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# **BMJ Open**

#### Prospective comparison of video laryngoscopes for emergency endotracheal intubation

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	Original artic
	Prospective comparison of video laryngoscopes
	for emergency endotracheal intubation
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Abstract Objective: Video laryngoscopes are used for management of difficult airways. This study compares the performance of the Pentax-Airway Scope<sup>™</sup> (PAS), King Vision<sup>®</sup> (KV), McGrath<sup>®</sup> MAC (MCG) and Macintosh laryngoscope (ML) in emergency tracheal intubations (TI). Setting: Two tertiary-level hospitals in Japan. **Participants:** All consecutive video-recorded cases of emergency TI in emergency departments and intensive care units between December 2013 and June 2015. Outcomes: The primary study endpoint was success rate of first attempts at TI. A subanalysis examined the success of first attempts by expert versus non-expert operators. A logistic regression analysis was performed to identify predictors of successful first attempts. Results: 287 emergency TI were included. TI was successful in 78% of first attempts with PAS, 58% with KV, 78% with MCG, and 58% with ML (P=0.004). In post hoc analysis, the success rates with PAS and MCG were significantly higher than with KV and ML. The success rates by non-expert operators were significantly higher (P=0.00004) with PAS (87%) and MCG (78%), than with KV (50%) and ML (46%), though not when performed by experts

adjustments for TI indications, difficult airway characteristics, and expert versus non-expert

(67% with PAS vs. 67% with MCG vs. 78% with KV vs. 78% with ML, P=0.556). After

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operator, PAS (odds ratio = 3.422, 95% confidence interval 1.551-7.550; P=0.002) and MCG (3.758, 1.640-8.612; P=0.002) were associated with higher odds of successful first attempt. **Conclusion:** PAS and MCG were associated with significantly higher success rates of first attempts at emergency TI than KV and ML, especially by non-expert operators.

5 Trial registration: UMIN000027925

Keywords: Emergency intubation, tracheal intubation, laryngoscopy, video-assisted

laryngoscopy, video laryngoscope

	Stre	ngths and limitations of this study
	•	This study is the first report directly comparing the three different types of VLs
		(Pentax-Airway Scope <sup>™</sup> (PAS), the King Vision <sup>®</sup> (KV), the McGrath <sup>™</sup> MAC (MCG) )
		and ML in the emergency TI.
	•	Significantly higher successful rates shown in PAS and MCG, especially when operated
		by non-experts, is another strength of this study possibly affecting clinical practice.
	•	Major limitation of this study is its observational design. Although we tried to adjust for
		almost all possible confounding factors based on previous studies, we cannot totally
		exclude other unnoticed confounding factors influencing the results,
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	Background
	Tracheal intubation (TI) performed in emergency setting is more challenging than when
	attempted in an operating room, because of patients, operators and environmental factors
	[1-3]. Consequently, the success rate is lower, the time needed to undertake the TI is longer
5	and the complication rate is higher [1, 2, 4, 5].
	Video laryngoscopes (VL) are increasingly being used to increase the safety and
	success rate of emergency TI. The main VL used in clinical practice are the Pentax-Airway
	Scope <sup>™</sup> (PAS; HOYA Corporation, Tokyo, Japan), the King Vision <sup>®</sup> (KV; King Systems,
	Noblesville, IN) and the McGrath <sup>™</sup> MAC (MCG; Medtronic Inc, Minneapolis, MN). VL are
10	classified by the guidance method of the tracheal tube. PAS and KV are L-shaped, with an
	attachment of the tracheal tube to the blade, while MCG has no attachment, which facilitates
	the flexible orientation of the tube. Compared with the Macintosh laryngoscope (ML), the

superiority of VL in viewing the glottis and in successfully completing TI has been confirmed

in a manikin model [6], in patients undergoing elective surgery [7-10], and in patients

presenting in emergency rooms [11-13]. No study, however, has examined the relative performance of VL, especially in emergency TI.

The identification of the optimal VL is important, in view of a) the high failure rate of

emergency TI in the emergency department (ED) and the intensive care unit (ICU), and b) the increased incidence of adverse events associated with unsuccessful attempts [14, 15].

The aim of this study was to identify the optimal VL among PAS, KV, MCG and ML

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in the emergency performance of TI in the ED or the ICU.

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# Methods

#### Study design and setting

This prospective, observational study was conducted at a university hospital and at a general, public hospital. The study protocol was approved by the institutional review boards of both 5 institutions. Both boards waived the need to obtain the patients' informed consents before collecting the data. We disclosed the information regarding this study by web page and offered an opportunity to opt out. The ED and ICU of both institutions treated ambulatory and postoperative, medical and surgical, pediatric and adult patients. The physicians were responsible for primary care in the ED and for critical care in the ICU. Both were staffed by board-certified attending 10 physicians in emergency or intensive care medicine, or by anesthesiologists, and by post-graduate residents (years 3-7) in emergency medicine, anesthesiology and internal medicine. In addition, transitional post-graduate residents (years 1 and 2) rotated for several months in the ED and ICU. Most of the transitional year residents completed  $\geq 1$  month of 15 training in anesthesiology in the operating room, during which they performed TI, using ML in patients undergoing general anesthesia, under the supervision of attending

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anesthesiologists. When difficult airways or cervical instability were anticipated, the choice

PAS (model S100L), KV, MCG and ML were available for this study. Channeled disposable blades were used with the KV. The laryngoscopes, drugs, or operators for the TI procedures were chosen by the attending physician(s) without protocol. Using a hand-held or fixed camera, the procedures were systematically video-recorded for archival and quality control. **Study participants** We included consecutive video-recorded cases of emergency TI performed in the ED and ICU of both institutions between December 2013 and June 2015. Data collection and measurements We recorded the patients demographic and clinical characteristics, indications for TI altered mental status), drugs used for TI (sedatives, analgesics or muscle relaxants), pre-procedurally defined complicating airway characteristics, including obesity (body mass index  $\geq 28$ ), limited mouth opening (inter-incisor distance  $\leq 4$  cm), restricted neck

of VL was left to the discretion of the supervisors.

(cardiopulmonary arrest, airway obstruction, respiratory failure, hemodynamic instability or

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	mobilization, short neck (thyro-mental distance <6 cm), facial trauma (diagnosed clinically
	and by imaging), edema of the glottis visualized by the operator, and presence of blood,
	secretions or vomitus in the airways, needing suction or interfering with the procedure. The
	laryngoscopes used, the length of clinical experience and the specialty of the operators were
5	recorded. The subjective difficulty, using a visual analogue scale between 0 (easy) and 100
	(difficult) was scored by the operators. The success of first attempts at TI, the number of
	attempts until successful TI, the changes of laryngoscopes and operators, the time between
	insertion of the laryngoscope into the mouth and the onset of ventilation after TI, the
	complications (edema or spasm of the glottis, dental injuries, regurgitation and airway
10	hemorrhages), esophageal intubations, and the laryngoscope in use when the complication or
	the esophageal intubation occurred, were recorded. The data were collected from the video
	recording for measurements of variables, in addition to medical records and a questionnaire.
	Study endpoints
15	The primary study endpoint was the rate of successful first attempt at TI, and the secondary
	endpoints were the time needed to perform the procedure, the subjective difficulty score,
	procedural complications and esophageal intubation.

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#### Sample size and statistical analysis

Estimated sample size was based on a previous TI study performed by residents in patients undergoing elective surgery, where the rates of successful first attempts, using the ML and PAS were 64 and 90%, respectively. Assuming a 20% difference in rates of successful first attempts between two laryngoscopes, we calculated a sample size of 62 procedures in each group at the 5%  $\alpha$  level and a power (1- $\beta$ ) of 80%. Including missing data, we set the sample sizes of each group at 70, and at a total of 280 procedures. Categorical variables are expressed as counts and percentages, and continuous variables

10 as means  $\pm$  standard deviations. We compared the outcomes among the 4 laryngoscopes by

Fisher's exact or Kruskal-Wallis tests. The procedures without an accurate measurement of time needed to perform the TI from the video recording and the procedures without descriptions of the subjective difficulty score were excluded from the each analysis. A *post hoc* analysis was performed, using Turkey's test for all paired comparisons. We also examined

15 whether the rates of successful first attempts differed among the 4 laryngoscopes, in each

pre-specified subgroups, according to the duration of clinical experience (1<sup>st</sup> and 2<sup>nd</sup>

post-graduate years as non-expert operators;  $\geq 3^{rd}$  post-graduate year as experts). A logistic

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regression analysis was performed to identify factors influencing the successful first attempt rate. We included possible confounding factors, which were significantly different among the 4 laryngoscopes (indication for TI and restricted neck mobility) and which were identified in previous studies (limited mouth aperture,<sup>16</sup> blood, secretion or vomitus in the airways,<sup>17</sup> experts versus non-expert operator<sup>18</sup>). A P value < 0.05 was considered statistically significant. The analyses were performed using the SPSS<sup>®</sup> statistical package, version 23 (IBM Corporation, Armonk, NY).

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## Results

# Characteristics of the study population The patients characteristics are summarized in table 1. Two-hundred and eighty-seven patients underwent video-recorded emergency TI. Among the indications for TI, hemodynamic instability was significantly different among the 4 laryngoscopes, with MCG most frequently used in presence of hemodynamic instability. Complicating airway characteristics were present in 56% of cases, consisting of blood, secretions or vomitus in the airways in 123 procedures (43%). PAS was often used during procedures complicated by a restricted neck mobility. Among the 67 non-experts, 57 operators (89.1%) had received some anesthesiology training in the operating room. They performed 33±14 TI, including 6±5 procedures using VL with PAS or MCG. TI was interrupted in 3 cases (1%), of which one was managed without TI, another underwent emergency cricothyroidotomy, and a third

suffered a fatal cardiopulmonary arrest. In the remaining 284 procedures, TI was attempted once in 199 (69%), twice in 49 (17%) and >twice in 36 instances (13%). The laryngoscope

15 was replaced in 22 cases (8%). Out of 59 procedures, the KV was replaced by another laryngoscope in 9 instances (15%; P=0.043 vs. other groups). The KV was replaced by another device in 7 procedures because of separation of the laryngoscope from its disposable

blade. The operator was replaced in 21 attempts at TI (7%), of which 19 were initially made by a non-expert operator. The number of operators were similarly replaced in the 4 study groups.

#### 5 Main results

The overall rate of successful first attempts was 69% and differed significantly (P=0.004) among the 4 laryngoscopes (table 2). In post hoc analysis, the rates of successful first attempts were higher with AWS and MCG than with KV or ML, though the difference was significant only in the subgroup of non-expert operators (table 2). The rates of successful first attempts were similar in non-experts and experts. By logistic regression analysis with adjustments for indication of TI, restricted neck mobilization, limited mouth opening, bloods/secretion/vomitus in the airway and experts/non-expert, the use of PAS and MCG was associated with significantly higher rates of successful first attempts at TI (table 3). There was a significant difference in time needed to perform TI among the 4 laryngoscopes, though no difference was found in the *post hoc* analysis. There was a significant difference in the difficulty scores among the 4 laryngoscopes and the use of MCG was significantly easier than ML in the post hoc analysis (table 4).

Complications of TI occurred in 21 procedures (7%), consisting of 1 dental

trauma, 7 spasms or edemas of the glottis, 5 instances of regurgitation and 10 hemorrhages, though there was no significant difference among the 4 laryngoscopes. The esophagus was intubated in 3 instances (1.2%) by non-experts using the ML.

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# Discussion

	In this prospective, observational, two-center study, after adjustments for confounding factors,
	the success rates of first attempts at emergency TI were significantly higher with PAS or
	MCG than with KV or ML, when performed by non-expert operators. The use of MCG was
5	associated with a lower subjective difficulty of performing TI than the use of ML.
	A previous study of VL for TI by experienced anesthetists in the operating room
	revealed a better visualization of the glottis with PAS than with ML, while the success rates
	and TI procedure times were similar [8]. Moreover, studies with inexperienced residents
	revealed a 96% success rate at first attempt with PAS, versus 70% with ML, and 44 sec to
10	secure the airways with PAS, versus 71 sec with ML [9]. Our results are concordant with
	these success rates, suggesting advantageous characteristics of PAS, specifically with novice
	operators. The suitable shape of the $PBLADE^{\ensuremath{\mathbb{R}}}$ , which indirectly visualizes the glottis
	regardless of the head and neck position, the existence of a blade channel to set the tracheal
	tube and the guiding function of the target mark on the screen, supports the preferential use of
15	PAS among the VL [19].
	MCG is a relatively compact device without tracheal tube guide channel [20].

Like ML, it offers an indirect view of the glottis by flexible manipulations of the

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	laryngoscope and tracheal tube. Several factors, therefore, such as a restricted neck mobility
	or the operator's experience with TI might influence the success rate of PAS versus MCG.
	However, the rates of successful first attempt at TI were nearly the same with PAS and MCG
	in this study population. A randomized study comparing the performance of PAS versus
5	MCG in emergency TI seems warranted.
	This study was the first to compare PAS versus KV in clinical settings. Although
	they have similar shapes and tracheal tube guiding characteristics, the rate of successful first
	attempt was significantly lower with KV than with PAS. The orientation of the KV tracheal
	tube is relatively downward compared with PAS, interfering with its advancement. In
10	addition, KV has no marking to help in the placement of the tube. Malfunction of the system,
	which occurred in 7 patients in this study, may also have lowered the success rate of KV.
	Several factors, which varied among the 4 laryngoscopes, had repercussions on the
	success rate of TI. Blood or vomitus in the airways, an important complication when
	performing TI in emergency, may lower the image quality. Blood, secretions or vomitus were
15	present in the airways in 43% of procedures, significantly lowering the rate of successful first
	attempts [17]. However, after adjustment for this factor, the multiple variable analysis
	confirmed the advantage of using PAS and MCG. A limited mouth aperture was also
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	correlated with the difficulty of TI [16]. This, however, was problematic in only 6% of cases
	and did not represent a major obstacle to the insertion of the devices.
	Limitations of our study
5	This was an observational study, in which confounding factors may have influenced the
	success rate of TI and biased the results. We adjusted, however, for possible confounding
	factors based on previous studies, and found a significant relationship between VL and rate of
	successful first attempts. Furthermore, we classified the "non-experts" on the basis of their
	clinical experience. A precise index to grade the level of intubation skill might have been
10	preferable, although it does not currently exist. Finaly, bias based on operator's familiarity
	with each laryngoscope cannot be excluded. However, given the scarce overall experience of
	TI itself prior to this study (4.6 times/person), the results of Non-expert group are likely to be
	less biased.

#### Conclusion

When performing emergency TI in the ED or the ICU, PAS and MCG were associated

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with significantly higher rates of successful first attempts, especially when operated by

non-experts.

1 2 3 4 5 6		List of A	Abbreviations
7 8 9		ML	Macintosh laryngoscope
10 11 12		TI	tracheal intubation
13 14 15		VL	video laryngoscope
16 17 18	5	AWS	Pentax-Airway Scope™
19 20 21 22		KV	King Vision <sup>®</sup>
23 24 25		McG	McGrath <sup>®</sup> MAC
26 27 28		TT	tracheal tube
29 30 31		ED	emergency department
32 33 34	10	ICU	intensive care unit
35 36 37		IRB	institutional review board
38 39 40		PGY	post-graduate year
41 42 43		DAF	difficult airway factors
44 45 46 47		FAS	first attempt success
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McGrath <sup>®</sup> MAC
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# Declarations

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**Contributions**: Suzuki conceived the study, designed the trial, collected and managed the data. Kusunoki, Tanigawa and Shime supervised the conduct of the trial and data collection. Suzuki drafted the manuscript, and all authors contributed substantially to its revision. Suzuki takes responsibility for the paper as a whole.

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

**Ethics approval and consent to participate**: This study was reviewed and approved by the research ethics committee of Hiroshima University (No.1069) and Hiroshima prefectural hospital (No.2013-76).

5 Trial registration number: University Hospital Medical Information Network

Clinical Trials Registry (UMIN000027925,

https://upload.umin.ac.jp/cgi-open-bin/ctr\_e/ctr\_view.cgi?recptno=R000016182); date of

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registration 26.06.2017 (retrospectively registered)

**Consent for publication**: Not applicable.

Data sharing statement: No additional data available.

Patient and Public Involvement statement: Patients were not involved.

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#### Table 1. Baseline and difficult airway characteristics

	All	Pentax-Airway	King VISION	McGrath	Macintosh	Р
	(n=287)	(n=82)	(n=59)	(n=82)	(n=64)	
Men	165 (57.5)	54 (65.9)	31 (52.5)	51 (62.2)	29 (45.3)	0.057
Age	65.4±20.5	60.7±24.8	69.0±16.2	67.4±17.1	65.7±21.4	0.45
Height, cm	158.1±14.4	156.9±19.3	159.3±9.0	$160.9 \pm 10.2$	154.9±14.9	0.044
Weight, kg	55.9±13.9	56.3±16.9	56.2±10.2	56.7±11.9	54.0±15.2	0.40
Body mass index	22.0±3.7	22.3±3.8	22.1±3.6	21.7±3.2	22.1±4.2	0.79
Expert operators	131 (45.6)	36 (43.9)	27 (45.8)	45 (54.9)	23 (35.9)	0.14
Indications for tracheal intubation						
Cardiopulmonary arrest	114 (39.7)	34 (41.5)	26 (44.1)	25 (30.5)	29 (45.3)	0.22
Airway obstruction	14 (4.9)	4 (4.9)	1 (1.7)	7 (8.5)	2 (3.1)	0.30
Respiratory failure	45 (15.7)	12 (14.6)	11 (18.6)	14 (17.1)	8 (12.5)	0.78
Hemodynamic instability	32 (11.1)	6 (7.3)	2 (3.4)	20 (24.4)	4 (6.3)	0.00
Altered mental status	82 (28.6)	26 (31.7)	19 (32.2)	16 (19.5)	21 (32.8)	0.18
Drugs used for tracheal intubation						
None	148 (51.6)	44 (53.7)	32 (54.2)	35 (42.7)	37 (57.8)	0.27
Sedatives	116 (40.4)	33 (40.2)	24 (40.7)	35 (42.7)	24 (37.5)	0.94
Analgesics	91 (31.7)	22 (26.8)	15 (25.4)	36 (43.9)	18 (28.1)	0.05
Muscle relaxants	59 (20.6)	15 (18.3)	10 (16.9)	22 (26.8)	12 (18.8)	0.45
Drugs used for tracheal intubation in Non-CPA cases	(n=173)	(n=48)	(n=33)	(n=57)	(n=35)	
None	34 (19.7)	10 (20.8)	6 (18.2)	10 (17.5)	8 (22.9)	0.92
Sedatives	116 (67.1)	33 (68.8)	24 (72.7)	35 (61.4)	24 (68.6)	0.72
Analgesics	91 (52.6)	22 (45.8)	15 (45.5)	36 (63.2)	18 (51.4)	0.25
Muscle relaxants	59 (34.1)	15 (31.3)	10 (30.3)	22 (38.6)	12 (34.3)	0.84
Difficult airway characteristics						
Obesity	16 (5.6)	6 (7.3)	3 (5.1)	3 (3.7)	4 (6.3)	0.79
Limited mouth opening	17 (5.9)	5 (6.1)	5 (8.5)	6 (7.3)	1 (1.6)	0.31
Restricted neck mobilization	39 (13.6)	19 (23.2)	6 (10.2)	7 (8.5)	7 (10.9)	0.04
Short neck	9 (3.1)	3 (3.7)	1 (1.7)	3 (3.7)	2 (3.1)	0.93
Facial trauma	13 (4.5)	7 (8.5)	1 (1.7)	4 (4.9)	1 (1.6)	0.17
Edema of glottis	7 (2.4)	2 (2.4)	0 (0.0)	4 (4.9)	1 (1.6)	0.39
Bloods, secretion or vomitus in airway	123 (42.9)	36 (43.9)	23 (39.0)	38 (46.3)	26 (40.6)	0.82
Cases with difficult airway characteristics	161 (56.1)	47 (57.3)	31 (52.5)	48 (58.5)	35 (54.7)	0.89

Values are numbers (%) of observations or means  $\pm$  standard deviations.

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	All laryngoscopes	Pentax-Airway Scope	King VISION	McGrath	Macintosh	Р
All operators, n	287	82	59	82	64	
Successful first attempt	199 (69)	64 (78)*	34 (58)	64 (78)†	37 (58)	0.004
Non-expert operators	156	46	32	37	41	
Successful first attempt	104 (67)	40 (87)‡	16 (50)	29 (78)§	19 (46)	0.00004
Expert operators	131	36	27	45	23	
Successful first attempt	95 (73)	24 (67)	18 (67)	35 (78)	18 (78)	0.556

Values are numbers (%) of observations; *post hoc* analyses were performed using Tukey's test for paired comparisons of 4 laryngoscopes. \*:vs. King VISION P=0.043, \*:vs. Macintosh P=0.039, †:vs. King VISION P=0.043, †:vs. Macintosh P=0.039 ‡:vs. King VISION P=0.002, ‡:vs. Macintosh P<0.001, §:vs. King VISION P=0.043, §:vs. Macintosh P=0.009

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Factors	Odd ratios	95% confidence intervals	Р
Laryngoscopes			
Macintosh (reference)	1	-	-
Pentax-Airway Scope	3.422	1.551-7.550	0.002
King VISION	1.056	0.487-2.289	0.889
McGrath	3.758	1.640-8.612	0.002
Indications for tracheal intubation			
Cardiopulmonary arrest	1 (reference)		
Airway obstruction	0.226	0.063-0.812	0.023
Respiratory failure	0.720	0.284-1.822	0.488
Hemodynamic instability	0.380	0.137-1.054	0.063
Altered mental status	0.361	0.180-0.723	0.004
Difficult airway characteristics			
Mouth opening			
Unlimited	1 (reference)	-	-
Limited	0.092	0.026-0.323	0.000
Neck mobility			
Unrestricted	1 (reference)	-	-
Restricted	0.951	0.414-2.182	0.905
Blood, secretions, vomitus in the airv	ways		
Absent	1 (reference)	-	-
Present	0.455	0.257-0.804	0.007
Operators			
Non-expert	1 (reference)	-	-
Expert	1.688	0.916-3.108	0.093

# Table 3. Multiple variable analysis of factors influencing the success rate of first attempts at tracheal intubations

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Table 4. Comparisons of times needed to perform tracheal intubations and of difficulty scores,

#### using 4 different laryngoscopes

	8 6	1					
		Overall	Pentax-Airway	King VISION	McGrath	Macintosh	Р
	Time to perform intubations, sec	60±31 (n=269)	63±34 (n=78)	63±31 (n=45)	62±31 (n=79)	52±27 (n=67)	0.043
	Difficulty score <sup>†</sup>	39±27 (n=258)	39±26 (n=72)	43±26 (n=45)	32±27* (n=78)	45±26 (n=63)	0.009
5	Values are means ± standard d <sup>†</sup> Difficulty was scored by visua post hoc analyses were perform	al analogue scale	e, from very easy (	0) to very difficu	lt (100). laryngoscopes.		
			's test for paired c				

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	Item No	Recommendation	Reported on pag No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in	1, 2
		the title or the abstract	
		(b) Provide in the abstract an informative and balanced	2-3
		summary of what was done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the	4-5
5		investigation being reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	6-8
Setting	5	Describe the setting, locations, and relevant dates, including	6
Setting		periods of recruitment, exposure, follow-up, and data collection	0
Participants	6	(a) Give the eligibility criteria, and the sources and methods of	7
i uniorpanto	Ŭ	selection of participants. Describe methods of follow-up	,
		(b) For matched studies, give matching criteria and number of	
		exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential	7-8
vulluolos	7	confounders, and effect modifiers. Give diagnostic criteria, if	, 0
		applicable	
Data sources/	8*	For each variable of interest, give sources of data and details of	7-8
measurement	0	methods of assessment (measurement). Describe comparability	7-0
measurement		of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	9
Quantitative variables	11	Explain how quantitative variables were handled in the	7-8
		analyses. If applicable, describe which groupings were chosen	
		and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to	9-10
		control for confounding	
		(b) Describe any methods used to examine subgroups and	9
		interactions	-
		(c) Explain how missing data were addressed	9
		(d) If applicable, explain how loss to follow-up was addressed	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg	11
i articipanto	15	numbers potentially eligible, examined for eligibility,	11
		confirmed eligible, included in the study, completing follow-up,	
		and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptivo data	1/*	· · · · · · · · · · · · · · · · · · ·	25
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic,	25
		clinical, social) and information on exposures and potential confounders	
			11
		(b) Indicate number of participants with missing data for each	11

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		variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	12-13, 26
Main results	16	( <i>a</i> ) Give unadjusted estimates and, if applicable, confounder- adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	26, 27
		( <i>b</i> ) Report category boundaries when continuous variables were categorized	
		( <i>c</i> ) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12, 26
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which	20

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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# **BMJ Open**

#### Comparison of three video laryngoscopes and direct laryngoscopy for emergency endotracheal intubation - a retrospective cohort study

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Secondary Subject Heading:	Emergency medicine	
Keywords:	Emergency intubation, tracheal intubation, laryngoscopy, video-assisted laryngoscopy, video laryngoscope, video laryngoscopy	



**Original** articles

# Comparison of three video laryngoscopes and direct laryngoscopy for

#### emergency endotracheal intubation - a retrospective cohort study

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Abstract **Objective:** Video laryngoscopes are used for the management of difficult airways. This study compared the performances of three video laryngoscopes (Pentax-Airway Scope<sup>TM</sup> [Pentax], King Vision<sup>®</sup> [King], and McGrath<sup>®</sup> MAC [McGrath]) with the Macintosh direct laryngoscope [Macintosh] as reference in emergency tracheal intubations (TIs) to identify the optimal video laryngoscopes among them. Setting: The emergency department and the intensive care unit of two tertiary-level hospitals in Japan. Participants: All consecutive video-recorded cases of emergency TI in emergency departments and intensive care units between December 2013 and June 2015. Outcomes: The primary study endpoint was first-pass intubation success. A subgroup analysis examined the first-pass intubation success of expert versus non-expert operators. A logistic regression analysis was performed to identify the predictors of first-pass success. **Results:** A total of 287 emergency TIs were included. The first-pass intubation success rates were 78%, 58%, 78%, and 58% for the Pentax, King, McGrath, and Macintosh instruments, respectively (P=0.004). In post hoc analysis, the success rates of the Pentax and McGrath instruments were significantly higher than those of the King and Macintosh instruments. The success rates of non-expert operators were significantly higher (P=0.00004) for the Pentax

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4 5		(87%) and McGrath (78%) instruments than those with the King (50%) and Macintosh (46%)
6 7 8 9		instruments but not when used by experts (67% with Pentax vs. 67% with McGrath vs. 78%
10 11 12		with King vs. 78% with Macintosh, P=0.556). After adjusting for TI indications, difficult
13 14 15 16		airway characteristics, and expert versus non-expert operator parameters, the odds for a
17 18 19	5	first-pass intubation success were significantly higher with the Pentax (odds ratio = 3.422,
20 21 22		95% confidence interval 1.551-7.550; P=0.002) and McGrath (3.758, 1.640-8.612; P=0.002)
23 24 25 26		instruments.
27 28 29		Conclusion: The Pentax and McGrath laryngoscopes were associated with significantly
30 31 32		higher first-pass success rates in emergency TI than those for the King and Macintosh
33 34 35 36	10	laryngoscopes, especially for non-expert operators.
37 38 39		Trial registration: UMIN000027925
40 41 42		
43 44 45 46		Keywords: Emergency intubation, tracheal intubation, laryngoscopy, video-assisted
47 48 49		laryngoscopy, video laryngoscope, video laryngoscopy
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59		

Strengths and limitations of this study

To our knowledge, this study is the first to directly compare three different video laryngoscopes (Pentax-Airway Scope<sup>™</sup>, King Vision<sup>®</sup>, McGrath<sup>™</sup> MAC) and the Macintosh laryngoscope for emergency TI. The strength of this study is that we precisely evaluated the intubation process among four laryngoscopes using real-world video records of TI. The major limitation of this study is its observational design. Although we tried to adjust for almost all possible confounding factors based on previous studies, we could not completely exclude the influence of other confounding factors on the results. 

Background

	Tracheal intubation (TI) performed in the emergency setting is more challenging than when
	attempted in an operating room due to patient, operator, and environment-associated factors
	[1-3]. Consequently, the success rate is lower, the time needed to undertake the TI is longer,
5	and the complication rate is higher [1, 2, 4, 5].
	Video laryngoscopes (VLs) are increasingly used to increase the safety and success
	rates of emergency TIs. The VLs used in clinical practice include the Pentax-Airway Scope™
	(Pentax), the King Vision <sup>®</sup> (King), and the McGrath <sup>™</sup> MAC (McGrath). VLs are classified
	according to the guidance method of the tracheal tube. The Pentax and King VLs are
10	L-shaped, with an attachment of the tracheal tube to the blade, while McGrath has no
	attachment, which facilitates the flexible orientation of the tube. Compared to the Macintosh
	laryngoscope (Macintosh), the superiority of VLs in viewing the glottis and in successfully
	completing TIs has been confirmed in a manikin model [6] and in patients undergoing
	elective surgery [7-10]. However, a randomized trial in intensive care units (ICUs) showed
15	no difference in first-pass intubation success rates between VLs and the Macintosh system
	[11]. A systematic review of emergency TIs in emergency departments (EDs) and ICUs
	showed that the use of VLs had no significant advantage with regards to first-attempt success

rates, although their use was significantly associated with a lower number of intubation attempts [12]. However, these studies included various types of VL in a single group and did not consider the characteristics of each VL. To our knowledge, no study has examined the relative performance of VLs, especially in emergency TIs. The identification of the optimal VL is important, in view of a) the high rate of difficult emergency TIs (10% in the non-operative area including the ED and the ICU) and multiple intubation attempts (11% in the ED) [1, 13] and b) the increased incidence of adverse events associated with unsuccessful attempts, in which more than one attempt at TI was a significant predictor of one or more adverse events (adjusted odds ratio= 7.5, 95%) confidence interval [CI] = 5.9 to 9.6)). [14]. The aim of this study was to identify the optimal VL among the Pentax, King, and McGrath systems when compared to the Macintosh for the emergency performance of TI in

the ED or ICU.

## Methods

#### Study design and setting

This retrospective, observational study was conducted at a university hospital and at a general, public hospital. This study was reviewed and approved by the research ethics committee of Hiroshima University and Hiroshima Prefectural Hospital (Nos. 1069 and 2013-76, respectively). Both boards waived the need to obtain patient informed consent before collecting the data. We disclosed information regarding this study on a webpage and offered an opportunity to opt out. The ICUs of both institutions treat ambulatory and postoperative, medical and surgical, and pediatric and adult patients. The physicians were responsible for primary care in

the ED and for critical care in the ICU. Both were staffed by board-certified attending physicians in emergency or intensive care medicine, or by anesthesiologists, and by post-graduate residents (years 3-7) in emergency medicine, anesthesiology, and internal medicine. In addition, transitional post-graduate residents (years 1 and 2) rotated for several

15 months in the EDs and ICUs. Most of the transitional year residents completed ≥1 month of training in anesthesiology in the operating room, during which they performed TI, using Macintosh in patients undergoing general anesthesia, under the supervision of attending

	an	nesthesiologists. When difficult airways or cervical instability were anticipated, the choice
	of	TVL was left to the discretion of the supervisors.
		Three VLs, including the Pentax (Pentax-Airway Scope™; AWS-S100, HOYA
	Co	orporation, Tokyo, Japan), King, (King Vision <sup>®</sup> , King Systems, Noblesville, IN) and
÷	5 M	cGrath (McGrath <sup>™</sup> MAC; 300-000-000, Medtronic Inc, Minneapolis, MN) systems, as
	W	ell as a Macintosh laryngoscope (Macintosh blade, KARL STORZ SE & Co, Tuttingen,
	G	ermany) as a reference standard, were available in this study. These VL had been
	co	ommonly used prior to this study for several years in both institutions and there was no
	sp	becific off-the-job training for these VLs. Channeled disposable blades were used with the
10	) <b>K</b> i	ing system. The laryngoscopes, drugs, or operators for the TI procedures were chosen by
	th	e attending physician(s) without protocol. Using a hand-held or fixed camera, the
	pr	ocedures were systematically video-recorded for archival and quality control.
	St	tudy participants
1:	5 W	ve included consecutive video-recorded cases of emergency TI performed in the ED and
	IC	CU of both institutions between December 2013 and June 2015.

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	Data collection and measurements
	We recorded the patient demographic and clinical characteristics; location of the TI (ED or
	ICU); indications for TI (cardiopulmonary arrest, airway obstruction, respiratory failure,
	hemodynamic instability, or altered mental status); drugs used for TI (sedatives, analgesics,
5	and muscle relaxants); pre-procedurally defined complicating airway characteristics
	including obesity (body mass index $\geq$ 28 kg/m <sup>2</sup> ), limited mouth opening (inter-incisor
	distance <4 cm), restricted neck mobilization, short neck (thyromental distance <6 cm),
	facial trauma (diagnosed clinically and by imaging), edema of the glottis visualized by the
	operator, and the presence of blood, secretions, or vomitus in the airways requiring suction or
10	interfering with the procedure. The laryngoscopes used, the length of clinical experience, and
	the specialty of the operators were recorded. The subjective difficulty, using a visual
	analogue scale between 0 (easy) and 100 (difficult) was scored by the operators. The
	first-pass intubation success rate, the number of attempts until successful TI, changes of
	laryngoscopes and operators, time between laryngoscope insertion into the mouth and the
15	onset of ventilation after TI, complications (edema or spasm of the glottis, dental injuries,
	regurgitation, and airway hemorrhages), esophageal intubations, and the laryngoscope in use
	when the complication or the esophageal intubation occurred, were recorded. The data were

collected from the video recording for measurements of variables, in addition to medical records and a questionnaire. Data collection and analysis were performed by a single author (KS).

## 5 Study endpoints

The primary study endpoint was the first-pass intubation success rate, while the secondary endpoints were the time needed to perform the procedure, the subjective difficulty score, procedural complications, and esophageal intubation.

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#### 10 Sample size and statistical analysis

The estimated sample size was based on our own unpublished TI study performed by residents in patients undergoing elective surgery, in which the first-pass intubation success rates using the Macintosh and Pentax instruments were 64% and 90%, respectively. Assuming a 20% difference in first-pass intubation success rates between the two laryngoscopes, we calculated a sample size of 62 procedures in each group at the 5%  $\alpha$  level and a power (1- $\beta$ ) of 80%. Including missing data, we set the sample sizes of each group at

70 and a total of 280 procedures.

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3 4 5		Categorical variables are expressed as counts and percentages and continuous variables
6 7		
8 9		as means $\pm$ standard deviations. We compared the outcomes among the four laryngoscopes by
10 11 12 13		Fisher's exact or Kruskal-Wallis tests. Procedures without an accurate measurement of the time
13 14 15 16		needed to perform the TI from the video recording as well as those without subjective
17 18 19	5	difficulty scores were excluded from the analysis. A post hoc analysis was performed by
20 21 22 23		comparing all laryngoscopes pairwise to each other using Tukey's test. We also examined
23 24 25 26		whether the first-pass intubation success rates differed among the four laryngoscopes, in each
27 28 29		prespecified subgroup, according to the duration of clinical experience (1st and 2nd
30 31 32 33		post-graduate years as non-expert operators and $\geq 3^{rd}$ post-graduate year as experts). A logistic
34 35 36	10	regression analysis was performed to identify factors influencing the first-pass intubation
37 38 39		success rate. We included possible confounding factors that differed significantly among the
40 41 42 43		four laryngoscopes (indication for TI and restricted neck mobility) and which were identified
43 44 45 46		in previous studies (limited mouth aperture,[15] blood, secretion or vomitus in the airways,[16]
47 48 49		experts versus non-expert operator[17]). P-values <0.05 were considered statistically
50 51 52	15	significant. The analyses were performed using IBM SPSS Statistics for Mac, version 23.0
53 54 55 56 57 58 59		(IBM Corporation, Armonk, NY).

## Results

The patient characteristics are summarized in Table 1. A total of 287 patients underwent video-recorded emergency TI. Among the indications for TI, hemodynamic instability differed significantly among the four laryngoscopes, with the McGrath most frequently used in the presence of hemodynamic instability. Complicating airway characteristics were present in 56% of cases, including blood, secretions, or vomitus in the airways in 123 procedures (43%). The Pentax was often used during procedures complicated by restricted neck mobility. Among the 67 non-experts, 57 operators (89.1%) had received some anesthesiology training in the operating room. They performed  $33\pm14$  TIs, including  $6\pm5$  procedures using Pentax or McGrath VLs. TI was interrupted in three cases (1%), of which one was managed without TI; another underwent emergency cricothyroidotomy and a third suffered fatal cardiopulmonary arrest. In the remaining 284 procedures, TI was attempted once in 199 (69%), twice in 49 (17%), and >twice in 36 instances (13%). The number of attempts until successful TI were 1.3±0.9 with Pentax, 1.4±0.7 with King, 1.3±0.6 with McGrath, and 1.5±0.7 with Macintosh (P=0.007). The laryngoscope was replaced in 22 cases (8%). Out of 59 procedures, the King was replaced by another laryngoscope in nine instances (15%; P=0.043 vs. other groups).

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 The King was replaced by another device in seven procedures because of separation of the laryngoscope from its disposable blade. The operator was replaced in 21 attempts at TI (7%), of which 19 were initially made by a non-expert operator. The number of operators were similarly replaced in the four study groups.

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#### Main results

The overall first-pass intubation success rate was 69% and differed significantly (P=0.004) among the four laryngoscopes (table 2). In *post hoc* analysis, the first-pass intubation success rates were higher for the Pentax and McGrath than those with the King or Macintosh laryngoscopes, respectively, although the difference was significant only in the subgroup of non-expert operators (Table 2). The first-pass intubation success rates were similar in non-experts and experts. Logistic regression analysis with adjustments for the indication for TI, restricted neck mobilization, limited mouth opening, blood/secretion/vomitus in the airway, and experts/non-expert revealed that the odds ratios for first-pass intubation success were significantly higher for the Pentax and McGrath laryngoscopes (Table 3). There were significant differences in the times needed to perform TI among the

four laryngoscopes, although no differences were observed in pairwise comparisons of the

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laryngoscopes in the post hoc analysis. There was a significant difference in the difficulty scores among the four laryngoscopes, with the McGrath significantly easier to use than the Macintosh in post hoc analysis (Table 4). TI complications occurred in 21 procedures (7%), consisting of one dental trauma, seven spasms or edemas of the glottis, five instances of regurgitation, and 10 hemorrhages, although there were no significant differences among the four laryngoscopes. The esophagus was intubated in three instances (1.2%) by non-experts using the Macintosh. 

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# Discussion

	In this retrospective, observational, two-center study, the first-pass success rates for
	emergency TI were significantly higher for Pentax or McGrath laryngoscopes than for King
	or Macintosh laryngoscopes when performed by non-expert operators. After adjusting for
5	confounding factors, the odds ratios for first-pass intubation success were significantly higher
	for the Pentax and McGrath laryngoscopes. The use of the McGrath was associated with a
	lower subjective difficulty of performing TI than that for the use of the Macintosh.
	A previous study of VLs for TI by experienced anesthetists in the operating room
	revealed a better visualization of the glottis with the Pentax than that with the Macintosh,
10	while the success rates and TI procedure times were similar [8]. Moreover, studies with
	inexperienced residents reported a 96% first-pass success rate with the Pentax versus 70%
	with the Macintosh and 44 and 71 sec, respectively, to secure the airways [9]. Our results are
	concordant with these success rates, suggesting the advantageous characteristics of the
	Pentax, particularly for novice operators. The suitable shape of the PBLADE®, which
15	indirectly visualizes the glottis regardless of the head and neck position, the existence of a
	blade channel to set the tracheal tube, and the guiding function of the target mark on the
	screen support the preferential use of the Pentax among the VLs [18].

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	The McGrath is a relatively compact device without a tracheal tube guide channel
	[19]. Like the Macintosh, it offers an indirect view of the glottis by flexible manipulations of
	the laryngoscope and tracheal tube. Several factors, therefore, such as a restricted neck
	mobility or the operator's experience with TI, might influence the success rate of the Pentax
5	versus the McGrath. However, the first-pass intubation success rates were nearly the same
	between these VLs in this study population. A randomized study comparing the performance
	of Pentax versus McGrath in emergency TI is, therefore, warranted.
	To our knowledge, the present study was the first to compare the Pentax and King
	in clinical settings. Although they have similar shapes and tracheal tube guiding
10	characteristics, the first-pass intubation success rate was significantly lower for the King than
	that for the Pentax. The orientation of the King tracheal tube is relatively downward
	compared to that of the Pentax, which may interfere with its advancement. In addition, the
	King has no marking to help in the placement of the tube. System malfunction, which
	occurred in seven patients in this study, may also have lowered the success rate of the King.
15	Several factors, which varied among the four laryngoscopes, had repercussions on the
	success rate of TI. Blood or vomitus in the airways, an important complication when
	performing emergency TI, may lower the image quality. Blood, secretions, or vomitus were

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present in the airways in 43% of procedures, significantly lowering the first-pass intubation success rate [16]. However, after adjusting for this factor, multiple variable analysis confirmed the advantage of the Pentax and McGrath. A limited mouth aperture was also correlated with the difficulty of TI [15]. This, however, was problematic in only 6% of cases and did not represent a major obstacle to the insertion of the devices. The results of the present study suggest the usefulness of the Pentax or McGrath VLs for emergency TI performed by novice physicians. However, the generalizability of the results for intubation in other settings (in the operating theater or prehospital settings, or by ê. Runer

non-physicians) remains uncertain.

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## **Study limitations**

This was an observational study, in which confounding factors may have influenced the success rate of TI and biased the results. However, after adjusting for possible confounding factors based on those reported in previous studies, we observed a significant relationship between VLs and first-pass intubation success rates. We included video-recorded cases of TI during the study period. Unfortunately, only 22% of cases were recorded due to the limited availability of physicians who were able to operate the video cameras. Thus, there might be a

selection bias. The data collection and analysis were performed by a single author (KS), leaving the potential for observer bias. Furthermore, we classified the "non-experts" based on their clinical experience. A precise index to grade the level of intubation skill might have been preferable, although it does not currently exist. Finally, bias based on operator familiarity with each laryngoscope cannot be excluded. However, given the scarce overall experience of TI itself prior to this study (4.6 times/person), the results of the non-expert biased. group are likely to be less biased.

## Conclusion

When performing emergency TI in the ED or the ICU, the use of the Pentax and

McGrath laryngoscopes was associated with significantly higher first-pass intubation success

rates, especially when operated by non-experts.

# List of Abbreviations

	TI	tracheal intubation
	VL	video laryngoscope
	Pentax	Pentax-Airway Scope™
5	King	King Vision <sup>®</sup>
	McGrath	McGrath <sup>®</sup> MAC
	Macintosh	Macintosh laryngoscope
	ICU	intensive care unit
	ED	emergency department
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## Declarations

Acknowledgements: We thank the attending physicians and residents of the Department of Emergency and Critical Care Medicine of Hiroshima University and the Critical Care Medical Center of Hiroshima Prefectural Hospital who contributed to the data collection.

**Contributions**: Suzuki conceived the study, designed the trial, and collected and managed the data. Kusunoki, Tanigawa, and Shime supervised the conduct of the trial and data collection. Suzuki drafted the manuscript, and all authors contributed substantially to its revision. Suzuki takes responsibility for the paper as a whole.

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

**Ethics approval and consent to participate**: This study was reviewed and approved by the research ethics committees of Hiroshima University (No.1069) and Hiroshima Prefectural Hospital (No.2013-76).

**Trial registration number:** University Hospital Medical Information Network

Clinical Trials Registry (UMIN000027925,

https://upload.umin.ac.jp/cgi-open-bin/ctr\_e/ctr\_view.cgi?recptno=R000016182); date of

registration 26.06.2017 (retrospectively registered)

**Consent for publication**: Not applicable.

**Data sharing statement:** No additional data available.

Patient and Public Involvement statement: Patients were not involved.

 

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Table 1. Baseline and difficult airway charac						
	All	Pentax-Airway Scope	King VISION	McGrath Mag	Macintosh	
Mar	(n=287)	(n=82)	(n=59)	$\frac{(n=82) \stackrel{9}{\omega}}{(n=82)}$	(n=64)	
Men	165 (57.5)	54 (65.9)	31 (52.5)	$51(62.2) \leq$	29 (45.3)	
Age, years	65.4±20.5	60.7±24.8	69.0±16.2	67.4±17.1 arcs	65.7±21.4	
Height, cm	158.1±14.4	156.9±19.3	159.3±9.0	160.9±10.2 <sup>5</sup>	154.9±14.9	
Weight, kg	55.9±13.9	56.3±16.9	56.2±10.2	56.7±11.9 9	54.0±15.2	
Body mass index	22.0±3.7	22.3±3.8	22.1±3.6	21.7±3.2 0	22.1±4.2	
Expert operators	131 (45.6)	36 (43.9)	27 (45.8)	45 (54.9) om	23 (35.9)	
	162 (56.4)/125 (43.6)	49 (59.8)/33 (40.2)	37 (62.7)/22 (37.3)	37 (45.1)/45 (5459)	39 (60.9)/25 (39.1)	
Indications for tracheal intubation	114 (20.7)	24 (41 5)	06 (44.1)	25 (30.5) from 7 (8.5) m	20 (45 2)	
Cardiopulmonary arrest	114 (39.7)	34 (41.5)	26 (44.1)	$\frac{25(30.5)}{7(9.5)}$	29 (45.3)	
Airway obstruction	14 (4.9)	4 (4.9)	1 (1.7)		2 (3.1)	
Respiratory failure	45 (15.7)	12 (14.6)	11 (18.6)		8 (12.5)	
Hemodynamic instability Altered mental status	32 (11.1)	6 (7.3)	2 (3.4)	20 (24.4)	4 (6.3)	
	82 (28.6)	26 (31.7)	19 (32.2)	20 (24.4) 16 (19.5) moon 35 (42.7) b	21 (32.8)	
Drugs used for tracheal intubation	140 (51 ()	14 (52 7)	22 (54.2)		27 (57.9)	
None Sedatives	148 (51.6)	44 (53.7)	32 (54.2)	35 (42.7) . 25 (42.7)	37 (57.8)	
	116 (40.4)	33 (40.2)	24 (40.7)	35 (42.7) <u>∃</u> .	24 (37.5)	
Analgesics	91 (31.7)	22 (26.8)	15 (25.4)	36 (43.9) <b>6</b>	18 (28.1)	
Muscle relaxants	59 (20.6) (m=172)	15 (18.3)	10(16.9)	22 (26.8) on	12(18.8)	
Drugs used for tracheal intubation in Non-CPA cases	(n=173)	(n=48)	(n=33)	(n=57)	(n=35)	
None	34 (19.7)	10 (20.8)	6 (18.2)	10 (17.5) 35 (61.4)	8 (22.9)	
Sedatives	116 (67.1)	33 (68.8)	24 (72.7)		24 (68.6)	
Analgesics	91 (52.6) 50 (24.1)	22 (45.8)	15 (45.5)	36 (63.2)역 22 (38.6)	18 (51.4)	
Muscle relaxants	59 (34.1)	15 (31.3)	10 (30.3)	· · · · ·	12 (34.3)	
Difficult airway characteristics	1((5.0)	((7,2))	2(51)	3 (3.7) 2024	4 (6 2)	
Obesity	16 (5.6)	6 (7.3)	3 (5.1)	· · · · · · · · · · · · · · · · · · ·	4 (6.3)	
Limited mouth opening	17 (5.9)	5 (6.1)	5 (8.5)	<sup>с</sup> (,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	1 (1.6)	
Restricted neck mobilization	39 (13.6)	19 (23.2)	6 (10.2)	7 (8.5) uest	7 (10.9)	
Short neck	9 (3.1)	3 (3.7)	1 (1.7)		2 (3.1)	
Facial trauma	13 (4.5)	7 (8.5)	1 (1.7)	4 (4.9) Protect	1 (1.6)	
Edema of glottis	7 (2.4)	2 (2.4)	0(0.0)	4 (4.9) of the definition of t	1 (1.6) 26 (40.6)	
Bloods, secretion, or vomitus in airway	123 (42.9)	36 (43.9)	23 (39.0)		26 (40.6)	
Cases with difficult airway characteristics	161 (56.1)	47 (57.3)	31 (52.5)	48 (58.5) by opyright	35 (54.7)	

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BMJ Open Removes (%) of observations or means ± standard deviations. ED, emergency department; ICU, intensive care unit; CP , eme, 27 on 30 March 2019. Downloaded from http://bmjopen.bmj.com/ on November 22, 2024 by guest. Protected by copyright.

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	All laryngoscopes	Pentax-Airway Scope	King VISION	McGr <b>g</b> th Mac	Macintosh	Р
All operators, n	287	82	59	30aMa	64	
First-pass intubation success	199 (69)	64 (78)*	34 (58)	64 (\$78)†	37 (58)	0.004
Non-expert operators	156	46	32	2049.	41	
First-pass intubation success	104 (67)	40 (87)‡	16 (50)	29 <b>9</b> 8)§	19 (46)	0.00004
Expert operators	131	36	27	wntad	23	
First-pass intubation success	95 (73)	24 (67)	18 (67)	35 <b>8</b> 78)	18 (78)	0.556

Values are numbers (%) of observations; post hoc analyses were performed using Tukey's test for paired comparisons gf four laryngoscopes .

\*:vs. King VISION P=0.043, \*:vs. Macintosh P=0.039, †:vs. King VISION P=0.043, †:vs. Macintosh P=0.039

:vs. King VISION P=0.002, :vs. Macintosh P<0.001, vs. King VISION P=0.043, vs. Macintosh P=0.009

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Factors	Odd ratios	95% confidence intervals	Р
Laryngoscopes			
Macintosh (reference)	1	-	-
Pentax-Airway Scope	3.422	1.551-7.550	0.002
King VISION	1.056	0.487-2.289	0.889
McGrath Mac	3.758	1.640-8.612	0.002
Indications for tracheal intubation			
Cardiopulmonary arrest	1 (reference)		
Airway obstruction	0.226	0.063-0.812	0.023
Respiratory failure	0.720	0.284-1.822	0.488
Hemodynamic instability	0.380	0.137-1.054	0.063
Altered mental status	0.361	0.180-0.723	0.004
Difficult airway characteristics			
Mouth opening			
Unlimited	1 (reference)	-	-
Limited	0.092	0.026-0.323	0.000
Neck mobility			
Unrestricted	1 (reference)	-	-
Restricted	0.951	0.414-2.182	0.905
Blood, secretions, vomitus in the airways			
Absent	1 (reference)	-	-
Present	0.455	0.257-0.804	0.007
Operators			
Non-expert	1 (reference)	-	-
Expert	1.688	0.916-3.108	0.093

Table 3. Multiple variable analysis of factors influencing the first-pass intubation success rates

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Γable 4. Comparisons of t	imes needed to	) perform tracheal int	ubations and o	f difficulty sco	2018-02 res for fouration	fferen
-	Overall	Pentax-Airway Scope		-	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	Р
Time to perform intubations, sec	60±31 (n=269)	63±34 (n=78)	63±31 (n=45)	62±31 (n=79)	52±27 (n=6)	0.043
Difficulty score <sup>†</sup>	39±27 (n=258)	39±26 (n=72)	43±26 (n=45)	32±27* (n=78)	45±26 (n=6)	0.009
<i>bost hoc</i> analyses were perform	med using Tukey	y's test for paired compar	isons of 4 laryngo	oscopes.	2019. Downloaded from http://bmjopen.bmj.com/ on November 22, 2024 by guest. Protected by copyright.	

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	Item		Reported on p
Title and abstract	<u>No</u>	Recommendation	<u>No</u>
Title and abstract	1	( <i>a</i> ) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
			2.2
		(b) Provide in the abstract an informative and balanced	2-3
		summary of what was done and what was found	
Introduction Background/rationale	2	Explain the scientific background and rationale for the	4-5
Dackground/rationale	2	investigation being reported	4-3
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
-	3	state specific objectives, including any prespecified hypotheses	4-3
Methods			6.0
Study design	4	Present key elements of study design early in the paper	6-8
Setting	5	Describe the setting, locations, and relevant dates, including	6
Deuticius (		periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of	7
		selection of participants. Describe methods of follow-up	<u> </u>
		(b) For matched studies, give matching criteria and number of	
37 . 11	7	exposed and unexposed	7.0
Variables	7	Clearly define all outcomes, exposures, predictors, potential	7-8
		confounders, and effect modifiers. Give diagnostic criteria, if	
Data anumana/	8*	applicable	7-8
Data sources/	8*	For each variable of interest, give sources of data and details of	/-8
measurement		methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	9
Quantitative variables	10	Explain how the study size was arrived at Explain how quantitative variables were handled in the	<del>7</del> -8
Qualititative variables	11	analyses. If applicable, describe which groupings were chosen	/-0
		and why	
Statistical methods	12	( <i>a</i> ) Describe all statistical methods, including those used to	9-10
		control for confounding	<i>y</i> 10
		(b) Describe any methods used to examine subgroups and	9
		interactions	,
		(c) Explain how missing data were addressed	9
		(d) If applicable, explain how loss to follow-up was addressed	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg	11
i un un un punto	10	numbers potentially eligible, examined for eligibility,	
		confirmed eligible, included in the study, completing follow-up,	
		and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic,	25
		clinical, social) and information on exposures and potential	
		confounders	
		(b) Indicate number of participants with missing data for each	11

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		variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	12-13, 26
Main results	16	( <i>a</i> ) Give unadjusted estimates and, if applicable, confounder- adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	26, 27
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12, 26
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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## Comparison of three video laryngoscopes and direct laryngoscopy for emergency endotracheal intubation - a retrospective cohort study

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**Original** articles

# Comparison of three video laryngoscopes and direct laryngoscopy for

## emergency endotracheal intubation - a retrospective cohort study

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Abstract **Objective:** Video laryngoscopes are used for managing difficult airways. This study compared three video laryngoscopes' (Pentax-Airway Scope<sup>™</sup> [Pentax], King Vision<sup>®</sup> [King], and McGrath<sup>®</sup> MAC [McGrath]) performances with the Macintosh direct laryngoscope [Macintosh] as emergency tracheal intubations (TIs) reference. Design: Retrospective cohort study. Setting: The emergency department and the intensive care unit of two Japanese tertiary-level hospitals. Participants: All consecutive video-recorded emergency TI cases in emergency departments and intensive care units between December 2013 and June 2015. Primary outcome measures: The primary study endpoint was first-pass intubation success. A subgroup analysis examined the first-pass intubation success of expert versus non-expert operators. A logistic regression analysis was performed to identify the predictors of first-pass intubation success. Results: A total of 287 emergency TIs were included. The first-pass intubation success rates were 78%, 58%, 78%, and 58% for the Pentax, King, McGrath, and Macintosh instruments, respectively (P=0.004, Fisher's exact test). The non-expert operators' success rates were

significantly higher (P=0.00004, Fisher's exact test) for the Pentax (87%) and McGrath

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	(78%) instruments than that for the King (50%) and Macintosh (46%) instruments, unlike
	that of the experts (67%, 67%, 78%, and 78% for Pentax, McGrath, King and Macintosh,
	respectively; P=0.556, Fisher's exact test). After TI indication, difficult airway
	characteristics, and expert versus non-expert operator parameters adjustments, the Pentax
5	(odds ratio = 3.422, 95% confidence interval 1.551-7.550; P=0.002) and McGrath (3.758,
	1.640-8.612; P=0.002) instruments showed significantly higher first-pass intubation success
	odds when compared to the Macintosh laryngoscope (reference, odds ratio = 1). The King
	instrument, however, (odds ratio = $1.056$ ; 95% confidence interval 0.487-2.289, p = 0.889)
	failed to show any significant superiority.
10	Conclusion: The Pentax and McGrath laryngoscopes showed significantly higher emergency
	TI first-pass intubation success rates than the King laryngoscope when compared to the
	Macintosh laryngoscope, especially for non-expert operators.
	Trial registration: UMIN000027925
15	Keywords: Emergency intubation, tracheal intubation, laryngoscopy, video-assisted

laryngoscopy, video laryngoscope, video laryngoscopy

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Strengths and limitations of this study To our knowledge, this study is the first to directly compare three different video laryngoscopes (Pentax-Airway Scope<sup>™</sup>, King Vision<sup>®</sup>, McGrath<sup>™</sup> MAC) and the Macintosh laryngoscope for emergency TI. The strength of this study is that we precisely evaluated the intubation process among four laryngoscopes using real-world video records of TI. The major limitation of this study is its observational design. Although we tried to adjust for almost all possible confounding factors based on previous studies, we could not completely exclude the influence of other confounding factors on the results. Liezoni

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# Background Tracheal intubation (TI) performed in the emergency setting is more challenging than when attempted in an operating room due to patient, operator, and environment-associated factors [1-3]. Consequently, the success rate is lower, the time needed to undertake the TI is longer, and the complication rate is higher [1, 2, 4, 5]. Video laryngoscopes (VLs) are increasingly used to increase the safety and success rates of emergency TIs. Amongst others, the VLs used in clinical practice include the Pentax-Airway Scope™ (Pentax), the King Vision<sup>®</sup> (King), and the McGrath™ MAC (McGrath). VLs are classified according to the guidance method of the tracheal tube. The Pentax and King VLs are L-shaped, with an attachment of the tracheal tube to the blade, while McGrath

has no attachment, which facilitates the flexible orientation of the tube. Compared to the Macintosh laryngoscope (Macintosh), the superiority of VLs in viewing the glottis and in successfully completing TIs has been confirmed in a manikin model [6] and in patients undergoing elective surgery [7-10]. However, a randomized trial in intensive care units
15 (ICUs) showed no difference in first-pass intubation success rates between VLs and the

Macintosh system [11]. A systematic review of emergency TIs in emergency departments

(EDs) and ICUs showed that the use of VLs had no significant advantage with regards to

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	first-attempt success rates, although their use was significantly associated with a lower
	number of intubation attempts [12]. However, these studies included various types of VL in a
	single group and did not consider the characteristics of each VL. To our knowledge, no study
	has examined the relative performance of VLs, especially in emergency TIs.
5	The identification of the optimal VL is important, in view of a) the high rate of
	difficult emergency TIs (10% in the non-operative area including the ED and the ICU) and
	multiple intubation attempts (11% in the ED) [1, 13] and b) the increased incidence of
	adverse events associated with unsuccessful attempts, in which more than one attempt at TI
	was a significant predictor of one or more adverse events (adjusted odds ratio= 7.5, 95%
10	confidence interval [CI] = 5.9 to 9.6)). [14].
	The aim of this study was to compare the emergency TI performances of the Pentax,
	King, and McGrath systems with that of the Macintosh in the ED or ICU.

# Methods

### Study design and setting

This retrospective, observational study was conducted at a university hospital and at a general, public hospital. This study was reviewed and approved by the research ethics committee of Hiroshima University and Hiroshima Prefectural Hospital (Nos. 1069 and 2013-76, respectively). Both boards waived the need to obtain patient informed consent before collecting the data. We disclosed information regarding this study on a webpage and offered an opportunity to opt out. The ICUs of both institutions treat ambulatory and postoperative, medical, and surgical, and pediatric and adult patients. The physicians were responsible for primary care in the ED and for critical care in the ICU. Both were staffed by board-certified attending physicians in emergency or intensive care medicine, or by anesthesiologists, and by postgraduate residents (years 3-7) in emergency medicine, anesthesiology, and internal medicine. In addition, transitional post-graduate residents (years 1 and 2) rotated for several months in

the EDs and ICUs. Most of the transitional year residents completed  $\geq 1$  month of training in anesthesiology in the operating room, during which they performed TI, using Macintosh in

patients undergoing general anesthesia, under the supervision of attending anesthesiologists.

 When difficult airways or cervical instability were anticipated, the choice of VL was left to the discretion of the supervisors. Three VLs, including the Pentax (Pentax-Airway Scope™; AWS-S100, HOYA Corporation, Tokyo, Japan), King, (King Vision<sup>®</sup>, King Systems, Noblesville, IN) and McGrath (McGrath<sup>™</sup> MAC; 300-000-000, Medtronic Inc, Minneapolis, MN) systems, as well as a Macintosh laryngoscope (Macintosh blade, KARL STORZ SE & Co, Tuttingen, Germany) as a reference standard, were available in this study. These VL had been commonly used prior to this study for several years in both institutions and there was no specific off-the-job training for these VLs. Channeled disposable blades were used with the King system. The laryngoscopes, drugs, or operators for the TI procedures were chosen by the attending physician(s) without protocol. Using a hand-held or fixed camera, the procedures were systematically video-recorded for archival and quality control.

## **Study participants**

15 We included consecutive video-recorded cases of emergency TI performed in the ED and ICU of both institutions between December 2013 and June 2015.

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3 4 5 6		Data collection and measurements	
7 8 9		We recorded the patient demographic and clinical characteristics; location of the TI (ED or	Ĺ
10 11 12		ICU); indications for TI (cardiopulmonary arrest, airway obstruction, respiratory failure,	
13 14 15 16		hemodynamic instability, or altered mental status); drugs used for TI (sedatives, analgesics	, ,
16 17 18 19	5	and muscle relaxants); pre-procedurally defined complicating airway characteristics	
20 21 22		including obesity (body mass index $\geq$ 28 kg/m <sup>2</sup> ), limited mouth opening (inter-incisor	
23 24 25 26		distance <4 cm), restricted neck mobilization, short neck (thyromental distance <6 cm),	
20 27 28 29		facial trauma (diagnosed clinically and by imaging), edema of the glottis visualized by the	
30 31 32		operator, and the presence of blood, secretions, or vomitus in the airways requiring suction	1 or
33 34 35 36	10	interfering with the procedure. The laryngoscopes used, the length of clinical experience, a	and
37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56		the specialty of the operators were recorded. The subjective difficulty, using a visual	
		analogue scale between 0 (easy) and 100 (difficult) was scored by the operators. The first-	
		pass intubation success rate, the number of attempts until successful TI, changes of	
		laryngoscopes and operators, time between laryngoscope insertion into the mouth and the	
	15	onset of ventilation after TI, complications (edema or spasm of the glottis, dental injuries,	
		regurgitation, and airway hemorrhages), esophageal intubations, and the laryngoscope in us	se
57 58 59 60		when the complication or the esophageal intubation occurred, were recorded. The data wer	re

collected from the video recording for measurements of variables, in addition to medical records and a questionnaire. Data collection and analysis were performed by a single author

### 5 Study endpoints

(KS).

The primary study endpoint was the first-pass intubation success rate, while the secondary endpoints were the time needed to perform the procedure, the subjective difficulty score, procedural complications, and esophageal intubation.

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### 10 Sample size and statistical analysis

The estimated sample size was based on our own unpublished TI study performed by residents in patients undergoing elective surgery, in which the first-pass intubation success rates using the Macintosh and Pentax instruments were 64% and 90%, respectively. Assuming a 20% difference in first-pass intubation success rates between the two laryngoscopes, we calculated a sample size of 62 procedures in each group at the 5%  $\alpha$  level and a power (1– $\beta$ ) of 80%. Including missing data, we set the sample sizes of each group at

70 and a total of 280 procedures.

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3 4 5 6		Categorical variables are expressed as counts and percentages and continuous variables
7 8 9		as means $\pm$ standard deviations. We compared the outcomes among the four laryngoscopes by
10 11 12		Fisher's exact or Kruskal-Wallis tests. Procedures without an accurate measurement of the
13 14 15 16		time needed to perform the TI from the video recording as well as those without subjective
17 18 19	5	difficulty scores were excluded from the analysis. A <i>post hoc</i> analysis was performed by
20 21 22		comparing all laryngoscopes pairwise to each other using Tukey's test. We also examined
23 24 25 26		whether the first-pass intubation success rates differed among the four laryngoscopes, in each
27 28 29		prespecified subgroup, according to the duration of clinical experience (1 <sup>st</sup> and 2 <sup>nd</sup> post-
30 31 32		graduate years as non-expert operators and $\geq 3^{rd}$ post-graduate year as experts). A logistic
33 34 35 36	10	regression analysis was performed to identify factors influencing the first-pass intubation
37 38 39		success rate. We included possible confounding factors that differed significantly among the
40 41 42		four laryngoscopes (indication for TI and restricted neck mobility) and which were identified
43 44 45		in previous studies (limited mouth aperture,[15] blood, secretion or vomitus in the airways,[16]
46 47 48 49		experts versus non-expert operator[17]). P-values <0.05 were considered statistically
50 51 52	15	significant. The analyses were performed using IBM SPSS Statistics for Mac, version 23.0
53 54 55		(IBM Corporation, Armonk, NY).
56 57 58 59 60		Patient and Public Involvement statement: Patients were not involved.

## Results

### Characteristics of the study population

The patient characteristics are summarized in Table 1. A total of 287 patients underwent video-recorded emergency TI. Among the indications for TI, hemodynamic instability differed significantly among the four laryngoscopes, with the McGrath most frequently used in the presence of hemodynamic instability. Complicating airway characteristics were present in 56% of cases, including blood, secretions, or vomitus in the airways in 123 procedures (43%). The Pentax was often used during procedures complicated by restricted neck mobility. Among the 67 non-experts, 57 operators (89.1%) had received some anesthesiology training in the operating room. They performed 33±14 TIs, including 6±5 procedures using Pentax or McGrath VLs. TI was interrupted in three cases (1%), of which one was managed without TI; another underwent emergency cricothyroidotomy and a third suffered fatal cardiopulmonary arrest. In the remaining 284 procedures, TI was attempted once in 199 (69%), twice in 49 (17%), and >twice in 36 instances (13%). The number of attempts until successful TI were 1.3±0.9 with Pentax, 1.4±0.7 with King, 1.3±0.6 with McGrath, and 1.5±0.7 with Macintosh (P=0.007). The laryngoscope was replaced in 22 cases (8%). Out of 59 procedures, the King was replaced by another laryngoscope in nine instances (15%;

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P=0.043 vs. other groups). The King was replaced by another device in seven procedures because of separation of the laryngoscope from its disposable blade. The operator was replaced in 21 attempts at TI (7%), of which 19 were initially made by a non-expert operator. The number of operators were similarly replaced in the four study groups.

# Main results

 The overall first-pass intubation success rate was 69% and differed significantly (P=0.004) among the four laryngoscopes (table 2). In *post hoc* analysis, the first-pass intubation success rates were higher for the Pentax and McGrath than those with the King or Macintosh laryngoscopes, respectively, although there were no significant differences in the expert operators' subgroup (Table 2). Overall, non-experts and experts showed similar first-pass intubation success rates of 67% and 73%, respectively. Logistic regression analysis with adjustments for the indication for TI, restricted neck mobilization, limited mouth opening, blood/secretion/vomitus in the airway, and experts/non-expert revealed that the odds ratios for first-pass intubation success were significantly higher for the Pentax and McGrath laryngoscopes than that for the King laryngoscope when compared to the Macintosh laryngoscope (Table 3).

	There were significant differences in the times needed to perform TI among the
	four laryngoscopes, although no differences were observed in pairwise comparisons of the
	laryngoscopes in the post hoc analysis (Table 4). There was a significant difference in the
	difficulty scores among the four laryngoscopes, with the McGrath significantly easier to use
5	than the Macintosh in <i>post hoc</i> analysis (Table 4).
	TI complications occurred in 21 procedures (7%), consisting of one dental
	trauma, seven spasms or edemas of the glottis, five instances of regurgitation, and 10
	hemorrhages, although there were no significant differences among the four laryngoscopes.
	The esophagus was intubated in three instances (1.2%) by non-experts using the Macintosh.
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# Discussion

In this retrospective, observational, two-center study, the first-pass intubation success rates
for emergency TI were significantly higher for Pentax or McGrath laryngoscopes than for
King or Macintosh laryngoscopes when performed by non-expert operators. After adjusting
for confounding factors, the odds ratios for first-pass intubation success were significantly
higher for the Pentax and McGrath laryngoscopes than that for the King laryngoscope, when
compared to the Macintosh laryngoscope. The use of the McGrath was associated with a
lower subjective difficulty of performing TI than that for the use of the Macintosh.
A previous study of VLs for TI by experienced anesthetists in the operating room
revealed a better visualization of the glottis with the Pentax than that with the Macintosh,
while the success rates and TI procedure times were similar [8]. Moreover, studies with
inexperienced residents reported a 96% first-pass intubation success rate with the Pentax
versus 70% with the Macintosh and 44 and 71 sec, respectively, to secure the airways [9].
Our results are concordant with these success rates, suggesting the advantageous
characteristics of the Pentax, particularly for novice operators. The suitable shape of the
PBLADE <sup>®,</sup> which indirectly visualizes the glottis regardless of the head and neck position,
the existence of a blade channel to set the tracheal tube, and the guiding function of the target

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	mark on the screen support the preferential use of the Pentax among the VLs [18].
	The McGrath is a relatively compact device without a tracheal tube guide channel
	[19]. Like the Macintosh, it offers an indirect view of the glottis by flexible manipulations of
	the laryngoscope and tracheal tube. Several factors, therefore, such as a restricted neck
5	mobility or the operator's experience with TI, might influence the success rate of the Pentax
	versus the McGrath. However, the first-pass intubation success rates were nearly the same
	between these VLs in this study population. A randomized study comparing the performance
	of Pentax versus McGrath in emergency TI is, therefore, warranted.
	The use of a stylet facilitates the manipulation of the tracheal tube adjacent to the
10	glottis. However, a randomized clinical trial in the ICU population, which showed no
	improvement in a McGrath-used first-pass intubation, did not use a stylet, which was used in
	all McGrath cases here [20]. This may be the reason for the nonconformance between the
	studies' results.
	To our knowledge, the present study was the first to compare the Pentax and King
15	in clinical settings. Although they have similar shapes and tracheal tube guiding

characteristics, the first-pass intubation success rate was significantly lower for the King than

that for the Pentax. The orientation of the King tracheal tube is relatively downward

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dvancement. In addition, the
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success rates compared to that

of direct laryngoscopy in emergency, critical and surgical patients [21, 22]. However, multiple models of VLs with various characteristics were combined as a "VL group" in the analysis. Here, we intended to compare the individual performances of VLs.

### 5 Study limitations

This was an observational study, in which confounding factors may have influenced the success rate of TI and biased the results. However, after adjusting for possible confounding factors based on those reported in previous studies, we observed a significant relationship between VLs and first-pass intubation success rates. We included video-recorded cases of TI during the study period. Unfortunately, only 22% of cases were recorded due to the limited availability of physicians who were able to operate the video cameras. Thus, there might be a selection bias. The data collection and analysis were performed by a single author (KS), leaving the potential for observer bias. Furthermore, we classified the "non-experts" based on their clinical experience. A precise index to grade the level of intubation skill might have been preferable, although it does not currently exist. Finally, bias based on operator familiarity with each laryngoscope cannot be excluded. However, given the scarce overall

this study (4.6 times/person), the results of the non-expert

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4	experience of TI itself prior to this study (4.6 times/person), the results of the
5	experience of 11 user prior to this study (no thread person), the results of the
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8	group are likely to be less biased.
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# Conclusion

When performing emergency TI in the ED or the ICU, the use of the Pentax and

McGrath laryngoscopes were associated with significantly higher first-pass intubation

success rates than that of the King laryngoscope when compared to the Macintosh

5 laryngoscope, especially when operated by non-experts.

# List of Abbreviations

)	TI	tracheal intubation
2	VL	video laryngoscope
	Pentax	Pentax-Airway Scope™
3 9 5 9	King	King Vision <sup>®</sup>
2	McGrath	McGrath <sup>®</sup> MAC
	Macintosh	Macintosh laryngoscope
3 ) )	ICU	intensive care unit
2	ED	emergency department
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# Declarations

Acknowledgements: We thank the attending physicians and residents of the Department of Emergency and Critical Care Medicine of Hiroshima University and the Critical Care Medical Center of Hiroshima Prefectural Hospital who contributed to the data collection.

Contributions: Suzuki conceived the study, designed the trial, and collected and managed the data. Kusunoki, Tanigawa, and Shime supervised the conduct of the trial and data collection. Suzuki drafted the manuscript, and all authors contributed substantially to its revision. Suzuki takes responsibility for the paper as a whole.

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Promotion of Science (JSPS) (Numbers JP 17K11573).

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

**Ethics approval and consent to participate**: This study was reviewed and approved by the research ethics committees of Hiroshima University (No.1069) and Hiroshima Prefectural Hospital (No.2013-76).

Trial registration number: University Hospital Medical Information Network

Clinical Trials Registry (UMIN000027925, https://upload.umin.ac.jp/cgi-open-

bin/ctr\_e/ctr\_view.cgi?recptno=R000016182); date of registration 26.06.2017

(retrospectively registered)

**Consent for publication**: Not applicable.

Data sharing statement: The data included deidentified participant data. The data are

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available from author (KS, e-mail: suzukik@hiroshima-u.ac.jp).

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### njopen-2018-02492 Table 1. Baseline and difficult airway characteristics King VISION All **Pentax-Airway Scope** McGrath Mac Macintosh Р (n=82) <sub>ເ</sub> (n=287) (n=82)(n=59) (n=64) Men 165 (57.5) 54 (65.9) 31 (52.5) 51 (62.2) 29 (45.3) 0.057 67.4±17.1 $65.4\pm20.5$ $60.7\pm24.8$ 69.0±16.2 65.7±21.4 Age, years 0.457 Height, cm 158.1±14.4 156.9±19.3 $159.3 \pm 9.0$ 160.9±10.2 154.9±14.9 0.044 56.7±11.9; Weight, kg 55.9±13.9 56.3±16.9 56.2±10.2 54.0±15.2 0.400 $22.0\pm3.7$ $22.3\pm3.8$ $22.1\pm3.6$ 21.7±3.2 $22.1\pm4.2$ Body mass index 0.794 45 (54.9)**≤** Expert operators 131 (45.6) 36 (43.9) 27 (45.8) 23 (35.9) 0.149 37 (45.1)/45 (5.4.9) Location of tracheal intubation (ED/ICU) 162 (56.4)/125 (43.6) 49 (59.8)/33 (40.2) 37 (62.7)/22 (37.3) 39 (60.9)/25 (39.1) 0.111 Indications for tracheal intubation 25 (30.5) Cardiopulmonary arrest 114 (39.7) 34 (41.5) 26 (44.1) 29 (45.3) 0.220 7 (8.5) H 14(4.9)4(4.9)2(3.1)Airway obstruction 1(1.7)0.305 14 (17.1) Respiratory failure 45 (15.7) 12 (14.6) 11 (18.6) 8 (12.5) 0.789 Hemodynamic instability 32 (11.1) 6 (7.3) 2(3.4)20 (24.4) 4 (6.3) 0.000 26 (31.7) 16 (19.5) Altered mental status 82 (28.6) 19 (32.2) 21 (32.8) 0.182 Drugs used for tracheal intubation None 148 (51.6) 44 (53.7) 32 (54.2) 35 (42.7) 37 (57.8) 0.274 Sedatives 116 (40.4) 33 (40.2) 24 (40.7) 35 (42.7) 24 (37.5) 0.944 36 (43.9) Analgesics 91 (31.7) 22 (26.8) 15 (25.4) 18 (28.1) 0.053 Muscle relaxants 59 (20.6) 15 (18.3) 10 (16.9) 22 (26.8) 12 (18.8) 0.450 (n=57) <sup>D</sup> (n=33) Drugs used for tracheal intubation in Non-CPA cases (n=173) (n=48)(n=35) 10 (17.5 None 34 (19.7) 10 (20.8) 6(18.2) 8 (22.9) 0.925 35 (61.4) Sedatives 116 (67.1) 33 (68.8) 24 (72.7) 24 (68.6) 0.722 36 (63.2) 0.250 Analgesics 91 (52.6) 22 (45.8) 15 (45.5) 18 (51.4) 22 (38.6) Muscle relaxants 59 (34.1) 15 (31.3) 10 (30.3) 12 (34.3) 0.842 3 (3.7) by guest. Protecte 3 (3.7) 4 (4.9) cte Difficult airway characteristics Obesity 16 (5.6) 6 (7.3) 3 (5.1) 4 (6.3) 0.793 Limited mouth opening 17 (5.9) 5 (6.1) 5 (8.5) 1(1.6)0.319 7 (10.9) 0.040 Restricted neck mobilization 39 (13.6) 19 (23.2) 6(10.2)Short neck 9 (3.1) 3(3.7)1(1.7)2(3.1)0.937 Facial trauma 1 (1.6) 13 (4.5) 7 (8.5) 1(1.7)0.171 Edema of glottis 7 (2.4) 2(2.4)0 (0.0) 1 (1.6) 0.390 38 (46.3) 0.821 Bloods, secretion, or vomitus in airway 123 (42.9) 36 (43.9) 23 (39.0) 26 (40.6) 48 (58.5)₹ Cases with difficult airway characteristics 161 (56.1) 47 (57.3) 31 (52.5) 35 (54.7) 0.897 copyright.

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BMJ Open Values are numbers (%) of observations or means ± standard deviations. ED, emergency department; ICU, intensive care unit; CP , enry

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### Table 2. First-pass intubation success rates of four laryngoscopes

Tuble 2. I list pass intubation success	rates of four fur jugose	opes		92		
	All laryngoscopes	Pentax-Airway Scope	King VISION	McGgath Mac	Macintosh	Р
All operators, n	287	82	59	<b>3</b> 82	64	
First-pass intubation success	199 (69)	64 (78)*	34 (58)	64 <u>(</u> 78)†	37 (58)	0.004
Non-expert operators	156	46	32	a37	41	
First-pass intubation success	104 (67)	40 (87)‡	16 (50)	29 <del>2</del> (78)§	19 (46)	0.00004
Expert operators	131	36	27	245	23	
First-pass intubation success	95 (73)	24 (67)	18 (67)	3\$\$ (78)	18 (78)	0.556
Values are numbers (%) of observations; <i>pc</i> *:vs. King VISION P=0.043, *:vs. Macinto ‡:vs. King VISION P=0.002, ‡:vs. Macinto	sh P=0.039, †:vs. King VIS	SION P=0.043, †:vs. Macin	tosh P=0.039	vnlo	yngoscopes	

Values are numbers (%) of observations; post hoc analyses were performed using Tukey's test for paired comparisons of four laryngoscopes . inloaded from http://bmjopen.bmj.com/ on November 22, 2024 by guest. Protected by copyright.

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Factors	Odd ratios	95% confidence intervals	Р	
Laryngoscopes				
Macintosh (reference)	1	-	-	
Pentax-Airway Scope	3.422	1.551-7.550	0.002	
King VISION	1.056	0.487-2.289	0.889	
McGrath Mac	3.758	1.640-8.612	0.002	
Indications for tracheal intubation				
Cardiopulmonary arrest	1 (reference)			
Airway obstruction	0.226	0.063-0.812	0.023	
Respiratory failure	0.720	0.284-1.822	0.488	
Hemodynamic instability	0.380	0.137-1.054	0.063	
Altered mental status	0.361	0.180-0.723	0.004	
Difficult airway characteristics				
Mouth opening				
Unlimited	1 (reference)	-	-	
Limited	0.092	0.026-0.323	0.000	
Neck mobility				
Unrestricted	1 (reference)	-	-	
Restricted	0.951	0.414-2.182	0.905	
Blood, secretions, vomitus in the airways				
Absent	1 (reference)	-	-	
Present	0.455	0.257-0.804	0.007	
Operators				
Non-expert	1 (reference)	-	-	
Expert	1.688	0.916-3.108	0.093	

Table 3. Multiple variable analysis of factors influencing the first-pass intubation success rates

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	Overall	Pentax-Airway Scope	King VISION	McGrath Mac	Macintos्मे	Р
Time to perform intubations, sec	60±31 (n=269)	63±34 (n=78)	63±31 (n=45)	62±31 (n=79)	52±27 (n=67)	0.043
Difficulty score <sup>†</sup>	39±27 (n=258)	39±26 (n=72)	43±26 (n=45)	32±27* (n=78)	45±26 (n=🕵)	0.009
•	39±27 (n=258) eviations; *P=0.0 l analogue scale, ned using Tukey'	39±26 (n=72) 27 vs. Macintosh. from very easy (0) to ver	43±26 (n=45) ry difficult (100). sons of 4 laryngos	32±27* (n=78)	45±26 (n=53)	

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Table 4. Comparisons of times needed to perform tracheal intubations and of difficulty scores for four	r#lifferent larvngoscones
Table 1. Comparisons of times needed to perform trachear intubations and of unitedity scores for four	Since one har yngoscopes

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	Item No	Recommendation	Reported on page No
Title and abstract	1	( <i>a</i> ) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		( <i>b</i> ) Provide in the abstract an informative and balanced	2-3
		summary of what was done and what was found	2-5
I		Summary of what was done and what was found	
Introduction Background/rationale	2	Explain the scientific background and rationale for the	1 5
Background/rationale	2	· ·	4-5
	2	investigation being reported	4.5
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	6-8
Setting	5	Describe the setting, locations, and relevant dates, including	6
		periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of	7
		selection of participants. Describe methods of follow-up	
		(b) For matched studies, give matching criteria and number of	
		exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential	7-8
		confounders, and effect modifiers. Give diagnostic criteria, if	
		applicable	
Data sources/	8*	For each variable of interest, give sources of data and details of	7-8
measurement		methods of assessment (measurement). Describe comparability	
		of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	9
Quantitative variables	11	Explain how quantitative variables were handled in the	7-8
<b>C</b>		analyses. If applicable, describe which groupings were chosen	
		and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to	9-10
Statistical methods	12	control for confounding	<i>y</i> 10
		(b) Describe any methods used to examine subgroups and	9
		(b) Describe any methods used to examine subgroups and interactions	2
			9
		(c) Explain how missing data were addressed	9
		(d) If applicable, explain how loss to follow-up was addressed	
		( <u>e</u> ) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study-eg	11
		numbers potentially eligible, examined for eligibility,	
		confirmed eligible, included in the study, completing follow-up,	
		and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic,	25
-		clinical, social) and information on exposures and potential	
		confounders	
		(b) Indicate number of participants with missing data for each	11
		(c) materie number of participants with missing data for each	**

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		variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	12-13, 26
Main results	16	( <i>a</i> ) Give unadjusted estimates and, if applicable, confounder- adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	26, 27
		(b) Report category boundaries when continuous variables were categorized	
		( <i>c</i> ) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12, 26
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.