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Original Article

Effects on hemodynamics of SEEK^{flex}-guided intubation for cervical spine surgery

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Abstract: Objectives: To evaluate the hemodynamic effects of Safe Easy Endotracheal Kit-flexible (SEEK^{flex})-guided intubation in patients undergoing cervical spine surgery. Methods: The post hoc analysis was based on a completed randomized controlled trial (RCT) comparing SEEK^{flex} versus stylet-assisted intubation under videolaryngoscopy. Hemodynamic parameters were recorded at baseline (T0), pre-induction (T1), pre-intubation (T2), and 1 min post-intubation (T3). Results: A total of 128 patients was enrolled in the post hoc analysis. One minute after intubation, systolic blood pressure (SBP) in the SEEK^{flex} group was 10.9 mmHg lower than that in the stylet group (124.8 mmHg vs. 135.7 mmHg, $P = 0.007$). Patients in the SEEK^{flex} group exhibited a significantly smaller increase in SBP (12.7 mmHg vs. 28.2 mmHg, $P < 0.001$), and the proportion of patients in the SEEK^{flex} group experiencing a greater than 30% increase in SBP was significantly lower in the SEEKflex group than in the stylet group (20.6% vs. 40.0%, $P = 0.017$). Conclusions: SEEK^{flex} significantly reduced hemodynamic fluctuations during intubation in cervical spine surgery.

Keywords: Intubation, safe easy endotracheal kit-flexible, cervical spine surgery, airway management

Introduction

Tracheal intubation in patients with cervical spine instability requires special attention to prevent excessive cervical motion, which may cause secondary nerve injury [1]. To minimize the risk of spinal nerve injury during intubation, anesthesiologists cannot maintain the patient in the "sniffing position" as they would for regular patients [2, 3]. Under traditional intubation methods such as Lightwand intubation, excessive hemodynamic responses occur due to the force applied by the laryngoscope blade to visualize the glottis opening and the mechanical stimulation of the peripheral tissues of the epiglottis by the tip of the tracheal tube before entering the glottis [4, 5]. These hemodynamic responses are manifested as increased heart rate, arterial blood pressure, and arrhythmias, which can lead to harmful cardiovascular and neurological effects, especially in vulnerable patients such as those with ischemic heart disease and cerebrovascular disease [6]. Various interventions have been attempted to obtund these hemodynamic response [7, 8]. Limited head and upper neck extension further exacerbates the problem because it limits the alignment of the three airway axes and amplifies stimulation of the tissue around the epiglottis during intubation [9]. Awake tracheal intubation with flexible bronchoscopy has been the favored approach, but its high cost makes large-scale implementation difficult [10]. Current medical practices and guidelines also promote the use of videolaryngoscopy for patients with unstable cervical spine conditions [11, 12].

Bougie has been accepted in guidelines as one of the tools for difficult airway management because of its flexible application scenarios

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and low cost [13]. Studies have shown that bougie-guided intubation improves first-attempt success rates and reduces complication rates [14-16]. Safe Easy Endotracheal Kit-flexible (SEEK^{flex}) is a novel bougie-like introducer developed by our team for the safe and easy management of difficult airways. Unlike conventional bougies, which are solid stylets that merely guide the tube, SEEK^{flex} integrates a removable inner stylet with an independent outer PVC sheath. The device has been registered as a medical device product in China (Approval No. 20232081322, Zhejiang). Several clinical studies have confirmed its performance in managing potentially difficult airways [17, 18]. Therefore, based on an ongoing study, we analyzed the hemodynamic responses in patients undergoing cervical spine surgery during tracheal intubation under SEEK^{flex} guidance compared with those under stylet guidance.

Methods

Study design and ethics statement

From February 2025 to September 2025, a randomized controlled trial (RCT) was conducted at Shanghai Changhai Hospital, enrolling patients with cervical immobilization undergoing elective surgery. The study was approved by Shanghai Changhai Hospital Medical Ethics Committee (No. CHEC2025-003).

The trial was registered prior to patient enrollment at the Chinese Clinical Trial Registry (ChiCTR2500097045; principal investigator: Ruifang Sheng; date of registration: 2025.02.11; https://www.chictr.org.cn/). All patients provided written informed consent at enrollment for the primary trial, including permission for secondary analysis of de-identified data.

Randomization

The initial RCT utilized a random number method for group allocation. Random numbers exceeding the required sample size were generated using software managed by statistical experts. Based on the participant enrollment order, researchers were required to sequentially select the appropriate intubation method (stylet- or SEEK^{flex}-guided intubation) after randomization, without skipping numbers. The trial protocol number was concealed before enrollment and stayed consistent throughout the subsequent trial stages.

This sub-analysis excluded patients enrolled for reasons other than cervical spine disorders, as well as those with incomplete hemodynamic parameter records during the study. The patient grouping was consistent with that of the original RCT, and the data analysts were unaware of the specific group assignments. Owing to the distinct physical designs of SEEK^{flex} and the stylet, blinding of the intubation operator was not feasible; however, outcome assessors and data analysts were blinded to group allocation.

Intervention

All patients were categorized into two groups: one undergoing endotracheal intubation guided by SEEK^{flex} and the other undergoing stylet-assisted intubation. Vocal cords were visualized using videolaryngoscopy in both groups. As a technique validated in multicenter randomized controlled clinical trials focusing on endotracheal intubation, the “eight-step” approach of SEEK^{flex}-guided intubation has been described in a previous study and can be specifically divided into the following steps: insert the laryngoscope and expose glottis; mold SEEK^{flex} and insert it into the mouth; push the outer PVC catheter of SEEK^{flex} into the trachea; fasten SEEK^{flex} in an appropriate depth; pull out the inner stiffening stylet of SEEK^{flex} and fix it at an appropriate length; insert the catheter along SEEK^{flex}; advance endotracheal tube and adjust its depth; and remove SEEK^{flex} and secure the catheter [19]. In stylet group, the anesthesiologist directly inserted the curved endotracheal tube into the glottis and advanced it to an appropriate depth. For both groups, the insertion depth was set at 23 cm for males and 22 cm for females.

All patients were preoxygenated with 100% oxygen for 3 min before induction of anesthesia and were induced by the same anesthesiologist according to the same protocol. Male patients received a tracheal tube with a diameter of 7.5 mm, whereas female patients were given a tracheal tube with a diameter of 7.0 mm.

Outcomes

Data on age, sex, ASA physical status, body mass index (BMI), and airway characteristics

were collected preoperatively. Peripheral oxygen saturation (SpO_2), heart rate (HR), and blood pressure (BP) were recorded at predetermined time points for all enrolled patients: resting quietly in the room for 5 min (T0), before anesthesia induction (T1), before tracheal intubation (T2), and 1 min after tracheal intubation (T3). Data at 3 min and 5 min after intubation were not collected in the original trial protocol, because the peak hemodynamic response to intubation typically occurs within 1 minute.

Sample size and statistical analysis

This study was a post hoc analysis of the original RCT. The sample size of the original RCT was calculated based on the primary endpoint of the first-attempt intubation success, and a total of 358 patients were included. This post hoc analysis maintained the two-group independent sample design, in line with the original RCT design, although the outcomes was modified. The primary endpoint was altered to the proportion of patients presenting an abnormal elevation in SBP (>30%) during intubation. It was hypothesized that the proportion in the control group would be 35%, whereas the trial group would reduce this proportion to 10%. With α set at 0.05 and β at 0.1, each group required 47 patients, which is fewer than the total number of patients ultimately recruited in this study.

Categorical data were presented as numbers and intergroup comparisons were performed using the Chi-square test. Quantitative data were presented as mean ± standard deviation or median and interquartile range. Intergroup comparison of normally distributed continuous data was performed using Student's t-test, whereas the Mann-Whitney U-test was used for non-normally distributed data. $P < 0.05$ was considered statistically significant. Repeated measurements were rectified via Bonferroni method; thus the significance threshold for comparison of hemodynamic parameters at T0-T3 was established at $P < 0.013$. SPSS version 25 statistical software (IBM Corp., Armonk, NY, USA) was used for analysis.

Results

After excluding patients who underwent non-cervical spine surgery and those with incomplete hemodynamic data, a total of 128 patients were enrolled. The baseline characteristics and airway assessment parameters were comparable between the two groups, as shown in **Table 1**.

Following a five-minute rest in the supine position in the operating room, no statistically significant differences in HR and BP were observed between the two groups. No significant differences were found either before induction or intubation. One minute after intubation, the systolic blood pressure (SBP) in the SEEK^{flex} group was 10.9 mmHg lower than that in the stylet group (124.8 mmHg vs. 135.7 mmHg, $P = 0.007$). By subtracting the hemodynamic indicators at T2 from those at T3, the increases in these parameters during intubation were quantified. The findings indicated that patients in the SEEK^{flex} group experienced a significantly smaller elevation in SBP (12.7 vs. 28.2 mmHg, $P < 0.001$) compared with patients in the stylet group. Furthermore, we compared the number of cases where HR and SBP showed significant increases at T3 compared to T2 in both groups. The results showed that the proportion of patients in the SEEK^{flex} group with a >30% increase in SBP was significantly lower (20.6% vs. 40.0%, $P = 0.017$) than that in the stylet group. Notably, in comparison to the SEEK^{flex} group, the stylet group also demonstrated a tendency toward a higher proportion of abnormal HR elevation, though the difference was not statistically significant (27.0% vs. 43.1%, $P = 0.057$). No episodes of severe hypertension (SBP > 180 mmHg), arrhythmia, or other severe adverse events were observed in either group during the intubation period. The hemodynamic indicators for each group are shown in **Table 2**.

All patients achieved successful intubation within three attempts. There was no significant difference in the distribution of intubation attempts between the two groups. The SEEK^{flex} group required a slightly longer intubation time (25 s vs. 22 s, $P = 0.001$) than the stylet group. The SEEK^{flex} group demonstrated a marginally higher first-pass intubation success rate than the stylet group. Twenty-four hours after intubation, sore throat, hoarseness, and tooth damage were self-rated and recorded in the ward. The occurrence of hoarseness in the SEEK^{flex} group was lower than that in the stylet group,

Table 1. Baseline characteristics of included patients allocated

	SEEK^{flex} (n = 63)	stylet (n = 65)
Age, y	57.3±10.0	55.9±12.7
Sex, male	37 (58.7%)	38 (58.5%)
Height, cm	164.6±7.2	165.4±8.2
Weight, kg	67.4±10.7	70.0±13.1
BMI, kg.m^{-2}	24.8±3.2	25.4±3.0
BMI, > 26	21 (33.3%)	23 (35.4%)
ASA classification, III	1 (1.6%)	1 (1.5%)
Mouth opening, < 40 mm	22 (34.9%)	13 (20.0%)
Thyromental distance, < 60 mm	34 (54.0%)	27 (41.5%)
Mallampati class, 3/4	34 (54.0%)	34 (52.3%)
Cormack-lehane score, 3/4	12 (19.0%)	9 (13.8%)
Upper lip bite test, level 3/4	6 (9.5%)	9 (13.8%)
Intubation operator, resident	39 (61.9%)	38 (58.5%)
Comorbidities		
Hypertension	28 (44.4%)	24 (36.9%)
Coronary heart disease, myocardial infarction	4 (6.3%)	5 (7.7%)
Diabetes	10 (15.9%)	6 (9.2%)
Asthma	1 (1.6%)	0
Stroke	1 (1.6%)	1 (1.5%)

There were no statistically significant differences between groups (all P > 0.05). Values are expressed as mean ± SD or number (proportion). ASA: American Society of Anesthesiologists; BMI: Body Mass Index.

but no statistically significant difference was observed. The two groups had similar rates of sore throat. One case of loose or lost teeth occurred in the stylet group. The intubation profiles and postoperative complications are shown in **Table 3**.

Discussion

SEEK^{flex}-guided intubation represents a novel technique for tracheal intubation. This study utilized SEEK^{flex} to guide tracheal intubation in patients undergoing cervical spine surgery. The findings indicated that patients undergoing SEEK^{flex}-guided intubation experienced a smaller elevation in blood pressure during intubation compared with patients using traditional intubation methods, which is consistent with the conclusions of relevant studies that new intubation tools can reduce the hemodynamic impact of intubation [19]. SEEK^{flex} also has the potential to increase the first-pass success rate of intubation, similar to the performance of other advanced intubation techniques that have achieved first-pass success rates of up to 96.7% or even 100% in clinical trials, and to decrease the occurrence of intubation-associated complications. However, no statistically significant differences were observed, possibly due to the limited sample size.

The study confirmed that SEEK^{flex}-guided intubation significantly reduced the incidence of elevated blood pressure compared with traditional intubation. Endotracheal intubation is a noxious stimulus that can cause adverse physiological responses involving systems such as the cardiovascular and respiratory systems [20-22]. The primary trigger for cardiovascular responses such as elevated blood pressure is direct stimulation of the vocal cords or trachea [23-25]. Conventional intubation methods frequently induce severe pharyngeal irritation, especially in patients with cervical immobilization, as their heads cannot be tilted posteriorly to improve glottic visibility [26, 27]. Reducing blood pressure elevation during intubation has important clinical significance. Relevant clinical studies have shown that patients' blood pressure peaks 1 to 2 min after intubation and then gradually return to the pre-intubation level [28]. For patients with hypertension or heart disease, blood pressure elevation caused by intubation may lead to an imbalance between

Table 2. Hemodynamic indicators of included patients allocated

	SEEK^{flex} (n = 63)	stylet (n = 65)	*p*
T0 HR, min^{-1}	76.5±10.4	77.5±12.9	0.623
T0 BP, mmHg			
SBP	138.1±19.9	137.3±19.0	0.826
DBP	82.3±10.7	81.9±12.2	0.877
MAP	98.4±12.9	97.4±12.7	0.665
T1 HR, min^{-1}	76.4±10.7	77.7±12.8	0.516
T1 BP, mmHg			
SBP	134.8±21.7	131.2±18.4	0.311
DBP	79.8±10.4	78.5±12.3	0.504
MAP	94.8±11.9	92.0±12.8	0.212
T2 HR, min^{-1}	70.4±10.4	71.2±12.7	0.685
T2 BP, mmHg			
SBP	112.1±13.6	107.5±14.6	0.069
DBP	70.3±12.4	68.4±12.1	0.592
MAP	81.3±11.5	78.5±12.0	0.177
T3 HR, min^{-1}	79.1±12.8	81.7±15.0	0.305
T3 BP, mmHg			
SBP	124.8±22.4	135.7±23.0	0.007
DBP	82.5±13.6	83.5±16.8	0.725
MAP	95.7±15.5	93.6±17.6	0.470
ΔHR*, min^{-1}	8.7±11.4	10.5±13.5	0.440
ΔBP*, mmHg			
SBP	12.7±23.0	28.2±21.4	< 0.001
DBP	12.2±16.5	14.3±14.6	0.439
MAP	14.4±16.5	15.1±15.3	0.805
HR elevation > 20% or T3 HR > 100 min^{-1}	17 (27.0%)	28 (43.1%)	0.057
SBP elevation > 30%	13 (20.6%)	26 (40.0%)	0.017

*ΔHR or ΔBP is calculated as the value at T3 minus that at T2. Values are expressed as mean ± SD or number (proportion).
SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MAP: Mean Arterial Pressure; HR: Heart Rate.

Table 3. Intubation profiles and postoperative complications in included patients allocated

	SEEK^{flex} (n = 63)	stylet (n = 65)	*p*
Intubation time, s	25 [14]	22 [12.5]	0.001
Number of intubation attempts			0.111
1	61 (96.8%)	57 (87.7%)	
2	2 (3.2%)	8 (12.3%)	
3	0	0	
Failed intubation, > 3 attempts	0	0	> 0.999
Hoarseness, 24 h after intubation	11 (17.5%)	20 (30.8%)	0.082
Sore throat, 24 h after intubation	17 (27.0%)	18 (27.7%)	0.920
Tooth damage	0	1 (1.5%)	> 0.999

Values are expressed as median [interquartile range] or number (proportion).

myocardial oxygen supply and demand, and even induce serious cardiovascular and cerebrovascular events such as cerebral hemorrhage and myocardial infarction.

The hemodynamic advantage of SEEK^{flex} can be attributed to its unique design: (1) the moldable inner stiffening stylet allows precise navigation toward the glottis without forceful

laryngoscope lifting; and (2) the flexible outer PVC sheath can be pre-inserted into the trachea independently, acting as a railroad track for the endotracheal tube [19]. This design eliminates the need for repeated manipulation of the tube tip against the epiglottis and vocal cords, thereby reducing direct mechanical stimulation. Our findings align with previous studies demonstrating that devices reducing tissue contact attenuate hemodynamic responses. For example, Hoshijima et al. reported that Airtraq® reduced hemodynamic responses compared with Macintosh laryngoscopy by minimizing epiglottic manipulation [29]. Similarly, bougie-guided intubation has been shown to improve first-pass success in difficult airways [30]. However, SEEK^{flex} advances this concept by decoupling the guidance function from the tube itself through the outer sheath, potentially offering greater protection than solid bougies. The reduction in SBP elevation observed in our study (15 mmHg lower than that in the stylet group) is comparable to or greater than the hemodynamic benefits reported for videolaryngoscopes in patients with cervical immobilization [5, 31].

Dental injuries are a major source of anesthesia-related complaints [32-34]. The study found no tooth damage in the SEEK^{flex} group, likely due to its unique design. The enhanced visibility and reduced force requirements during SEEK^{flex}-guided intubation may explain why no dental injuries were observed in this study. The incidence of sore throat was comparable between the SEEK^{flex} group and the stylet group 24 h post-intubation. The incidence of hoarseness was lower in the SEEK^{flex} group, but the difference was not statistically significant. This phenomenon might be attributed to the slim profile of SEEK^{flex}, which reduces friction with surrounding tissues during intubation. The exact etiology of hoarseness and sore throat remains unclear, and may involve secondary factors such as mucosal irritation or inflammatory reactions [35, 36]. SEEK^{flex}-guided intubation minimizes tracheal tube rotation during passage through the epiglottis and glottis by pre-inserting the outer PVC catheter of SEEK^{flex} into the trachea, thereby preventing damage caused by repeated friction. However, given the post hoc nature and the low incidence of complications such as hoarseness (~20%) and dental injury (<2%), the available sample size (n = 128) was underpowered to detect statistically significant differences in these rare secondary endpoints. Given that the SEEK intubation procedure involves an additional step compared with stylet insertion, the intubation time was slightly prolonged; however, the increase was only about 10%, which is less than the time extension observed in previous bougie studies [37-39].

However, this study has several limitations. Firstly, owing to the design differences between SEEK^{flex} and the stylet, the intubation operator could not be blinded, which may have introduced bias into the intubation outcomes. Secondly, real-time invasive arterial monitoring was not performed in this study. Instead, heart rate and blood pressure were measured using a cuff. Consequently, the hemodynamic measurements in the study were not sufficiently accurate. Thirdly, follow-up was only conducted 24 h postoperatively, during which patients self-evaluated the severity of throat pain and hoarseness. Future studies should establish more objective assessment criteria to further explore the influence of SEEK^{flex} on the incidence of throat pain and hoarseness. Finally, and most importantly, this study was a post hoc analysis of a prospective randomized controlled trial. The reliability of the outcomes may have been affected by selection bias and potential confounding variables.

Conclusions

This study highlights the advantages of SEEK^{flex}-guided intubation in adult patients scheduled for cervical spine surgery. SEEK^{flex} significantly reduced hemodynamic fluctuations during intubation compared with traditional intubation methods. SEEK^{flex}-guided intubation is an innovative method that enhances the safety of endotracheal intubation.

Disclosure of conflict of interest

None.

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