± 5.4  | 30.1 ± 2.2  | 59.4 ± 3.9  | 59.1 ± 3.6  |
|             | Conventional        | 97       | 60.5 ± 5.3  | 57.3 ± 4.0  | 56.4 ± 4.5  | 49.6 ± 4.8  | 29.5 ± 2.4  | 61.4 ± 4.2  | 60.2 ± 4.8  |
| HR (time/m) | UFTA                | 97       | 130.4 ± 4.3 | 129.3 ± 4.3 | 124.4 ± 4.9 | 128.4 ± 4.3 | /           | 136.4 ± 4.6 | 136.4 ± 6.3 |
|             | Conventional        | 97       | 129.4 ± 4.1 | 130.4 ± 4.1 | 131.4 ± 4.3 | 131.4 ± 4.3 | /           | 137.2 ± 4.8 | 136.8 ± 5.8 |
| CVP (mmHg)  | UFTA                | 97       | 4.5 ± 0.9   | 4.9 ± 0.7   | 5.3 ± 1.0   | 5.3 ± 1.1   | /           | 6.4 ± 0.3   | 6.4 ± 0.4   |
|             | Conventional        | 97       | 4.6 ± 0.8   | 5.0 ± 0.9   | 5.2 ± 1.2   | 5.2 ± 1.0   | /           | 6.8 ± 0.5   | 6.8 ± 0.4   |

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anesthesia management, UFTA is relatively low-risk and safe in terms of fatality and mortality with shorter extubation time and ICU stay [18].

Prolonged tracheal intubation and mechanical ventilation are major risk factors for respiratory-related complications [19]. A large number of studies have shown that compared with conventional anesthesia management for cardiac surgery, extubation in the operating room after surgery reduces the use of muscle relaxants, facilitates the restoration of spontaneous breathing, decreases the risks of ventilator-related iatrogenic lung inflammation, respiratory tract damage and other pulmonary complications [20]. A propensity score matching analysis showed that the use of UFTA in patients with low to moderate risks of cardiac surgery would improve cost-effectiveness and outcomes as compared to conventional anesthesia management [21]. A prospective observational study showed that extubation in the operating room was successful in 87.1% of the patients without any increase in mortality and morbidity, but with a decrease in ICU length of stay and less use of hospital resources [22].

For CHD surgery, the optimization in UFTA mainly includes perioperative anesthesia managements, such as anesthesia method, selection of anaesthetics, control of perioperative body temperature and postoperative analgesia. In the present study, all children were given a combined intravenous-inhalational anesthesia with sufentanil before CPB. The anesthetic depth was adjusted based on the circulation to reduce the stress induced by extubation and thoracotomy. Remifentanil and propofol infused through the veins after postoperative rewarming in the UFTA group, which was used to provide sedative and analgesic effect and minimize surgical stimulation-induced stress and intraoperative awareness, are ultra-short-acting. They also reduce the dose of sufentanil during operation for better early extubation and postoperative respiratory depression and duration of ventilation time. Studies have also shown that reducing the use of narcotics and analgesics help the recovery of pulmonary function and gastrointestinal function [21].

Perioperative body temperature is a major factor affecting extraction after cardiac surgery [23]. In the present study, body temperature was kept above 36.0 °C. This would accelerate the metabolism of anesthetics and muscle relaxants for better homeostasis of internal environment. Postoperative analgesia can affect extubation and prognosis after cardiac surgery. We used ropivacaine and dexmedetomidine combined with morphine for analgesia in UFTA group. The outcomes are satisfactory and no adverse events such as post-operative agitation were observed. This is important for better and early recovery of pulmonary function.

There are also limitations in this study. For example, hematological parameters related to ventilator-associated pneumonia, such as procalcitonin was not measured; the size of sample was relatively small and most of the patients had mild illness without severe pulmonary artery hypertension before operation. Therefore, studies with larger sample size and more complicated CHD surgeries are needed to further validate the feasibility of UFTA in CHD children.

### Table 3
Comparison of extubation time, ICU stay, postoperative hospital stay and SAS scores between children undergoing ultra-fast track anesthesia and conventional anesthesia

|                        | Ultra-fast track anesthesia | Conventional anesthesia |
|------------------------|-----------------------------|-------------------------|
| No. case               | 97                          | 97                      |
| Extubation time (min)  | 22.9 ± 3.5 ±                 | 189.1 ± 31.2            |
| ICU stay (h)           | 20.7 ± 6.5 ±                | 28.5 ± 4.2              |
| Postoperative hospital stay (d) | 11.5 ± 3.0 ± | 16.1 ± 2.4              |
| SAS scores             |                             |                         |
| At extubation          | 3.8 ± 0.6 ± a               | 4.8 ± 0.7               |
| 6h- postoperation      | 3.9 ± 0.4 ±                 | 3.9 ± 0.6               |
| 12h- postoperation     | 4.0 ± 0.6 ±                 | 4.0 ± 0.6               |
| 24h- postoperation     | 4.0 ± 0.5 ±                 | 3.9 ± 0.5               |

*P < 0.05 vs conventional anesthesia

### Table 4
Comparison of ventilator-associated pneumonia and continuous positive airway pressure use and reintubation rate between children undergoing ultra-fast track anesthesia and conventional anesthesia

|                        | Ultra-fast track anesthesia | Conventional anesthesia |
|------------------------|-----------------------------|-------------------------|
| No. case               | 97                          | 97                      |
| Ventilator-associated pneumonia (n) | 3                           | 5 ± a                   |
| Continuous positive airway pressure use (n) | 3                           | 3                       |
| Reintubation (n)       | 5                           | 6                       |
| Respiratory tract infections (n) | 3                           | 4                       |

*P < 0.05 vs conventional anesthesia

### Table 5
Comparison of adverse events between children undergoing ultra-fast track anesthesia and conventional anesthesia

| Adverse event            | Ultra-fast track anesthesia | Conventional anesthesia |
|--------------------------|-----------------------------|-------------------------|
| No. case                 | 97                          | 97                      |
| Airway obstruction       | 0                           | 0                       |
| Arrhythmia               | 1                           | 1                       |
| Infection                | 1                           | 2                       |
| Bleeding                 | 1                           | 1                       |
| Pneumothorax             | 0                           | 0                       |

*P < 0.05 vs conventional anesthesia
Conclusions
UFTA generates stable hemodynamics during operation, shorter extubation time, shorter ICU and hospitalization stay without increase in adverse reactions. It is worthy of recommendation for clinical practice.

Abbreviations
ASA: American Society of Anesthesiologists; BP: Blood pressure; CHD: Congenital heart disease; CPB: Cardiopulmonary bypass; CVP: Central venous pressure; E: Expiration; ICU: Intensive care unit; PETCO2: Partial pressure of carbon dioxide; RR: Respiratory-exchange ratio; SAS: Sedation-agitation scores; SIMV: Synchronous intermittent mandatory ventilation; UFTA: Ultra-fast-track anesthesia; VAS: Visual analogue scale; VT: Tidal volume

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Authors’ contributions
JX, GZ, and NL: Project conceptualization, investigation and data analysis. GZ, YL and NL: Data collection, analysis and methodology development. JX, GZ, YL and NL: manuscript writing. The manuscript was read and approved by all authors.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The study was approved by the Research Ethics Committee of China Emergency General Hospital and informed consent was obtained from every guardian of child participated in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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