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Decreasing the pressure of endotracheal tube cuff slowly with a constant speed can decrease coughing incidence during extubation: a randomized clinical trial

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Abstract

Background To discuss whether decreasing the pressure of endotracheal tube cuff slowly with a constant speed can decrease the incidence of coughing during extubation.

Methods Ninety patients undergoing elective noncardiac surgery under general anesthesia with endotracheal intubation were randomly divided into two groups: group P, the pilot balloon was connected to a syringe and an aneroid manometer through a three-way stopcock, respectively, and the decrease of cuff pressure was controlled at 3 cmH_2O/s during deflating before extubation; group C, the pressure in endotracheal tube cuff was decreased suddenly with a syringe extracting the air from the cuff rapidly at once exactly before extubation. The incidence of coughing during extubation period was recorded. Mean arterial pressure (MAP) and heart rate (HR) were recorded before general anesthesia induction (T0), just before cuff deflation (T1), immediately after deflation (T2), at 1 min (T3), 3 min (T4), and 5 min after extubation (T5). The occurrence of adverse reactions was also recorded.

Results The initiation of coughing during extubation period occurs at immediately the time of balloon deflation. Compared with group C, the incidence of coughing was significantly decreased ($P=0.001$), MAP and HR were significantly decreased at T2-T4 and T2-T5, respectively ($P<0.05$ for all), and the incidence of pharyngolaryngeal discomfort after extubation was significantly reduced ($P=0.021$) in group P.

Conclusions Decreasing the pressure of endotracheal tube cuff slowly with a constant speed can significantly reduce the incidence of coughing during extubating period, stabilize hemodynamics, and reduce the incidence of adverse reactions.

Keywords Endotracheal tube, Cuff, Pressure, Coughing response, Hemodynamics, Extubation

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Introduction

Tracheal intubation is one of the most commonly used airway management methods in general anesthesia [1], which has the advantages of simple operation, high safety, and convenient management. However, extubation manipulation often cause significant systemic stress reaction manifested as varying degrees of cough, which may cause seriously increased blood pressure and heart rate (HR). The incidence of coughing during extubation has been estimated as ranging between 15 and 94% [2, 3]. Except for increased blood pressure and heart rate, adverse coughing may also augment intracranial pressure and intraocular pressure, even lead to bleeding from surgical wounds, cerebral hemorrhage, arrhythmia, and myocardial ischemia [4], especially detrimental to patients with related underlying diseases. Furthermore, cough itself may also further aggravate the airway reflex, leading to laryngospasm or bronchospasm [5]. Inhibition of coughing can effectively reduce the complications during extubation and reduce the risk of spreading of respiratory disease viruses, which cannot only provide optimal patient care but also protect the hospital staff [6].

In recent years, many interventions have been proposed to decrease the incidence of coughing, including intravenously injected opioids [7], lidocaine [8], and dexmedetomidine [9], intra-cuff administration of lidocaine [4], extubation under deep general anaesthesia [10], and extubation in prone position [11]. These measures have achieved certain effects, while may also bring a series of related side effects, such as local anesthetic toxicity, respiratory depression, delayed recovery time and extubation time, and residual sedation. Therefore, how to inhibit the cough reaction safely and effectively during extubation period is worth in-depth discussion.

The pressure in the tracheal tube cuff plays an important role in the occurrence of coughing during extubation [12]. The cuff is usually deflated rapidly at once using a syringe in clinical work, while this method can cause a sudden decrease in the pressure of the cuff and produce serious cough. Changing the deflation mode might alleviate the severity of coughing. Hence, this study was carried out to investigate whether decreasing the pressure of endotracheal tube slowly and at a constant speed could reduce the incidence of coughing and stabilize hemodynamics during extubation period in noncardiac surgery patients under general anesthesia.

Methods

Participants

This prospective, randomized, and double-blind controlled study was approved by the Institutional Research Ethics Committee of the Affiliated Hospital of Yangzhou University, Yangzhou, China (2022-YKL01-project 10) with registration at ClinicalTrials.gov (NCT05647395). All study participants provided written informed consent without any deviation from the principles of the Declaration of Helsinki. Patients who were scheduled to undergo noncardiac surgery under general anesthesia with a requirement for tracheal intubation were recruited between December 2022 and April 2023. The inclusion criteria were patients aged 18–80 years and had an American Society of Anesthesiologists (ASA) status I or II, with the general anesthesia duration less than 3 h. Patients with the following characteristics were excluded from the study: requiring surgery on the neck, larynx, or oropharynx; history of chronic respiratory disease; administration of cough medicine; presentation with signs of a difficult airway; endotracheal tube insertion time longer than 30 s; chronic coughing; increased risk of perioperative aspiration; recent respiratory tract infection; and severe heart, liver, or kidney diseases.

Treatment

Patients were double-blindly assigned into two groups, group P and group C, at a 1:1 ratio using a computer-generated random number table according to different ways to decrease cuff pressure at the time of extubation. In group P, the spring-loaded one way valve of the tracheal tube was connected to a syringe and an aneroid manometer (VBM Technology GmbH, Sulz, Germany) through a three-way stopcock, respectively. The air in cuff was extracted slowly at a constant speed with the manometer parameters indication to make the pressure in the cuff decreased by 3 cmH_2O/s before the endotracheal tube was removed. In group C, the pressure in the endotracheal tube cuff was decreased suddenly with a syringe extracting the air from the cuff rapidly at once exactly before extubation.

Anesthesia protocol

None of the patients received preoperative medication. After entering the operating theater, all patients were monitored routinely with noninvasive blood pressure measurement, electrocardiogram (ECG), and peripheral oxygen saturation (SpO_2) with multifunctional monitors (MP50; Philips, Boeblingen, Germany). For all patients, general anesthesia was induced with midazolam 0.05 mg/kg, propofol medium/long-chain triglyceride (MCT/LCT) emulsion 1.5–2 mg/kg, and sufentanil 0.2–0.4 μg/kg. Succinylcholine 1–1.5 mg/kg was given to facilitate tracheal intubation. An endotracheal tube (batch number: 20220914, Beijing Target Medical Technologies, Inc., Beijing, China) was inserted for mechanical ventilation after sufficient muscle relaxation. An endotracheal tube with an inner diameter of 6.5 mm or 7.0 mm for females and

7.0 mm or 7.5 mm for males was selected. The glidescope-directed technique was used to make the tube insertion finished within 30 s smoothly and successfully. After the endotracheal tube position was checked and confirmed, air was filled into the tube pilot balloon. The pressure in the balloon was set at 20–30 cmH_2O using an aneroid manometer. The ventilator parameters were set at tidal volume of 6–8 mL/kg, with a ventilation frequency of 12–14 times/min during mechanical ventilation. General anesthesia was maintained with propofol MCT/LCT emulsion 4–10 $mgkg^{-1}$ h^{-1}, remifentanil 0.05–0.2 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and sevoflurane with a minimum alveolar concentration of 1. The total dose of sufentanil was controlled at 0.4 μg/kg. Cisatracurium was injected intermittently to maintain moderate muscle relaxation. A Narcotrend anesthesia depth monitor (Monitor Technik, Germany) was used to monitor the depth of anesthesia, and the Narcotrend index values were controlled between 20 and 46. Muscle relaxation was monitored using a muscle relaxation monitor (Datex-Ohmeda S/5, ohmeda, Inc., USA). Sevoflurane was discontinued and cisatracurium was no longer supplemented approximately 30 min before surgery completion. Propofol and remifentanil infusion were stopped at the end of surgery. The doses of anesthetics were adjusted according to the changes of hemodynamics and the depth of anesthesia to ensure the fluctuations of mean arterial pressure (MAP) and heart rate (HR) maintained within ± 20% of the baseline values. If MAP was lower than 60 mmHg or decreased greater than 20% baseline, ephedrine or phenylephrine was used. Atropine was used when HR was slower than 50 beats/min or decreased greater than 20% baseline.

The pressure of the endotracheal tube cuff was measured every 10 min during surgery, maintained at 20–30 cmH_2O, and recorded after intubation and before extubation. The endotracheal tube would be removed when the patients' respiratory function had recovered and train-of-four (TOF) stimulation monitored T4/T1 recovered to 75%, and patients could follow verbal commands and demonstrate purposeful movement. In group P, the syringe and the aneroid manometer were connected with the spring-loaded one way valve through a three-way stopcock, respectively. The pressure in the endotracheal tube cuff was decreased slowly at a constant rate of 3 cmH_2O/s before the endotracheal tube was removed. In group C, the pressure in the endotracheal tube cuff was decreased suddenly with a syringe extracting the air from the cuff rapidly at once exactly before extubation. The tracheal tube cuff deflation and the extubation were manipulated by N L and H L who were not involved in the cough evaluation and data recording. All patients were transferred to the post-anesthesia care unit (PACU) after extubation for at least 30 min monitoring.

Recorded parameters

The incidence of cough during extubation period was evaluated and recorded by C C and B Y, who were unaware of the deflating methods. The severity of cough was graded using a four-category scale [13]: 0 = no cough; 1 = mild cough, only once, with no limb movement; 2 = moderate cough, at least twice, but lasted shorter than 5 s, with limb movement; and 3 = severe cough, lasted longer than 5 s, with head elevation, jaw stiffness, prolonged breath holding, uncontrolled limb movements, or cyanosis. Grades 2 and 3 were defined as coughing with clinical significance. The cough action resulted from suction in the mouth after extubation was not included.

Mean arterial pressure (MAP), HR, and SpO_2 were recorded before general anesthesia induction (T0), the moment just before the gas in the pilot balloon was extracted (T1), the moment just after the gas in the pilot balloon was extracted (T2), 1 min after extubation (T3), 3 min after extubation (T4), and 5 min after extubation (T5). Demographic data, including gender, age, weight, body mass index (BMI), and ASA classification, and intraoperative data including the doses of anesthetics, type of surgery, length of anesthesia, and the retaining time of endotracheal tube. Adverse reactions such as pharyngolaryngeal discomfort, including sore throat, dysphagia, and dysphonia, and hypoventilation (respiratory rate < 8 beats per min or SpO_2 < 95% with inhaling oxygen through mask) after endotracheal tube removal was recorded. All the data were recorded by a blinded anesthetist, who was unaware of the deflating methods (Fig. 1).

Statistical analysis

The necessary sample size was calculated using PASS 15.0 (NCSS LLC., USA). The incidence rate of coughing with clinical significance during extubating period was the main outcome indicator in this study. Based on our pilot study, the incidence rate was 65% in group C and 29% in group P. A two-sided test with $\alpha = 0.05$ and a test efficacy of 90% was performed to include at least 36 patients in each group. A minimum of 45 patients were recruited in each group considering 20% attrition rate to minimize the impact of missing data.

Statistical analysis was done using SPSS 23.0 (IBM Corporation, USA). Data with a normal distribution were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was used for comparisons between groups. Continuous data were compared between groups using Student's *t*-test. Welch's ANOVA was used for variance nonhomogeneity.

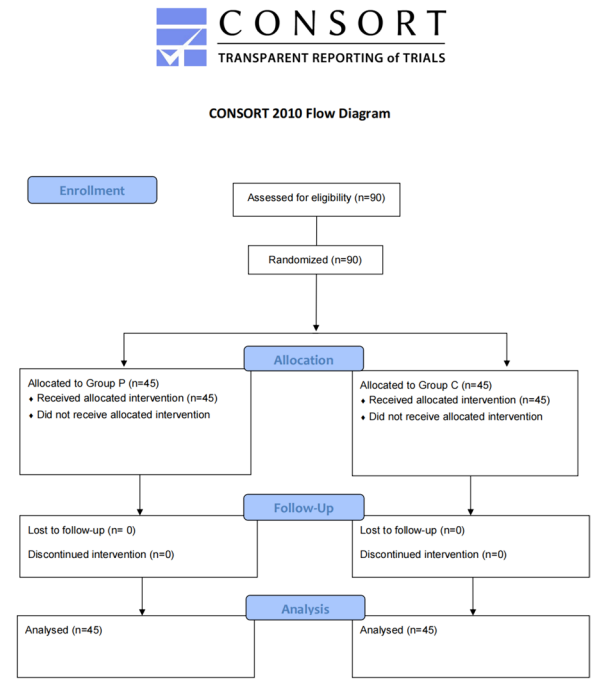

Fig. 1 CONSORT 2010 flow diagram

Non-normally distributed metric data were represented with M (P_{25}, P_{75}), and counting data were represented as example (%), which were compared using chi-square test or Fisher's exact test. *P* value of < 0.05 was considered statistically significant.

Results

A total of 90 patients were originally recruited and were included in the final analysis. No patients were eliminated from the study. There were no significant differences in the demographics in terms of gender ratio, age, BMI, ASA, doses of anesthetics, type of surgery, length of anesthesia, and the retaining time of endotracheal tube between the two groups ($P > 0.05$ for all, Table 1).

There were no significant differences in the pressure of the cuff either after intubation or before extubation between the two groups ($P = 0.217$; $P = 0.394$, respectively, Table 2).

It is worth noting that the initiation of coughing during extubation was the immediate time at the deflation of the endotracheal tube balloon in both groups. In group C, 19 patients were diagnosed with moderate cough, and 11 patients with severe cough. In group P, 12 patients developed moderate cough, and 2 patients developed severe cough. The incidence of coughing with clinical significance was significantly lower in group P than in group C (31.1% [14/45] vs. 66.7% [30/45]; $P = 0.001$).

Compared with group C, MAP was significantly decreased at T2 ($P = 0.001$), T3 ($P = 0.001$), and T4 ($P = 0.004$); HR was significantly decreased at T2 ($P = 0.019$), T3 ($P = 0.006$), T4 ($P = 0.002$), and T5 ($P = 0.022$) in group P. MAP was significantly higher at T2 ($P < 0.001$), T3 ($P < 0.001$), and T4 ($P = 0.001$) than T1 in group P, and significantly higher at T2 ($P < 0.001$), T3 ($P < 0.001$), T4 ($P < 0.001$), and T5 ($P < 0.001$) in group C. HR was significantly increased at T2-T5 in both groups, compared with T1 ($P < 0.001$ for all) (Table 3).

The incidence of pharyngolaryngeal discomfort after extubation was significantly decreased in group P

Table 1 Comparisons of demographics and clinical characteristics between the two groups

Group	Group P	Group C	*P*
Gender (M/F)	21/24	21/24	0.584
Age (y)	48.5 ± 10.9	47.4 ± 10.7	0.628
BMI (kg/m^2)	24.7 ± 2.5	24.3 ± 2.6	0.478
ASA (I/II)	21/24	23/22	0.833
Propofol dose for induction (mg/kg)	1.59 ± 0.23	1.60 ± 0.30	0.86
Propofol dose for maintenance (mg·kg^{-1}·h^{-1})	4.43 ± 0.31	4.34 ± 0.21	0.14
Remifentanil total dose (μg·kg^{-1}·min^{-1})	0.12 ± 0.02	0.13 ± 0.04	0.178
Cisatracurium total dose (mg/kg)	0.14 ± 0.05	0.14 ± 0.05	0.882
Time of sevoflurane inhalation (min)	38.9 ± 17.7	36.3 ± 13.5	0.440
Type of surgery (general surgery/orthopedics/urology)	22/12/11	21/12/12	0.967
Length of anesthesia (min)	70.5 ± 30.9	64 ± 23.7	0.288
Retaining time of endotracheal tube (min)	103 ± 31.3	92 ± 27.7	0.093

Data are expressed as mean ± SD or cases

Abbreviations: *BMI*, body mass index; *ASA*, American Society of Anesthesiologists physical status

P for between-group comparisons

Table 2 Comparisons of the pressure of the endotracheal tube cuff between the two groups

Group	Group P	Group C	*P*
Pressure in the cuff after intubation (cmH_2O)	26.0 ± 1.5	25.6 ± 1.5	0.217
Pressure in the cuff before extubation (cmH_2O)	26.0 ± 1.4	25.8 ± 1.2	0.394

Data are expressed as mean ± SD

P for between-group comparisons

than group C ($P=0.021$). No significant differences in hypoventilation after extubation occurred between the two groups ($P=0.459$, Table 4).

Discussion

Different deflation modes for endotracheal tube cuff may have different effects on coughing during extubation period. In this study, compared with decreasing the pressure in the endotracheal tube cuff suddenly with a syringe extracting the air from the cuff rapidly, the incidence of coughing during extubation was significantly decreased by deflating the pilot balloon slowly with a constant decreasing rate of 3 cmH_2O.

The tracheal tube with a cylindrical high-volume and low-pressure cuff is widely used in clinical work due to their large contact area with the tracheal wall, which reduces the pressure on the tracheal mucosa [14]. However, the cuff pressure is still an important factor of perioperative endotracheal intubation-related complications, which is often ignored by clinicians. Excessive cuff pressure with long persistence can increase not only the risk of ischemic necrosis of tracheal mucosa, but the incidence of coughing and pharyngolaryngeal discomfort [12]. The cuff pressure of 20–30 cmH_2O was applied in this study as was previously recommended to effectively seal the airway, prevent aspiration, and reduce the occurrence of complications [15]. Blood flow in the tracheal mucosa begins decreasing when the pressure in the cuff exceeds 30 cmH_2O and reduces markedly when the pressure reaches 40.8 cmH_2O [16].

Cough is a protective mechanism of the respiratory system induced by the unavoidable stimulation of the larynx, trachea, carina, or bronchi [17]. The exact mechanisms of the coughing response are unknown and may be caused by a variety of factors [18]. When the peripheral sensory nerve endings under the airway epithelium, which is widely distributed in the pharynx, larynx, and trachea mucosa, were triggered by a variety of stimuli, including mechanical and chemical irritation, information will be transmitted through the vagus nerve to a specific area within the brainstem [19]. The effector then receives the information, and coughing response will occur. One of

Table 3 Comparisons of MAP and HR at each point between the two groups

Group	Time point	Group P	Group C	*P*
MAP (mmHg)	T_0	99.02 ± 13.26	99.57 ± 11.52	0.832
	T_1	89.11 ± 12.52	87.86 ± 10.12	0.605
	T_2	98.96 ± 12.29	106.87 ± 9.62	0.001
	T_3	96.91 ± 11.59	105.24 ± 10.71	0.001
	T_4	95.04 ± 9.63	101.33 ± 10.30	0.004
	T_5	92.47 ± 9.09	95.27 ± 7.70	0.118
	$P_{T0\text{-}T1}$	< 0.001	< 0.001	
	$P_{T0\text{-}T2}$	> 0.999	0.010	
	$P_{T0\text{-}T3}$	0.994	0.077	
	$P_{T0\text{-}T4}$	0.634	> 0.999	
	$P_{T0\text{-}T5}$	0.028	0.438	
	$P_{T1\text{-}T2}$	< 0.001	< 0.001	
	$P_{T1\text{-}T3}$	< 0.001	< 0.001	
	$P_{T1\text{-}T4}$	0.001	< 0.001	
	$P_{T1\text{-}T5}$	0.413	< 0.001	
	$P_{T2\text{-}T3}$	0.095	0.367	
	$P_{T2\text{-}T4}$	0.018	< 0.001	
	$P_{T2\text{-}T5}$	< 0.001	< 0.001	
	$P_{T3\text{-}T4}$	0.673	0.004	
	$P_{T3\text{-}T5}$	0.010	< 0.001	
	$P_{T4\text{-}T5}$	0.050	< 0.001	
HR (beats/min)	T_0	75.98 ± 7.57	76.27 ± 10.45	0.881
	T_1	64.82 ± 9.58	66.04 ± 11.61	0.587
	T_2	80.29 ± 16.53	87.40 ± 11.06	0.019
	T_3	76.69 ± 14.24	84.36 ± 11.54	0.006
	T_4	72.67 ± 11.71	79.82 ± 9.74	0.002
	T_5	70.53 ± 11.34	76.07 ± 11.30	0.022
	$P_{T0\text{-}T1}$	< 0.001	< 0.001	
	$P_{T0\text{-}T2}$	0.399	< 0.001	
	$P_{T0\text{-}T3}$	> 0.999	0.001	
	$P_{T0\text{-}T4}$	0.476	0.361	
	$P_{T0\text{-}T5}$	0.014	> 0.999	
	$P_{T1\text{-}T2}$	< 0.001	< 0.001	
	$P_{T1\text{-}T3}$	< 0.001	< 0.001	
	$P_{T1\text{-}T4}$	< 0.001	< 0.001	
	$P_{T1\text{-}T5}$	0.005	< 0.001	
	$P_{T2\text{-}T3}$	0.009	0.050	
	$P_{T2\text{-}T4}$	< 0.001	< 0.001	
	$P_{T2\text{-}T5}$	< 0.001	< 0.001	
	$P_{T3\text{-}T4}$	0.002	< 0.001	
	$P_{T3\text{-}T5}$	< 0.001	< 0.001	
	$P_{T4\text{-}T5}$	0.320	0.002	

Data are expressed as mean ± SD

Abbreviations: *MAP*, mean arterial pressure; *HR*, heart rate; *T0*, before general anesthesia induction; *T1*, just before cuff deflation; *T2*, immediately after deflation; *T3*, at 1 min after extubation; *T4*, at 3 min after extubation; *T5*, at 5 min after extubation

Table 4 Occurrence of pharyngeal discomfort and hypoventilation in both groups [*n* = 45, cases (%)]

Group	Group P	Group C	*P*
Pharyngeal discomfort	3 (6.7)	12 (26.7)	0.021
Hypoventilation	3 (6.7)	5 (11.1)	0.459

Data are expressed as cases (%)

P for between-group comparisons

the important findings of our results is that the initiation of coughing during extubation period is at the immediate deflation of the endotracheal tube balloon rather than the immediate moment of extubation, which might be related to the initiation of the cuff pressure decrease. We also found that the incidence of coughing and the changes of hemodynamics were significantly decreased when the pilot balloon was deflated slowly at a constant decreasing rate of 3 cmH_2O before the endotracheal tube was removed using the manometer parameters indicator than when the pressure in the endotracheal tube cuff suddenly disappeared with a syringe extracting the air from the cuff rapidly at once exactly before extubation. One of the important mechanisms may be that the ischemic tracheal mucosa can restore blood supply slowly when the pressure of endotracheal tube cuff falls slowly and at a constant rate, which can relieve the ischemia–reperfusion injury and alleviate the extent of coughing. Moreover, extracting the gas in endotracheal tube cuff slowly and at a constant rate may increase the adaptation of the tracheal mucosa to the change of the pressure in the cuff, decrease the fluctuation of sympathetic and parasympathetic nervous systems, and reduce the reaction of respiratory tract during the period when the endotracheal tube cuff pressure changes. In Wang et al.'s study [20], they found that deflating the tracheal tube cuff continuously and slowly until the pressure reached zero in 5 s using a cuff pressure gauge or using a 10-mL syringe at 1 mL/s could reduce the incidence and severity of cough reflex during extubation. However, they proposed that deflating with the cuff pressure gauge could increase the incidence of postoperative hoarseness.

This study has some limitations to consider. First, this study excluded patients requiring surgery to the neck, larynx, or oropharynx, which could affect the nerves of trachea directly or indirectly and increase the incidence of adverse effects such as coughing, hoarseness, and pharyngeal discomfort. Second, the patients who underwent general anesthesia duration more than 3 h were excluded. The retaining time of endotracheal tube was an important factor of intubation-related complications [21]. Effects of different deflation modes for endotracheal tube cuff on coughing and hemodynamics in patients undergoing prolonged surgery need further study. Finally, no histological study or fiberoptic bronchoscopy was performed to confirm the severity of tracheal mucosal injuries. The pathophysiology of coughing during extubation period deserves further research.

Conclusions

To conclude, decreasing the pressure of endotracheal tube cuff slowly with a constant speed can decrease the incidence of coughing, reduce postoperative complications associated with extubation, and stabilize hemodynamics.

Authors' contributions

Yanlong Yu and Zhuan Zhang conceived and designed the research; Yanlong Yu, Hu Li, Ning Li, and Chao Chen collected data and conducted the research; Xinqi Zhang, Bo Yuan, and Hao Wu analyzed and interpreted the data; Yanlong Yu, Hu Li, and Ning Li wrote the initial draft; Zhuan Zhang and Hao Wu revised the manuscript; Yanlong Yu and Zhuan Zhang had primary responsibility for final content. All authors read and approved the final version of the manuscript.

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Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Research Ethics Committee of the Affiliated Hospital of Yangzhou University, Yangzhou, China (2022-YKL01-project 10) with registration at ClinicalTrials.gov (NCT05647395).

Consent to participate

All study participants provided written informed consent without any deviation.

Consent for publication

Patients signed informed consent regarding publishing their data and photographs.

Competing interests

The authors declare no competing interests.

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