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A comparison of the king vision® and glidescope® video intubation systems in patients at risk for difficult intubation

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A B S T R A C T

Background: One factor that contributes to the difficulty during intubation is poor visualization of the airway anatomy during laryngoscopy.
Aim: To compare the efficacy and first-pass success rate of the King Vision® Video Laryngoscopes against the GlideScope® Video Laryngoscope in patients with anticipated difficult airways.
Methods: 225 adult patients scheduled for surgery requiring general anesthesia and tracheal intubation that met ≥2 of the following inclusion criteria: Mallampati classification (MP) III-IV, inter-incisor distance < 4 cm, neck circumference > 43 cm, and/or thyromental distance < 6 cm were randomized into 3 groups: GlideScope® (GS; n = 75), King Vision® – Channeled (KV-Ch; n = 75), and King Vision® – Non-Channeled (KV-NCh; n = 75). Intubation time and number of intubation attempts were collectively considered as the primary objective, amongst resident anesthesiologists.
Results: The rate of success of tracheal intubation was 96% for GS, 81.3% for KV-Ch, and 96% for KV-NCh. Furthermore, first-pass success was highest for the KV-NCh at 89.3%, with GS and KV-Ch having a significant difference ($P = 0.0083$).
Conclusion: The GS and KV-NCh performed similarly in facilitating successful tracheal intubation during the first attempt. In contrast, the KV-Ch was less successful overall.

1. Introduction

Since the introduction of the laryngoscope into clinical anesthesia practice, attempts have been made to improve, and even perfect, the design of the laryngoscope blade [1–20]. These innovations were primarily based on the concept of improved visualization of laryngeal structures and increasing the likelihood of successful tracheal intubation. When compared to direct laryngoscopy, video-assisted laryngoscopy (VAL), also known as indirect laryngoscopy, has been demonstrated to provide superior glottic visualization in both normal and difficult intubation scenarios [1–4]. Although the view of peri-laryngeal anatomy may be superior with VAL, successful delivery of the endotracheal tube (ETT) through the glottic opening and advancement into the trachea can be difficult. One factor that contributes to the difficulty during intubation is poor visualization of the airway anatomy during laryngoscopy. There is a fairly uniform reporting of the incidence of failed intubation in recent literature. Failed intubation occurs in approximately 0.05% or 1:2230 of surgical patients and in approximately 0.13%–0.35%, or 1:750 to 1:280 of obstetric patients [5,6].

There are several advantages when utilizing a VAL technique,

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whenever tracheal intubation is required. One advantage is an overall improvement in the safety of the airway procedure, and another is an increased successful intubation rate by allowing tracheal intubation monitoring [7]. The manner in which these airway devices achieve laryngeal visualization can ultimately affect how an ETT is delivered through the glottis. Nonetheless, traditional malleable stylets can be used in creating a shape that matches the curvature of a preferred laryngoscope blade and can be used to facilitate ETT insertion during VAL as well. It should be noted that several reports have been published describing trauma to the upper airway (anterior tonsillar pillar, soft palate) during intubation with video laryngoscopes [8–13]. This risk underscores the importance of maintaining direct visual contact, as both the laryngoscope blade and the ETT are initially inserted into the oropharynx and past the uvula.

The purpose of this three-arm study was to compare the efficacy and first-pass success rate of the King Vision® Video Intubation System (KVVIS) to the GS in patients with anticipated difficult airways. We hypothesized that the King Vision® Channeled Video Laryngoscope (KV-Ch) is more efficacious in terms of successful tracheal intubation in comparison to the GS. It was further hypothesized that the King Vision® Video Laryngoscope with Standard Blade (Non-Channeled; KV-NCh) is equivalent to the GS regarding successful tracheal intubation, as well.

2. Materials and methods

This study was reviewed and approved by the Institutional Review Board (IRB) at the University of Texas Health Science Center at Houston (UTHealth) McGovern Medical School (Houston, TX, USA) and was registered on ClinicalTrials.gov (NCT03685968). Written informed consent was obtained from 225 surgical patients, scheduled for an elective surgical procedure necessitating the use of general anesthesia and tracheal intubation. Patients enrolled in the study were required to meet at least 2 out of 4 preselected identifiable markers of potentially difficult laryngoscopy prior to enrollment. The study was designed as a single-blinded, three-arm, randomized controlled trial comparing the GS (Group 1; n = 75), KV-NCh (Group 2; n = 75) and KV-Ch (Group 3; n = 75) for use of tracheal intubation amongst resident anesthesiologists.

2.1. Patient selection

Patients were enrolled from the adult surgical operating rooms of 2 academic hospitals, Lyndon Baines Johnson General Hospital and Memorial Hermann Hospital — Texas Medical Center, in Houston, TX from August 2013 to December 2015. Patients were included in the study if they met at least 2 of the following difficult airway factors: Mallampati classification III or IV, inter-incisor distance <4 cm, neck circumference >43 cm, and/or a thyromental distance $\leq$ 6 cm. In addition to, each patient's age, gender, weight, height, and body mass index (BMI) being recorded as well.

Patients were excluded from the study if any of the following criteria was met: documented easy tracheal intubation under direct laryngoscopy (without aid or use of a bougie), a history of failed tracheal intubation or failed bask-mag ventilation, known unstable cervical spine injury, age < 18yo, ASA IV, and/or presentation for an emergency surgical procedure (Fig. 1.).

2.2. Anesthetic management

After application of standard ASA monitors, baseline vital sign measurements were recorded and all patients were pre-oxygenated with 100% oxygen for approximately 5 min. General anesthesia was induced by a bolus administration of propofol (2 mg/kg) and fentanyl (1mcg/kg). A muscle relaxant was administered after adequate bag mask ventilation was confirmed. Patient's lungs were ventilated with 100% oxygen via facemask until full paralysis was achieved (0 twitches on train-of-four twitch monitor). The resident then performed laryngoscopy and attempted to intubate with the randomized video laryngoscope, which was provided by a computer-generated block randomization from the study coordinator. If assistance in improving laryngeal exposure was necessary, external laryngeal manipulation was performed. Residents were only allowed 2 attempts for laryngoscopy and intubation. If > 2 attempts were required, the attending anesthesiologist performed the third laryngoscopy attempt with the same randomized video laryngoscope. If intubation remained unsuccessful after the third attempt, the attending anesthesiologist used an alternative method/device for tracheal intubation and the study procedure was deemed a *failure*. A standard polyvinylchloride ETT was used for each intubation with an ETT inner diameter of 7.0 mm and 8.0 mm, for female and male patients, respectively.

2.3. Airway devices and accessories

King Vision®Video Laryngoscope (King Systems Inc., Noblesville, Indiana, USA) - The King Vision® Video Laryngoscope is a video-based system, created for tracheal intubation, that utilizes a video camera embedded into the disposable blade and a portable, reusable display (Fig. 2.). Similar to the GS, this is a hyper-angulated blade that does not promote direct visualization of glottis structures. The resulting video image is displayed on a small, color, anti-fog coated, organic light emitting diode (OLED) display attached atop the grip handle of the laryngoscope. The unit is powered with 3 AAA batteries and is only available in one adult size for both blades. The vertical profile, or blade thickness, of the KV-Ch is 18 mm and 13 mm for the KV-NCh. This study utilized both blade profiles.

GlideScope®Advance Video Laryngoscope (AVL) Single-Use (Verathon Inc., Bothell, Washington, USA) - The AVL model is a newer version of the original GlideScope®. It has a hyper-curved blade, which does not allow a direct view of laryngeal structures, along with a vertical profile of 18 mm. There is a video camera with a light-emitting diode, housed toward the distal end of the blade. The attached cable transfers the image captured by the camera to a color liquid crystal display (LCD), which is located on a freestanding monitor that plugs in to an electrical output source (Fig. 3.). The GS features a reusable internal video baton for placement within disposable blades. A stylet is recommended with its use to facilitate tracheal tube passage. Either a regular (e.g., Satin-Slip) stylet, or the dedicated GlideRite Stylet®, designed to mock the shape/curvature of the GS blade, can be used effectively during intubation [14].

GlideRite Stylet® - The GlideRite (Rigid) Stylet® is a stainless-steel stylet designed for use in a $\geq$ 6 mm ETT. The angle of the GlideRite rigid stylet® itself, complements the unique blade angle of the GlideScope®, which eliminates the need to manually shape the stylet, improves maneuverability, and help facilitate ETT placement. In this study, the GlideRite rigid stylet® was used for both, the GS and the KV-NCh.

All investigators in the study were trained on how to properly utilize all 3-airway devices, based on manufacturer recommendations prior to patient enrollment. Also, each resident performed at least 3 intubations (on non-enrolled patients) with each video laryngoscope prior to their participation in the study. A size 3 KV-NCh and KV-Ch blade was used, and either a size 3, or 4, GS blade was utilized in this study.

2.4. Outcome measures

The primary objective measures in this study were first-pass

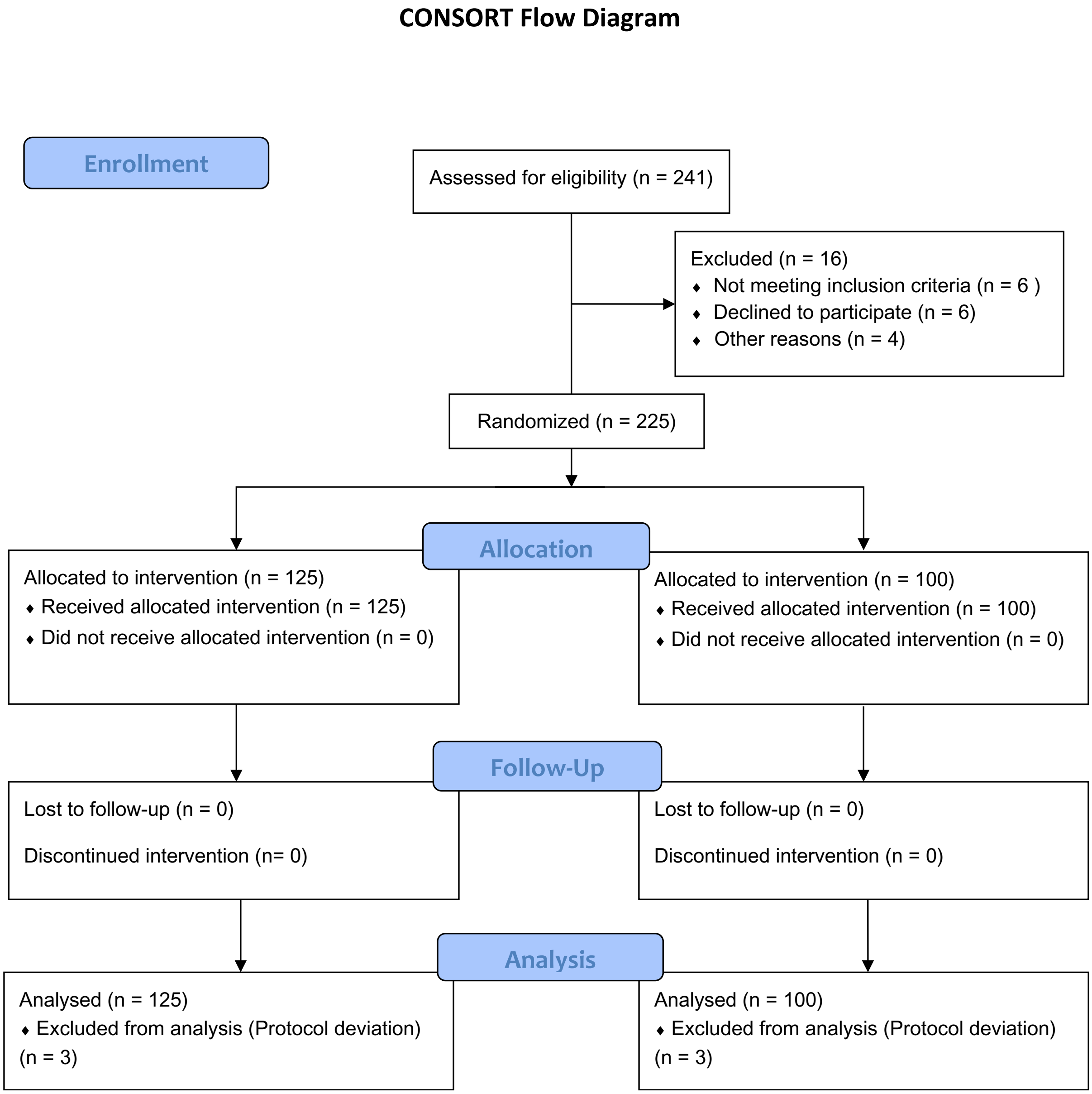

Fig. 1. CONSORT patient enrollment flow diagram of the trial.

Fig. 2. King Vision® video laryngoscopes; (Left – channeled; Middle – non-channeled (standard); Right – display).

intubation success rate and intubation time (in seconds; s), once the video laryngoscope blade entered the oropharynx (passed the lips) until successful intubation. A successful intubation was defined by persistent end-tidal carbon dioxide waveform on capnography. An attempt was defined as introduction of the video laryngoscope into the oropharynx. If the device was withdrawn from the oropharynx, for whatever reason, regardless of the elapsed time required, and either the same or a new provider attempted intubation, this was defined as a 'new attempt'. Time was recorded from placement of the video laryngoscope into the oropharynx and continued until 3 capnograph breaths were obtained following intubation by the study coordinator.

A multitude of secondary outcomes were recorded and analyzed, which consisted of adequate visualization of the vocal cords, as defined by the modified Cormack-Lehane (C-L) classification scale, [15] as well as elapsed time during both laryngoscopy and intubation, respectively. The use of external laryngeal manipulation, the use of a bougie, and the use of alternative (rescue)

Fig. 3. The Glidescope Advanced Video Laryngoscope (AVL; left) and freestanding LCD monitor (right).

intubating methods (i.e. direct laryngoscopy, flexible intubation scope) were recorded. Following intubation, each respective study laryngoscopist was required to complete a subjective questionnaire — assessing their level of difficulty during laryngoscopy (with the randomized video laryngoscope), ETT placement, and device usage. The laryngeal view at the time of ETT passage was also recorded on a scale of no view, partial view, or complete (full) view. Also, an inspection of the oropharynx, pharynx, epiglottis, and arytenoids was performed to determine if there was any trauma during the intubation procedure, including minor irritation, abrasions, bleeding or perforations. Research personnel conducted a pre- and post-operative evaluation of every patient to assess for any study related airway conditions.

2.5. Statistical analysis

A power analysis was performed during the study design to determine the appropriate sample size. In order to achieve a power of 0.80 at a significance level of 0.05, it was determined that a total of 71 patients per group would be required. In this study, a total of 75 patients were enrolled in each group. The comparisons of demographics between the KV-Ch vs the GS and KV-NCh vs GS were conducted by two-sample *t*-test for continuous variables and by Chi-square test for categorical variables. The Wilcoxon rank sum test was used to compare the intubation time for the final attempt between the KV-Ch vs GS and KV-NCh vs GS and the Fisher's exact test was applied to compare the number of attempts and final C-L grade views between groups. The frequency and percentage of adverse events were also summarized for each group. All statistical analyses were performed using SAS 9.4 (SAS Institute. Inc., Cary, NC) and a p-value <0.05 was considered as significant.

3. Results

An intention to treat analysis was used in examining the data. Patient demographics, difficult airway factors, and participating resident anesthesiologists were similar in all 3 groups and are summarized in Table 1. There were no significant differences in age, BMI, or number of difficult airway factors.

3.1. Intubation success and laryngeal view

The overall intubation success rates for all 3 video laryngoscopes were 96% (GS), 81.3% (KV-Ch), and 96% (KV-NCh), and the overall first-pass success rates were 85.3% (GS), 70.7% (KV-Ch), and 89.3% (KV-NCh), respectively. When comparing tracheal intubation success rates between the GS and the KV-NCh, there was no significant difference between the 2 groups ($P = 1.0000$). However, when comparing tracheal intubation success rates between the GS to the KV-Ch, there was a statistically significant difference ($P = 0.0083$). Still, when comparing the GS to the KV-Ch, there was a statistically significant difference ($P = 0.0463$).

During laryngoscopy, the most common initial C-L grade view for all 3 groups was a Grade 1; accounting for nearly 80% of the overall initial C-L grade views (78.1%) during the first attempt. There was no statistically significant difference between the 3 groups when comparing the initial C-L grade views (Table 2). Prior to intubation, the most common final C-L grade view for the 3 groups was a Grade 1 (79.5%). There was no statistically significant difference between the groups when comparing the final C-L grade views (Table 2). External laryngeal manipulation, or the ‘BURP’ maneuver, was utilized in 27.9% of the GS cases, 22.4% of the KV-Ch cases, and 34.25% of the KV-NCh cases, which was provided by the physician's discretion and clinical judgement. And as a result, only 5 patients (2.3%) showed improvement of the initial C-L grade view during laryngoscopy and intubation, overall (Table 3).

3.2. Time to intubate

The average time needed to successfully intubate a patient, between all groups, were 46.1 s (GS), 44.9 s (KV-Ch), and 47.0 s. (KV-NCh). There was no significant difference regarding the elapsed time required for a successful intubation. Further details related to timing are reported in Table 2.

3.3. Unsuccessful intubation

Failure to successfully intubate a patient occurred within 9% of our patient population, collectively (Table 2). The *failures* of the GS group (n = 3; 15%) were rescued with a flexible intubation scope (FIS) in one case, direct laryngoscopy using a Mac 4 (in another), and during the third case, it was “unknown” due to incomplete data collection. The *failed* attempts with the KV-Ch (n = 14; 75%) were all rescued with either direct laryngoscopy (Mac or Miller variations) or the GS. Finally, in the KV-NCh group (n = 3; 15%), 2 out of 3 *failures* were rescued with the GS, while one patient was rescued with a FIS.

Table 1
A comparison of demographics, difficult airway factors, and resident anesthesiologists amongst the three video laryngoscopes.

Variable	GSAVL	KVChVL	KVNChVL	*P* 1	*P* 2
Gender, n (%)	n = 74	n = 75	n = 75	0.8100[c]	0.9385[c]
Female	39 (52.7)	41 (54.7)	40 (53.3)		
Male	35 (47.3)	34 (45.3)	35 (46.7)		
Age (in years)	n = 72	n = 74	n = 74	0.9603[t]	0.402[t]
mean ± SD	48.1 ± 11.8	48.0 ± 15.2	50.0 ± 14.2		
Height (in)	n = 73	n = 73	n = 71	0.6435[t]	0.6799[t]
mean ± SD	66.7 ± 4.2	66.4 ± 4.3	66.4 ± 4.2		
Weight (kg)	n = 73	n = 74	n = 73	0.7229[t]	0.831[t]
mean ± SD	117.5 ± 20.3	116.2 ± 25.5	116.8 ± 21.5		
BMI (kg/m^2)	n = 73	n = 74	n = 71	0.9124[t]	0.9619[t]
mean ± SD	41.2 ± 8.1	41.4 ± 9.9	41.1 ± 8.5		
Neck circumference (cm)	n = 75	n = 75	n = 75	0.9776[t]	0.2408[t]
mean ± SD	47.1 ± 4.3	47.1 ± 4.7	47.9 ± 4.3		
Interincisor gap distance (cm)	n = 75	n = 75	n = 75	0.863[t]	0.6425[t]
mean ± SD	4.1 ± 1.0	4.1 ± 0.9	4.1 ± 1.0		
Thyromental distance (cm)	n = 74	n = 75	n = 75	0.8817[t]	0.2149[t]
mean ± SD	6.8 ± 1.7	6.8 ± 1.9	7.1 ± 1.7		
Sternomental distance (cm)	n = 75	n = 74	n = 74	0.5981[t]	0.5398[t]
mean ± SD	13.4 ± 2.3	13.6 ± 2.3	13.7 ± 2.1		
Resident level, n (%)	n = 73	n = 75	n = 74	0.7651[f]	0.6254[f]
*AA	1 (1.4)	0 (0.0)	0 (0.0)		
CA-1	12 (16.4)	11 (14.7)	9 (12.2)		
CA-2	36 (49.3)	44 (58.7)	35 (47.3)		
CA-3	22 (30.1)	18 (24.0)	29 (39.2)		
*CRNA	2 (2.7)	2 (2.7)	1 (1.4)		

[c] denotes p-values obtained by Chi-square test; [f] denotes p-values obtained by Fisher's exact test; [t] denotes p-values obtained by two sample *t*-test; * denotes non-resident anesthesia provider and was therefore excluded; AA – Anesthesiologist Assistant; CRNA – Certified Registered Nurse Anesthetist.
P-value 1: *P*-value for the comparison between GSAVL and KVChVL.
P-value 2: *P*-value for the comparison between GSAVL and KVNChVL.

Table 2
A comparison of intubation success rates, number of attempts, final intubation times, and corresponding C-L grade views amongst the three video laryngoscopes.

Variable	GSAVL	KVChVL	KVNChVL	*P* 1	*P* 2
Success, n (%)	n = 75	n = 75	n = 75	0.0083[f]	1.0000[f]
No	3 (4.0)	14 (18.7)	3 (4.0)		
Yes	72 (96.0)	61 (81.3)	72 (96.0)		
1st **attempt success**, n (%)	n = 75	n = 75	n = 75	0.0301[c]	0.4614[c]
No	11 (14.7)	22 (29.3)	8 (10.7)		
Yes	64 (85.3)	53 (70.7)	67 (89.3)		
2nd **attempt success**, n (%)	n = 10	n = 14	n = 6	0.7795[c]	0.3069[f]
No	5 (50.0)	7 (50.0)	1 (16.7)		
Yes	5 (50.0)	7 (50.0)	5 (83.3)		
3rd **attempt success**, n (%)	n = 5	n = 2	n = 0	1.0[f]	N/A
No	2 (40.0)	1 (50.0)	N/A		
Yes	3 (60.0)	1 (50.0)	N/A		
Final intubation time (s)	n = 72	n = 61	n = 72	0.7805[t]	0.8358[t]
mean ± SD	46.1 ± 27.4	44.9 ± 21.5	47.0 ± 24.3		
Final intubation time (s)	n = 72	n = 61	n = 72	0.7696[w]	0.4141[w]
median (Q1, Q3)	38.1 (28.0, 56.9)	42.3 (27.0, 60.0)	42.3 (30.5, 57.0)		
Initial C-L grade view, n (%)	n = 72	n = 72	n = 75	0.5688[f]	0.4291[f]
Grade 1	60 (83.3)	53 (73.6)	58 (77.3)		
Grade 2a	8 (11.1)	10 (13.9)	14 (18.7)		
Grade 2b	3 (4.2)	6 (8.3)	3 (4.0)		
Grade 3	1 (1.4)	2 (2.8)	0 (0)		
Grade 4	0 (0.0)	1 (1.4)	0 (0)		
Final C-L grade view, n (%)	n = 72	n = 72	n = 75	0.3921[f]	0.3989[f]
Grade 1	61 (84.7)	54 (75.0)	59 (78.7)		
Grade 2a	7 (9.7)	11 (15.3)	13 (17.3)		
Grade 2b	4 (5.6)	4 (5.6)	3 (4.0)		
Grade 3	0 (0.0)	2 (2.8)	0 (0.0)		
Grade 4	0 (0.0)	1 (1.4)	0 (0.0)		
Improved C-L grade view after BURP, n (%)	n = 72	n = 72	n = 75	1.0[f]	0.6148[f]
Yes	2 (2.8)	2 (2.8)	1 (1.3)		
No	70 (97.2)	70 (97.2)	74 (98.7)		

[c] denotes p-values obtained by Chi-square test; [f] denotes p-values obtained by Fisher's exact test; [t] denotes p-values obtained by two sample *t*-test; [w] denotes p-values obtained by Wilcoxon rank sum test.
P-value 1: p-value for the comparison between GSAVL and KVChVL.
P-value 2: p-value for the comparison between GSAVL and KVNChVL.

Table 3
A comparison of the initial and final C-L grade views amongst the three groups.

Video Laryngoscope	Initial C-L Grade View	Final C-L Grade View	Frequency	%	*P* 1	*P* 2
Glidescope AVL, n = 72					1.0[f]	0.6148[f]
	1	1	60	26.67		
	2a	1	1	0.44		
	2a	2a	7	3.11		
	2b	2b	3	1.33		
	3	2b	1	0.44		
	–	–	3	1.33		
King Vision ChVL, n = 72						
	1	1	53	23.56		
	2a	2a	9	4.00		
	2a	2b	1	0.44		
	2b	1	1	0.44		
	2b	2a	2	0.89		
	2b	2b	3	1.33		
	3	3	2	0.89		
	–	–	3	1.33		
King Vision NChVL, n = 75						
	1	1	58	25.78		
	2a	1	1	0.44		
	2a	2a	13	5.78		
	2b	2b	3	1.33		

[f] denotes p-value obtained by Fisher's exact test.
P-value 1: p-value for the comparison between GSAVL vs KVCh.
P-value 2: p-value for the comparison between GSAVL vs KVNCh.

3.4. *Subjective user evaluation*

When analyzing the various subjective assessments provided by resident anesthesiologists (as well as attending anesthesiologists), both the GS and KV-NCh produced similar results regarding their respective level of difficulty — pertaining to laryngoscopy, ETT delivery, and usage. The GS proved to be the *easiest* video laryngoscope utilized, out of the 3 groups (Table 4a). When compared to the KV-Ch, there was a significant difference when performing laryngoscopy and regarding overall device usage ($P = 0.0006$; $P = 0.0037$). Furthermore, when compared to the KV-NCh, the GS showed no significant difference within any of the listed assessment categories, as the GS provided slightly better assessments than the KV-NCh. Further details have been summarized in Table 4.

3.5. *Post-operative outcomes*

In comparison of the GS group to the KV-Ch, the GS group had 7 patients report with mild neck soreness and 2 with severe neck soreness, compared to 1 patient with mild neck soreness in the KV-Ch group. Six patients reported mild neck soreness in the KV-NCh group, 1 with moderate neck soreness, and 1 with severe neck soreness. Further details associated with both pre-operative and

Table 4
Summary statistics of subjective assessments regarding the utilization of the three video laryngoscopes.

Assessment Categories	GSAVL	KVChVL	KVNChVL	*P* 1	*P* 2
Difficulty of laryngoscopy, n (%)	n = 67	n = 71	n = 72	0.0006[f]	0.5125[f]
Very easy	37 (55.2)	20 (28.2)	35 (48.6)		
Easy	22 (32.8)	21 (29.6)	21 (29.2)		
Slight resistance	5 (7.5)	18 (25.4)	11 (15.3)		
Difficult	3 (4.5)	8 (11.3)	4 (5.6)		
Not possible	0 (0.0)	4 (5.6)	1 (1.4)		
Difficulty of ETT delivery, n (%)	n = 66	n = 71	n = 71	0.0202[f]	0.6248[f]
Very easy	19 (28.8)	18 (25.4)	16 (22.5)		
Easy	27 (40.9)	17 (23.9)	27 (38.0)		
Slight resistance	10 (15.2)	17 (23.9)	15 (21.1)		
Difficult	10 (15.2)	12 (16.9)	11 (15.5)		
Not possible	0 (0.0)	7 (9.9)	2 (2.8)		
Laryngeal view, n (%)	n = 67	n = 71	n = 70	0.1007[f]	0.7325[c]
Partial	14 (20.9)	14 (19.7)	13 (18.6)		
Obstructed	0 (0.0)	5 (7.0)	0 (0.0)		
Complete	53 (79.1)	52 (73.2)	57 (81.4)		
Ease of use, n (%)	n = 67	n = 71	n = 70	0.0037[f]	0.3206[f]
Very easy	37 (55.2)	26 (36.6)	30 (42.9)		
Easy	25 (37.3)	24 (33.8)	30 (42.9)		
Slight resistance	5 (7.5)	10 (14.1)	8 (11.4)		
Difficult	0 (0.0)	6 (8.5)	2 (2.9)		
Not possible	0 (0.0)	5 (7.0)	0 (0.0)		

[c] denotes p-values obtained by Chi-square test; [f] denotes p-values obtained by Fisher's exact test.
P-value 1: p-value for the comparison between GSAVL and KVChVL.
P-value 2: p-value for the comparison between GSAVL and KVNChVL.

post-operative patient conditions have been summarized in Table 5 and Table 6.

There were no statistically significant differences in hoarseness, sore mouth, sore jaw, dysphonia, dysphagia, or tongue injury. The only statistically significant difference in the post-operative patient airway conditions analysis was regarding a sore throat ($P = 0.0100$), when comparing the GS to the KV-Ch (Table 6). Blood staining was a noted observational outcome that occurred in 11.7% of the patients that were randomized to the GS and 12% of the intubations in the KV-Ch group. The KV-NCh group had an incidence of blood staining of 6.8%.

4. Discussion

This study was designed to compare three acutely angled video laryngoscopes in patients with anticipated difficult airways that resulted in relatively similar outcomes. When comparing overall tracheal intubation success rates between all 3 video laryngoscopes, there was only a statistically significant difference between the GS and the KV-Ch. Additionally, the KV-Ch exhibited increased difficulty of intubation. In a study by Kriege et al., a comparison between King Vision's channeled and non-channeled blades demonstrated nearly equal intubation success rates, with the channeled blade having a significantly longer intubation time [16]. Our findings, regarding the King Vision® video laryngoscopes, differ in that the channeled scope had a slightly faster intubation time, on average. This could be due to better training with the KV-Ch for the providers in our study, or, a result of the channeled blade being more effective in patients with anticipated airway difficulties. Although all study resident and attending anesthesiologists were trained on how to properly utilize the KVVIS prior to actual patient enrollment, the primary reason for difficulty during intubation was either placement and/or passage of the ETT, despite having decent visualization of the glottis; [17–21] which could potentially explain the relatively low first-pass success rate of all three devices, regardless of training and experience level. Also, when comparing the prevalence of different C-L grade views between the 3 video laryngoscopes, no statistically significant difference was found. Postoperatively, patient airway-related conditions were minimal and similar between the 3 groups, with (mild) hoarseness, (mild) neck soreness, and (mild to moderate) dysphagia being the most common conditions reported. Furthermore, the only statistically significant difference in the post-operative patient airway conditions was regarding neck soreness ($P = 0.0100$), when comparing GS to KV-Ch groups.

Although the blade angles are similar between the channeled and non-channeled video laryngoscopes, the key difference between the 2 blades is a “channel” or “groove” that was created to help facilitate ETT delivery without requiring a stylet. In 2014, Akisiha et al., demonstrated that the King Vision® channeled laryngoscope was a viable alternative to a traditional Macintosh laryngoscope in a manikin model [17]. Additionally, in 2014, Murphy et al. demonstrated that the King Vision® video laryngoscope was slightly faster than a Macintosh laryngoscope in certain airway scenarios and had a higher success rate in a difficult cadaver airway scenario [18]. This study demonstrated that these video laryngoscopes can be similarly effective in patients with more challenging airways.

Our data demonstrated that the GS and KV-NCh were equivalent with regards to first-pass success and overall intubation success.

Table 5
Summary statistics of pre-operative airway conditions amongst the three video laryngoscopes.

Airway Conditions	GSAVL	KVChVL	KVNChVL	*P* 1	*P* 2
Hoarseness, n (%)	n = 54	n = 53	n = 55	0.5112[f]	0.2308[f]
None	49 (90.7)	47 (88.7)	51 (92.7)		
Mild	5 (9.3)	4 (7.5)	2 (3.6)		
Moderate	0 (0.0)	2 (3.8)	2 (3.6)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		
Sore mouth, n (%)	n = 54	n = 53	n = 55	0.3632[f]	1.0[f]
None	53 (98.1)	50 (94.3)	53 (96.4)		
Mild	1 (1.9)	3 (5.7)	2 (3.6)		
Moderate	0 (0.0)	0 (0.0)	0 (0.0)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		
Sore throat, n (%)	n = 54	n = 53	n = 55	0.4905[f]	0.4954[f]
None	53 (98.1)	50 (94.3)	53 (96.4)		
Mild	0 (0.0)	2 (3.8)	2 (3.6)		
Moderate	1 (1.9)	1 (1.9)	0 (0.0)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		
Sore jaw, n (%)	n = 54	n = 53	n = 55	N/A	1.0[f]
None	54 (100.0)	53 (100.0)	54 (98.2)		
Mild	0 (0.0)	0 (0.0)	1 (1.8)		
Moderate	0 (0.0)	0 (0.0)	0 (0.0)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		
Dysphonia, n (%)	n = 54	n = 53	n = 55	N/A	1.0[f]
None	54 (100.0)	53 (100.0)	54 (98.2)		
Mild	0 (0.0)	0 (0.0)	1 (1.8)		
Moderate	0 (0.0)	0 (0.0)	0 (0.0)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		
Dysphagia, n (%)	n = 54	n = 53	n = 55	0.8539[f]	0.1451[f]
None	49 (90.7)	49 (92.5)	54 (98.2)		
Mild	2 (3.7)	2 (3.8)	1 (1.8)		
Moderate	3 (5.6)	1 (1.9)	0 (0.0)		
Severe	0 (0.0)	1 (1.9)	0 (0.0)		
Alteration of tongue, n (%)	n = 54	n = 53	n = 55	1.0[f]	1.0[f]
None	53 (98.1)	53 (100.0)	54 (98.2)		
Mild	1 (1.9)	0 (0.0)	0 (0.0)		
Moderate	0 (0.0)	0 (0.0)	1 (1.8)		
Severe	0 (0.0)	0 (0.0)	0 (0.0)		

[c] denotes p-values obtained by Chi-square test; [f] denotes p-values obtained by Fisher's exact test.

Table 6
Summary statistics of post-operative airway conditions amongst the three video laryngoscopes.

Airway Conditions	GSAVL	KVChVL	KVNChVL	*P* 1	*P* 2
Hoarseness, n (%)	n = 64	n = 65	n = 70	0.9137[f]	0.5476[f]
None	38 (59.4)	42 (64.6)	48 (68.6)		
Mild	18 (28.1)	16 (24.6)	16 (22.9)		
Moderate	7 (10.9)	6 (9.2)	4 (5.7)		
Severe	1 (1.6)	1 (1.5)	2 (2.9)		
Sore mouth, n (%)	n = 64	n = 65	n = 70	0.6383[f]	0.7534[f]
None	55 (85.9)	60 (92.3)	63 (90.0)		
Mild	7 (10.9)	4 (6.2)	4 (5.7)		
Moderate	1 (1.6)	1 (1.5)	2 (2.9)		
Severe	1 (1.6)	0 (0.0)	1 (1.4)		
Sore throat, n (%)	n = 64	n = 65	n = 70	0.0100[f]	0.8242[f]
None	55 (85.9)	61 (93.8)	62 (88.6)		
Mild	7 (10.9)	1 (1.5)	6 (8.6)		
Moderate	0 (0.0)	3 (4.6)	1 (1.4)		
Severe	2 (3.1)	0 (0.0)	1 (1.4)		
Sore jaw, n (%)	n = 64	n = 65	n = 70	0.2393[f]	0.5106[f]
None	60 (93.8)	64 (98.5)	68 (97.1)		
Mild	3 (4.7)	1 (1.5)	2 (2.9)		
Moderate	0 (0.0)	0 (0.0)	0 (0.0)		
Severe	1 (1.6)	0 (0.0)	0 (0.0)		
Dysphonia, n (%)	n = 64	n = 65	n = 70	0.3250[f]	0.8037[f]
None	57 (89.1)	62 (95.4)	65 (92.9)		
Mild	5 (7.8)	3 (4.6)	4 (5.7)		
Moderate	1 (1.6)	0 (0.0)	1 (1.4)		
Severe	1 (1.6)	0 (0.0)	0 (0.0)		
Dysphagia, n (%)	n = 64	n = 65	n = 70	0.5170[f]	0.3817[f]
None	51 (79.7)	51 (78.5)	61 (87.1)		
Mild	8 (12.5)	8 (12.3)	3 (4.3)		
Moderate	3 (4.7)	6 (9.2)	4 (5.7)		
Severe	2 (3.1)	0 (0.0)	2 (2.9)		
Alteration of tongue, n (%)	n = 64	n = 65	n = 70	0.2442[f]	0.8636[f]
None	62 (96.9)	65 (100.0)	68 (97.1)		
Mild	1 (1.6)	0 (0.0)	1 (1.4)		
Moderate	0 (0.0)	0 (0.0)	1 (1.4)		
Severe	1 (1.6)	0 (0.0)	0 (0.0)		

[c] denotes p-values obtained by Chi-square test; [f] denotes p-values obtained by Fisher's exact test.

However, the KV-Ch did not compare favorably regarding first attempt success rates. In many studies, a video laryngoscope assures improved laryngeal visualization compared to a traditional laryngoscope; [21-25] however, it doesn't guarantee successful ETT placement, which was also demonstrated within our study (i.e. Table 2). The initial view obtained within each of the 3 groups was equal, suggesting that the issue was not obtaining the view, but with ETT delivery. The lack of success, and primary contributor of the majority of failed intubations overall, for the KV-Ch were related to the difficulty of advancing the ETT within the provided channel. Despite lubrication of both the ETT and the channel, which are highly recommended by the manufacturer, both residents and attending anesthesiologists commented on the difficulty of advancing the ETT within the channel. Additionally, when using the KV-Ch, the view often became obscured during ETT advancement and passage through the vocal cords. We also noticed that the KV-Ch had a better success rate, during ETT delivery, when the tip of the blade was placed in the vallecula. When the blade was positioned too deep and used to lift the epiglottis, the ETT was difficult to maneuver and successfully place within the trachea. The inability to intubate despite an adequate view of the glottic opening was another important flaw that occurred with the GlideScope® AVL. This is due to the difficulty of aligning the orotacheal structures with the ETT [21,25,26]. Due to this known limitation, the hypothesis that the channel within the King Vision Channeled Laryngoscope would demonstrate superior intubation success was developed.

The equivalent success, subjective user evaluation and safety data between the GS and KV-NCh could be attributed to the similar ETT delivery. With the channeled blade, the ETT delivery system is different than a standard intubation and represented a new and unique method of ETT delivery. As laryngeal views were equivalent in all 3 groups, this different style of ETT delivery and unfamiliar route could explain some of the variations in success with the KV-NCh group. Our findings support the use of all of the studied devices on patients with anticipated difficult airways. Additional studies using a cohort of physicians extensively trained with the KV-Ch may provide a better understanding of the effectiveness of its intended design.

4.1. Limitations

Limitations to this study include the difference in level of familiarity between the GS and KVVIS. The original design of the study involved residents as the preferred laryngoscopist in order to avoid attending bias in laryngoscope preferences. However, since this study occurred over a two-year period, residents used the GS more often when compared to the King Vision in non-study patients due to the availability of laryngoscopes at our institution. Multiple studies indicate increased intubation success with increasing use of specific laryngoscopes, which supports the theory that some of the difference in success is related to GS experience. There are recent studies alluding to the idea that expertise with video laryngoscope intubations requires up to 76 attempts [27]. The difference in familiarity and relative ease level could explain the variable success with each video laryngoscope [27,28]. Attending and resident anesthesiologists were more likely to attempt a third or fourth intubation with the GS, while with the KVVIS they were more likely to switch to an alternate device.

5. Conclusion

In this comparison study involving resident anesthesiologists, the GS and KV-NCh were found to be equivalent in facilitating tracheal intubation on the first attempt. In contrast, the KV-Ch was less successful in facilitating first attempt intubation success, when compared to both GS and KV-NCh. Even when tracheal intubation was performed by practitioners that rarely utilize the KVVIS, there was a slight decrease in time (during intubation) with the KV-Ch versus the KV-NCh, as compared to the GS. This study demonstrates that the KV-NCh can be a viable alternative to the GS for resident anesthesiologists, as a teaching tool, as well as, in patients with anticipated difficult airways.

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Author's individual contribution to the manuscript

Travis H. Markham, MD: This author helped with conception, design, acquisition of data, interpretation of data, analysis of data, drafting of the article, revising the article, and final approval.

Omonele O. Nwokolo, MD: This author helped with design, acquisition of data, drafting of the article, and final approval.

Sara Guzman-Reyes, MD: This author helped with the acquisition of data, revising the article, and final approval.

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Sam D. Gumbert, MD: This author helped with the acquisition of data and final approval.

Chunyan Cai, PhD: This author helped with design, analysis of data, interpretation of data, revising the article, and final approval.

Tyrone Burnett Jr., BS: This author helped with the acquisition of data, interpretation of data, drafting of the article, revising the article, and final approval.

Tariq A. Syed, MS: This author helped with the acquisition of data, interpretation of data, drafting of the article, revising the article, and final approval.

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