

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<u>http://bmjopen.bmj.com</u>).

If you have any questions on BMJ Open's open peer review process please email <u>info.bmjopen@bmj.com</u>

BMJ Open

BMJ Open

Prospective comparison of video laryngoscopes for emergency endotracheal intubation

Journal:	BMJ Open
Manuscript ID	bmjopen-2018-024927
Article Type:	Research
Date Submitted by the Author:	01-Jul-2018
Complete List of Authors:	Suzuki, Kei; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences Kusunoki, Shinji; Hiroshima Prefectural Hospital, Critical Care Medical Center Tanigawa, Koichi ; Fukushima Medical University, Fukushima Global Medical Science Center Shime, Nobuaki; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences
Keywords:	Emergency intubation, tracheal intubation, laryngoscopy, video-assisted laryngoscopy, video laryngoscope, ACCIDENT & EMERGENCY MEDICINE



BMJ Open

	Original articles
	Prospective comparison of video laryngoscopes
	for emergency endotracheal intubation
	Kei SUZUKI ¹ , M.D., Shinji KUSUNOKI ² , M.D., Ph.D., Koichi TANIGAWA ³ , M.D., Ph.D.,
5	Nobuaki SHIME ¹ , M.D., Ph.D.
	From
	¹ Department of Emergency and Critical Care Medicine, Graduate School of Biomedical
	Sciences, Hiroshima University, Hiroshima, Japan
	² Critical Care Medical Center, Hiroshima Prefectural Hospital, Hiroshima, Japan
0	³ Fukushima Global Medical Science Center, Fukushima Medical University, Fukushima,
	Japan
	E-mail addresses:
	Kei Suzuki: suzukik@hiroshima-u.ac.jp
15	Shinji Kusunoki: <u>kusunokish@gmail.com</u>
	Koichi Tanigawa: tanigawa@fmu.ac.jp
-	Nobuaki Shime: nshime@hiroshima-u.ac.jp
20	Corresponding author
20	Nobuaki Snime, MD, PnD
	Creducte School of Diamadical Sciences, Uiroshime University
	1.2.3 Kasumi Minami ku
	Hiroshima 734 8551 Japan
)5	$\frac{1}{1000} + \frac{1}{21} + \frac{1}{22} + \frac{1}{27} + \frac{1}{21} + \frac{1}{22} + \frac{1}{257} + \frac{1}{2580}$
23	$e_{mail: nshime@hiroshima_u ac in}$
	e-man. <u>Institute@intestituta-u.ac.jp</u>
	For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Abstract

Objective: Video laryngoscopes are used for management of difficult airways. This study compares the performance of the Pentax-Airway Scope[™] (PAS), King Vision[®] (KV),

McGrath[®] MAC (MCG) and Macintosh laryngoscope (ML) in emergency tracheal

5 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

10 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

15 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

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

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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

2 3 4 5 6 7	
8 9 10 11 12 13 14 15	
16 17 18 19 20 21 22	5
23 24 25 26 27 28 29	
30 31 32 33 34 35 36	
37 38 39 40 41 42 43	
44 45 46 47 48 49 50	
51 52 53 54 55 56 57 57	
58 59	

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

BMJ Open

	Stre	engths and limitations of this study
	•	This study is the first report directly comparing the three different types of VLs
		(Pentax-Airway Scope TM (PAS), the King Vision [®] (KV), the McGrath TM MAC (MCG))
		and ML in the emergency TI.
5	•	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,
10		

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 [™] (PAS; HOYA Corporation, Tokyo, Japan), the King Vision [®] (KV; King Systems,
	Noblesville, IN) and the McGrath [™] 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
15	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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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

to beet eview only

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

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 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 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 ≥ 1 month of training in anesthesiology in the operating room, during which they performed TI, using ML 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.

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 IES

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

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

altered mental status), drugs used for TI (sedatives, analgesics or muscle relaxants),

pre-procedurally defined complicating airway characteristics, including obesity (body mass

index ≥ 28), limited mouth opening (inter-incisor distance ≤ 4 cm), restricted neck

Page 9 of 31

ge 9 of 31	BMJ Open
	9
	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.

BMJ Open

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% α 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 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 whether the rates of successful first attempts differed among the 4 laryngoscopes, in each pre-specified subgroups, according to the duration of clinical experience (1st and 2nd post-graduate years as non-expert operators; $\geq 3^{rd}$ post-graduate year as experts). A logistic

BMJ Open

2		
3		
4		regression analysis was performed to identify factors influencing the successful first attempt
5		
6		
7		rate. We included possible confounding factors, which were significantly different among the 4
8		
9		
10		laryngoscopes (indication for TI and restricted neck mobility) and which were identified in
11		
12		
13		previous studies (limited mouth aperture, ¹⁶ blood, secretion or vomitus in the airways, ¹⁷ experts
14		
15		
16	5	versus non-expert operator ¹⁸) A P value < 0.05 was considered statistically significant. The
17	5	
18		
19		analyses were performed using the SPSS [®] statistical package, version 23 (IBM Corporation
20		analyses were performed using the SI SS statistical package, version 25 (IDW Corporation,
21		
22		
23		Armonk, NY).
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
51		
52		
53		
54		
55		
56		
57		

The patients characteristics are summarized in table 1. Two-hundred and eighty-seven

Results

Characteristics of the study population

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 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

BMJ Open

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.

to beet terien only

		•	
011	00		1
vu	0.0		
	cu	cuss	cussio

31	BMJ Open
	15
	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 $PBLADE^{$ [®] , 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
	For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

	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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

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 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 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

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

to beer terien only non-experts.

1 2 3 4 5 6		List of Abbrevi	iations
7 8 9		ML	Macintosh laryngoscope
10 11 12		TI	tracheal intubation
13 14 15 16		VL	video laryngoscope
17 18 19	5	AWS	Pentax-Airway Scope™
20 21 22		KV	King Vision [®]
23 24 25		McG	McGrath [®] MAC
26 27 28		TT	tracheal tube
29 30 31 32		ED	emergency department
33 34 35	10	ICU	intensive care unit
36 37 38		IRB	institutional review board
39 40 41		PGY	post-graduate year
42 43 44		DAF	difficult airway factors
45 46 47 48	15	FAS	first attempt success
48 49 50 51 52 53 54 55 56 57	15		
58			

Declarations

Acknowledgements: We thank the attending physicians and residents from the department of emergency and critical care medicine of Hiroshima University and from the critical care medical center of Hiroshima prefectural hospital who contributed to the data collection.

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.

Funding: This work was supported by KAKENHI Grants from the Japan Society for the

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 committee of Hiroshima University (No.1069) and Hiroshima prefectural hospital (No.2013-76).

Trial registration number: University Hospital Medical Information Network

Clinical Trials Registry (UMIN000027925,

_view.cg .stered) vable. vble. 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.

References

1. Martin LD, Mhyre JM, Shanks AM, *et al.* 3,423 emergency tracheal intubations at a university hospital: airway outcomes and complications. *Anesthesiology*

2011;114:42-48.

2. Schmidt UH, Kumwilaisak K, Bittner E, et al. Effects of supervision by attending

anesthesiologists on complications of emergency tracheal intubation. Anesthesiology

2008;109:973-977.

- 3. Benedetto WJ, Hess DR, Gettings E, *et al.* Urgent tracheal intubation in general hospital units: an observational study. *J Clin Anesth.* 2007;19:20-24.
- Schwartz DE, Matthay MA, Cohen NH. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. *Anesthesiology* 1995;82:367-376.
 - 5. Simpson GD, Ross MJ, McKeown DW, *et al.* Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. *Br J Anaesth.*

15 2012;108:792-799.

6. Liu L, Tanigawa K, Kusunoki S, *et al.* Tracheal intubation of a difficult airway using Airway Scope, Airtrag, and Macintosh laryngoscope: a comparative manikin study of

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

1		25
2		
3		
4		inexperienced personnel. Anesth Analg. 2010;110:1049-1055.
5		
6		
7		7. Carlson JN, Brown CA. Does the use of video laryngoscopy improve intubation
8		
9		
10		outcomes? Ann Emerg Med. 2014;64:165-166.
11		
12		
13		8. Teoh WH, Saxena S, Shah MK, et al. Comparison of three videolaryngoscopes: Pentax
14		
15		
16	5	Airway Scope, C-MAC, Glidescope vs the MacIntosh larvngoscope for tracheal
1/		
18		
19		intubation. Angesthesia 2010:65:1126-1132.
20		
21		
22		9 Hirabayashi V Seo N Tracheal intubation by non-anaesthetist physicians using the
23		<i>y</i> . Thrabayashi 1, 500 W. Hachear intubation by non-anaesthetist physicians using the
24		
25		Airway Scope Emarg Mad I 2007:24:572 573
20		All way Scope. Emerg Med J. 2007,24.572-575.
2/		
28		10 Tavilar AM Daals M Lauraalatt S. of al The McCrath Series 5 wide larmer assesses us
29		10. Taylor AM, Peck M, Launcelou S, <i>et al.</i> The McGrath® Series 5 videolaryngoscope vs
30 21		
21 22	10	
22	10	the Macintosh laryngoscope: a randomised, controlled trial in patients with a simulated
37		
35		
36		difficult airway. Anaesthesia 2013;68:142-147.
37		
38		
39		11. De Jong A, Molinari N, Conseil M, <i>et al.</i> Video laryngoscopy versus direct
40		
41		
42		laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review
43		
44		
45		and meta-analysis. Intensive Care Med. 2014;40:629-639.
46		
47		
48	15	12. Silverberg MJ, Li N, Acquah SO, et al. Comparison of video laryngoscopy versus
49		
50		
51		direct laryngoscopy during urgent endotracheal intubation: a randomized controlled
52		
53		
54		trial. Crit Care Med. 2015;43:636-641.
55		
56		
57		
58		
59		

	13. Janz DR, Semler MW, Lentz RJ, et al. Randomized Trial of Video Laryngoscopy for
	Endotracheal Intubation of Critically Ill Adults. Crit Care Med. 2016;44:1980-1987.
	14. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated
	intubation attempts and adverse events in emergency departments: An analysis of a
5	multicenter prospective observational study. Ann Emerg Med. 2012;60:749-754.e2.
	15. Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when
	performing orotracheal intubation in the emergency department. Acad Emerg Med.
	2013;20:71-78.
	16. Breckwoldt J, Klemstein S, Brunne B, et al. Difficult prehospital endotracheal
10	intubation - predisposing factors in a physician based EMS. Resuscitation
	2011;82:1519-1524.
	17. Gaither JB, Spaite DW, Stolz U, et al. Prevalence of difficult airway predictors in cases
	of failed prehospital endotracheal intubation. J Emerg Med 2014;47(3):294-300.
	18. Crewdson K, Lockey DJ, Røislien J, et al. The success of pre-hospital tracheal
15	intubation by different pre-hospital providers: a systematic literature review and
	meta-analysis. Crit Care 2017;21:31.
	19. Koyama J, Aoyama T, Kusano Y, et al. Description and first clinical application of
	For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

AirWay Scope for tracheal intubation. J Neurosurg Anesth. 2006;18:247-250.

20. Kotera A, Irie H, Iwashita S, et al. Comparison of the McGrath MAC video

laryngoscope and the Pentax Airwayscope during chest compression: a manikin study.

J Intensive Care 2014;2:18.

to occure work

BMJ Open

Table 1. Baseline and difficult airway characteristics

	All	Pentax-Airway	King VISION	McGrath	Macintosh	D
	(n=287)	(n=82)	(n=59)	(n=82)	(n=64)	1
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	0.457
Height, cm	158.1±14.4	156.9±19.3	159.3±9.0	160.9±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	0.400
Body mass index	22.0±3.7	22.3±3.8	22.1±3.6	21.7±3.2	22.1±4.2	0.794
Expert operators	131 (45.6)	36 (43.9)	27 (45.8)	45 (54.9)	23 (35.9)	0.149
Indications for tracheal intubation						
Cardiopulmonary arrest	114 (39.7)	34 (41.5)	26 (44.1)	25 (30.5)	29 (45.3)	0.220
Airway obstruction	14 (4.9)	4 (4.9)	1 (1.7)	7 (8.5)	2 (3.1)	0.305
Respiratory failure	45 (15.7)	12 (14.6)	11 (18.6)	14 (17.1)	8 (12.5)	0.789
Hemodynamic instability	32 (11.1)	6 (7.3)	2 (3.4)	20 (24.4)	4 (6.3)	0.000
Altered mental status	82 (28.6)	26 (31.7)	19 (32.2)	16 (19.5)	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
Analgesics	91 (31.7)	22 (26.8)	15 (25.4)	36 (43.9)	18 (28.1)	0.053
Muscle relaxants	59 (20.6)	15 (18.3)	10 (16.9)	22 (26.8)	12 (18.8)	0.450
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)	0.925
Sedatives	116 (67.1)	33 (68.8)	24 (72.7)	35 (61.4)	24 (68.6)	0.722
Analgesics	91 (52.6)	22 (45.8)	15 (45.5)	36 (63.2)	18 (51.4)	0.250
Muscle relaxants	59 (34.1)	15 (31.3)	10 (30.3)	22 (38.6)	12 (34.3)	0.842
Difficult airway characteristics						
Obesity	16 (5.6)	6 (7.3)	3 (5.1)	3 (3.7)	4 (6.3)	0.793
Limited mouth opening	17 (5.9)	5 (6.1)	5 (8.5)	6 (7.3)	1 (1.6)	0.319
Restricted neck mobilization	39 (13.6)	19 (23.2)	6 (10.2)	7 (8.5)	7 (10.9)	0.040
Short neck	9 (3.1)	3 (3.7)	1 (1.7)	3 (3.7)	2 (3.1)	0.937
Facial trauma	13 (4.5)	7 (8.5)	1 (1.7)	4 (4.9)	1 (1.6)	0.171
Edema of glottis	7 (2.4)	2 (2.4)	0 (0.0)	4 (4.9)	1 (1.6)	0.390
Bloods, secretion or vomitus in airway	123 (42.9)	36 (43.9)	23 (39.0)	38 (46.3)	26 (40.6)	0.821
Cases with difficult airway characteristics	161 (56.1)	47 (57.3)	31 (52.5)	48 (58.5)	35 (54.7)	0.897

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

review only

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

	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

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 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 success rate of first attempts at tracheal intubations

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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

using 4 different laryngoscopes

STROBE Statement—	-Checklist of item	is that should be	e included in report	s of <i>cohort studies</i>
			1	

	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 summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the 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 periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(b) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
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 analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(<i>a</i>) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	9
		(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
		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, clinical, social) and information on exposures and potential confounders	25
		(b) Indicate number of participants with missing data for each	11

For peer review only - http://bmjopen!bmj.com/site/about/guidelines.xhtml

	variable of interest	
	(c) Summarise follow-up time (eg, average and total amount)	
15*	Report numbers of outcome events or summary measures over time	12-13, 26
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	
17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12, 26
18	Summarise key results with reference to study objectives	14
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
20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
21	Discuss the generalisability (external validity) of the study results	16
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
	15* 16 17 18 19 20 21 22	variable of interest (c) Summarise follow-up time (eg, average and total amount) 15* Report numbers of outcome events or summary measures over time 16 (a) 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 (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 17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses 18 Summarise key results with reference to study objectives 19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias 20 Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence 21 Discuss the generalisability (external validity) of the study results 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

*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.

BMJ Open

BMJ Open

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

Journal:	BMJ Open
Manuscript ID	bmjopen-2018-024927.R1
Article Type:	Research
Date Submitted by the Author:	03-Dec-2018
Complete List of Authors:	Suzuki, Kei; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences Kusunoki, Shinji; Hiroshima Prefectural Hospital, Critical Care Medical Center Tanigawa, Koichi ; Fukushima Medical University, Fukushima Global Medical Science Center Shime, Nobuaki; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences
Primary Subject Heading :	Emergency medicine
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

Kei SUZUKI¹, M.D., Shinji KUSUNOKI², M.D., Ph.D., Koichi TANIGAWA³, M.D., Ph.D.,

Nobuaki SHIME¹, M.D., Ph.D.

From

¹Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences, Hiroshima University, Hiroshima, Japan

²Critical Care Medical Center, Hiroshima Prefectural Hospital, Hiroshima, Japan

.ral. ., Fukush. ³Fukushima Global Medical Science Center, Fukushima Medical University, Fukushima, Japan

E-mail addresses:

Kei Suzuki: suzukik@hiroshima-u.ac.jp

Shinji Kusunoki: kusunokish@gmail.com

Koichi Tanigawa: tanigawa@fmu.ac.jp

Nobuaki Shime: nshime@hiroshima-u.ac.jp

Corresponding author

- Nobuaki Shime, MD, PhD
 - Professor & Chief, Department of Emergency and Critical Care Medicine

Graduate School of Biomedical Sciences, Hiroshima University

- 1-2-3 Kasumi, Minami-ku,
- Hiroshima 734-8551, Japan
- Phone: +81-82-257-5456 Fax: +81-82-257-5589
 - e-mail: nshime@hiroshima-u.ac.jp

	Abstract
	Objective: Video laryngoscopes are used for the management of difficult airways. This study
	compared the performances of three video laryngoscopes (Pentax-Airway Scope TM [Pentax],
	King Vision [®] [King], and McGrath [®] MAC [McGrath]) with the Macintosh direct
5	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
10	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
15	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
BMJ Open

2 3					
4 5 6		(87%) and McGrath (78%) instruments than those with the King (50%) and Macintosh (46%)			
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	instruments.				
20 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	10	laryngoscopes, especially for non-expert operators.			
36 37 38 39 30					
40 41 42					
43 44 45 46		Keywords: Emergency intubation, tracheal intubation, laryngoscopy, video-assisted			
47 48 49		laryngoscopy, video laryngoscope, video laryngoscopy			
50 51 52	15				
53 54 55					
56 57					
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[™], King Vision[®], McGrath[™] 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 [®] (King), and the McGrath [™] 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

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

	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®, King Systems, Noblesville, IN) and
5	McGrath (McGrath [™] 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
10	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.

BMJ Open

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

 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.

relie

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% α level and a power (1- β) of 80%. Including missing data, we set the sample sizes of each group at

70 and a total of 280 procedures.

BMJ Open

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 time
13 14 15		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		comparing all laryngoscopes pairwise to each other using Tukey's test. We also examined
23 24 25		whether the first-pass intubation success rates differed among the four laryngoscopes, in each
20 27 28 29		prespecified subgroup, according to the duration of clinical experience (1st and 2nd
30 31 32		post-graduate years as non-expert operators and $\geq 3^{rd}$ post-graduate year as experts). A logistic
33 34 35	10	regression analysis was performed to identify factors influencing the first-pass intubation
30 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]
40 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		(IBM Corporation, Armonk, NY).
59		

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%; P=0.043 vs. other groups).

BMJ Open

 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 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

1.

 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.

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 $PBLADE^{(B)}$, 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].		

	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

Page 17 of 34

5

1 2

BMJ Open

1

3
4
5
6
7
8
0
9 10
10
11
12
13
14
15
16
17
18
10
20
20
21
22
23
24
25
26
27
28
20
29
30
31
32
33
34
35
36
37
38
30
40
40
41
42
43
44
45
46
47
48
10
50
50 F1
51
52
53
54
55
56
57
58
50
22
υU

10

15

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
non-physicians) remains uncertain.

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 <text><text><text><text> 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

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.

for oper teries only

List of Abbreviations

, 8 9 10		TI	tracheal intubation
11 12 13		VL	video laryngoscope
14 15 16 17		Pentax	Pentax-Airway Scope™
18 19 20	5	King	King Vision [®]
21 22 23 24		McGrath	McGrath [®] MAC
25 26 27		Macintosh	Macintosh laryngoscope
28 29 30 31		ICU	intensive care unit
32 33		ED	emergency department
34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 50 51 52 53 54 55 56 57 58	10		
59 60			

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.

Funding: This work was supported by KAKENHI Grants from the Japan Society for the Promotion of Science (JSPS) (Numbers JP 17K11573).

1e

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.

References

1. Martin LD, Mhyre JM, Shanks AM, *et al.* 3,423 emergency tracheal intubations at a university hospital: airway outcomes and complications. *Anesthesiology*

2011;114:42-48.

- 5 2. Schmidt UH, Kumwilaisak K, Bittner E, *et al.* Effects of supervision by attending anesthesiologists on complications of emergency tracheal intubation. *Anesthesiology* 2008;109:973-977.
 - 3. Benedetto WJ, Hess DR, Gettings E, *et al.* Urgent tracheal intubation in general hospital units: an observational study. *J Clin Anesth.* 2007;19:20-24.
- Schwartz DE, Matthay MA, Cohen NH. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. *Anesthesiology* 1995;82:367-376.
 - 5. Simpson GD, Ross MJ, McKeown DW, *et al.* Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. *Br J Anaesth.*

2012;108:792-799.

6. Liu L, Tanigawa K, Kusunoki S, *et al.* Tracheal intubation of a difficult airway using Airway Scope, Airtraq, and Macintosh laryngoscope: a comparative manikin study of

	inexperienced personnel. Anesth Analg. 2010;110:1049-1055.
	7. Carlson JN, Brown CA. Does the use of video laryngoscopy improve intubation
	outcomes? Ann Emerg Med. 2014;64:165-166.
	8. Teoh WH, Saxena S, Shah MK, et al. Comparison of three videolaryngoscopes:
5	Pentax Airway Scope, C-MAC, Glidescope vs the MacIntosh laryngoscope for
	tracheal intubation. Anaesthesia 2010;65:1126-1132.
	9. Hirabayashi Y, Seo N. Tracheal intubation by non-anaesthetist physicians using the
	Airway Scope. Emerg Med J. 2007;24:572-573.
	10. Taylor AM, Peck M, Launcelott S, et al. The McGrath® Series 5 videolaryngoscope
10	vs the Macintosh laryngoscope: a randomised, controlled trial in patients with a
	simulated difficult airway. Anaesthesia 2013;68:142-147.
	11. Janz DR, Semler MW, Lentz RJ, et al. Randomized Trial of Video Laryngoscopy for
	Endotracheal Intubation of Critically Ill Adults. Crit Care Med. 2016;44:1980-1987.
	12. Rombey T, Schieren M, Pieper D. Video versus direct laryngoscopy for inpatient
15	emergency intubation in adults: a systematic review and meta-analysis of randomized
	controlled trials. Dtsch Arztebl Int. 2018;115:437-444.
	13. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated

 BMJ Open

	,	2

	intubation attempts and adverse events in emergency departments: An analysis of a
	multicenter prospective observational study. Ann Emerg Med. 2012;60:749-754.e2.
	14. Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when
	performing orotracheal intubation in the emergency department. Acad Emerg Med.
5	2013;20:71-78.
	15. Breckwoldt J, Klemstein S, Brunne B, <i>et al.</i> Difficult prehospital endotracheal
	intubation - predisposing factors in a physician based EMS. <i>Resuscitation</i>
	2011-82-1519-1524
	16 Caithar ID Spaite DW Stale II at al Provalance of difficult airway predictors in
	16. Gather JB, Sparte DW, Storz O, <i>et al</i> . Prevalence of difficult all way predictors in
10	cases of failed prehospital endotracheal intubation. <i>J Emerg Med</i> 2014;47(3):294-300.
	17. Crewdson K, Lockey DJ, Røislien J, et al. The success of pre-hospital tracheal
	intubation by different pre-hospital providers: a systematic literature review and
	meta-analysis. Crit Care 2017;21:31.
	18. Koyama J, Aoyama T, Kusano Y, et al. Description and first clinical application of
15	AirWay Scope for tracheal intubation. J Neurosurg Anesth. 2006;18:247-250.
	19. Kotera A, Irie H, Iwashita S, et al. Comparison of the McGrath MAC video
	laryngoscope and the Pentax Airwayscope during chest compression: a manikin study.

J Intensive Care 2014;2:18.

to beet teries only

Table 1. Baseline and difficult airway characteristics

	All	Pentax-Airway Scope	King VISION	McGrath Mac	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, years	65.4±20.5	60.7±24.8	69.0±16.2	67.4±17.1	65.7±21.4	0.457
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	0.400
Body mass index	22.0±3.7	22.3±3.8	22.1±3.6	21.7±3.2	22.1±4.2	0.794
Expert operators	131 (45.6)	36 (43.9)	27 (45.8)	45 (54.9)	23 (35.9)	0.149
Location of tracheal intubation (ED/ICU)	162 (56.4)/125 (43.6)	49 (59.8)/33 (40.2)	37 (62.7)/22 (37.3)	37 (45.1)/45 (54.9)	39 (60.9)/25 (39.1)	0.111
Indications for tracheal intubation						
Cardiopulmonary arrest	114 (39.7)	34 (41.5)	26 (44.1)	25 (30.5)	29 (45.3)	0.220
Airway obstruction	14 (4.9)	4 (4.9)	1 (1.7)	7 (8.5)	2 (3.1)	0.305
Respiratory failure	45 (15.7)	12 (14.6)	11 (18.6)	14 (17.1)	8 (12.5)	0.789
Hemodynamic instability	32 (11.1)	6 (7.3)	2 (3.4)	20 (24.4)	4 (6.3)	0.000
Altered mental status	82 (28.6)	26 (31.7)	19 (32.2)	16 (19.5)	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
Analgesics	91 (31.7)	22 (26.8)	15 (25.4)	36 (43.9)	18 (28.1)	0.053
Muscle relaxants	59 (20.6)	15 (18.3)	10 (16.9)	22 (26.8)	12 (18.8)	0.450
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)	0.925
Sedatives	116 (67.1)	33 (68.8)	24 (72.7)	35 (61.4)	24 (68.6)	0.722
Analgesics	91 (52.6)	22 (45.8)	15 (45.5)	36 (63.2)	18 (51.4)	0.250
Muscle relaxants	59 (34.1)	15 (31.3)	10 (30.3)	22 (38.6)	12 (34.3)	0.842
Difficult airway characteristics						
Obesity	16 (5.6)	6 (7.3)	3 (5.1)	3 (3.7)	4 (6.3)	0.793
Limited mouth opening	17 (5.9)	5 (6.1)	5 (8.5)	6 (7.3)	1 (1.6)	0.319
Restricted neck mobilization	39 (13.6)	19 (23.2)	6 (10.2)	7 (8.5)	7 (10.9)	0.040
Short neck	9 (3.1)	3 (3.7)	1 (1.7)	3 (3.7)	2 (3.1)	0.937
Facial trauma	13 (4.5)	7 (8.5)	1 (1.7)	4 (4.9)	1 (1.6)	0.171
Edema of glottis	7 (2.4)	2 (2.4)	0 (0.0)	4 (4.9)	1 (1.6)	0.390
Bloods, secretion, or vomitus in airway	123 (42.9)	36 (43.9)	23 (39.0)	38 (46.3)	26 (40.6)	0.821
Cases with difficult airway characteristics	161 (56.1)	47 (57.3)	31 (52.5)	48 (58.5)	35 (54.7)	0.897

 Values are numbers (%) of observations or means ± standard deviations. ED, emergency department; ICU, intensive care unit; CPA, cardiopulmonary arrest.

For peer review only

 Р

0.004

0.00004

0.556

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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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

 For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

 For peer review only

Table 4. Comparisons of times needed to perform tracheal intubations and of difficulty scores for four different laryngoscopes

	Overall	Pentax-Airway Scope	King VISION	McGrath Mac	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 [†]	39±27 (n=258)	39±26 (n=72)	43±26 (n=45)	32±27* (n=78)	45±26 (n=63)	0.009

Values are means \pm standard deviations; *P=0.027 vs. Macintosh.

[†]Difficulty was scored by visual analogue scale, from very easy (0) to very difficult (100).

post hoc analyses were performed using Tukey's test for paired comparisons of 4 laryngoscopes.

	Item <u>N</u> o	Recommendation	Reported on pag <u>N</u> o
Title and abstract	1	(<i>a</i>) Indicate the study's design with a commonly used term in	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
		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
		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	0	methods of assessment (measurement) Describe comparability	, 0
		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
Ouantitative variables	11	Explain how quantitative variables were handled in the	7-8
		analyses If annlicable describe which groupings were chosen	, 0
		and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to	9-10
Statistical methods	12	control for confounding	9-10
		(b) Describe any methods used to examine subgroups and	0
		(b) Describe any methods used to examine subgroups and	2
		(a) Explain how missing data wara addrassad	0
		(c) Explain now missing data were addressed	<i>y</i>
		(a) It applicable, explain now 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	

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

		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	12-13, 26
		time	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-	26, 27
		adjusted estimates and their precision (eg, 95% confidence	
		interval). Make clear which confounders were adjusted for and	
		why they were included	
		(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	12, 26
	\sim	interactions, and sensitivity analyses	
Discussion	C		
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of	16
		potential bias or imprecision. Discuss both direction and	
		magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering	14
		objectives, limitations, multiplicity of analyses, results from	
		similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study	16
		results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the	20
		present study and, if applicable, for the original study on which	
		the present article is based	

*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.

BMJ Open

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

Journal:	BMJ Open
Manuscript ID	bmjopen-2018-024927.R2
Article Type:	Research
Date Submitted by the Author:	17-Jan-2019
Complete List of Authors:	Suzuki, Kei; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences Kusunoki, Shinji; Hiroshima Prefectural Hospital, Critical Care Medical Center Tanigawa, Koichi ; Fukushima Medical University, Fukushima Global Medical Science Center Shime, Nobuaki; Hiroshima University, Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences
Primary Subject Heading :	Emergency medicine
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
Kei SUZUKI ¹ , M.D., Shinji KUSUNOKI ² , M.D., Ph.D., Koichi TANIGAWA ³ , M.D., Ph.D.,
Nobuaki SHIME ¹ , M.D., Ph.D.
From
¹ Department of Emergency and Critical Care Medicine, Graduate School of Biomedical Sciences, Hiroshima University, Hiroshima, Japan
² Critical Care Medical Center, Hiroshima Prefectural Hospital, Hiroshima, Japan
³ Fukushima Global Medical Science Center, Fukushima Medical University, Fukushima,
Japan
E-mail addresses:
Kei Suzuki: suzukik@hiroshima-u.ac.jp
Shinji Kusunoki: kusunokish@gmail.com
Koichi Tanigawa: tanigawa@fmu.ac.jp
Nobuaki Shime: nshime@hiroshima-u.ac.jp
Corresponding author
Nobuaki Shime, MD, PhD
Professor & Chief, Department of Emergency and Critical Care Medicine
Graduate School of Biomedical Sciences, Hiroshima University
1-2-3 Kasumi, Minami-ku,
Hiroshima 734-8551, Japan
Phone: +81-82-257-5456 Fax: +81-82-257-5589

e-mail: nshime@hiroshima-u.ac.jp

	Abstract
	Objective: Video laryngoscopes are used for managing difficult airways. This study
	compared three video laryngoscopes' (Pentax-Airway Scope [™] [Pentax], King Vision [®]
	[King], and McGrath [®] MAC [McGrath]) performances with the Macintosh direct
5	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
10	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.
15	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

BMJ Open

	(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
BMJ Open

Strengths and limitations of this study

To our knowledge, this study is the first to directly compare three different video laryngoscopes (Pentax-Airway Scope[™], King Vision[®], McGrath[™] 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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

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. Amongst others, the VLs used in clinical practice include the Pentax-
	Airway Scope [™] (Pentax), the King Vision [®] (King), and the McGrath [™] MAC (McGrath).
	VLs are classified according to the guidance method of the tracheal tube. The Pentax and
10	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

BMJ Open

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 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 5 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 10 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 15 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 anesthesiologists.

2
4
5
6
7
8
9
10
11
12
12
14
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
20
29
30 21
21
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
51
52 52
55
54
55
56
57
58
59

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 [®] , King Systems, Noblesville, IN) and
McGrath (McGrath [™] 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.

BMJ Open

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

relie

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% α level and a power (1– β) of 80%. Including missing data, we set the sample sizes of each group at

70 and a total of 280 procedures.

BMJ Open

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		time needed to perform the TI from the video recording as well as those without subjective
16 17 18 19	5	difficulty scores were excluded from the analysis. A post hoc 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 (1st and 2nd 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%;

BMJ Open

 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
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.
10	

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 ^{®,} 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

2 3 4 5 6		mark on the screen support the preferential use of the Pentax among the VLs [18].
7 8 9		The McGrath is a relatively compact device without a tracheal tube guide channel
10 11 12		[19]. Like the Macintosh, it offers an indirect view of the glottis by flexible manipulations of
13 14 15		the laryngoscope and tracheal tube. Several factors, therefore, such as a restricted neck
16 17 18 19	5	mobility or the operator's experience with TI, might influence the success rate of the Pentax
20 21 22		versus the McGrath. However, the first-pass intubation success rates were nearly the same
23 24 25		between these VLs in this study population. A randomized study comparing the performance
26 27 28 20		of Pentax versus McGrath in emergency TI is, therefore, warranted.
30 31 32		The use of a stylet facilitates the manipulation of the tracheal tube adjacent to the
33 34 35	10	glottis. However, a randomized clinical trial in the ICU population, which showed no
36 37 38		improvement in a McGrath-used first-pass intubation, did not use a stylet, which was used in
39 40 41 42		all McGrath cases here [20]. This may be the reason for the nonconformance between the
42 43 44 45		studies' results.
46 47 48		To our knowledge, the present study was the first to compare the Pentax and King
49 50 51	15	in clinical settings. Although they have similar shapes and tracheal tube guiding
52 53 54 55		characteristics, the first-pass intubation success rate was significantly lower for the King than
56 57 58 59 60		that for the Pentax. The orientation of the King tracheal tube is relatively downward

Page 17 of 35

1

BMJ Open

2 3 4 5 6		compared to that of the Pentax, which may interfere with its advancement. In addition, the
7 8 9		King has no marking to help in the placement of the tube. System malfunction, which
10 11 12		occurred in seven patients in this study, may also have lowered the success rate of the King.
13 14 15 16		Several factors, which varied among the four laryngoscopes, had repercussions on the
17 18 19	5	success rate of TI. Blood or vomitus in the airways, an important complication when
20 21 22		performing emergency TI, may lower the image quality. Blood, secretions, or vomitus were
23 24 25		present in the airways in 43% of procedures, significantly lowering the first-pass intubation
20 27 28 29		success rate [16]. However, after adjusting for this factor, multiple variable analysis
30 31 32		confirmed the advantage of the Pentax and McGrath. A limited mouth aperture was also
33 34 35	10	correlated with the difficulty of TI [15]. This, however, was problematic in only 6% of cases
36 37 38 39		and did not represent a major obstacle to the insertion of the devices.
40 41 42		The results of the present study suggest the usefulness of the Pentax or McGrath VLs
43 44 45		for emergency TI performed by novice physicians. However, the generalizability of the
46 47 48 40		results for intubation in other settings (in the operating theater or prehospital settings, or by
50 51 52	15	non-physicians) remains uncertain.
53 54 55		Systematic review and meta-analysis of randomized controlled trials revealed that
56 57 58 59 60		video laryngoscopy does not improve first-attempt intubation 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

1	
2	
3	
4	experience of TI itself prior to this study (4.6 times/person), the results of the non-expert
6	
7	
8	group are likely to be less biased.
9	
10	
11	
12	
14	
15	
16	
17	
18	
19	
20 21	
22	
23	
24	
25	
26	
27	
28 20	
30	
31	
32	
33	
34	
35	
30	
38	
39	
40	
41	
42	
45 44	
45	
46	
47	
48	
49 50	
50 51	
52	
53	
54	
55	
56	
5/	
50 59	
60	

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

laryngoscope, especially when operated by non-experts.

cially when o_μ...

1 2 3 4 5 6 7		List of Abbrevi	ations
8 9 10		TI	tracheal intubation
11 12 13 14		VL	video laryngoscope
15 16 17		Pentax	Pentax-Airway Scope™
18 19 20	5	King	King Vision [®]
21 22 23 24		McGrath	McGrath [®] MAC
25 26 27		Macintosh	Macintosh laryngoscope
28 29 30 31		ICU	intensive care unit
32 33 34		ED	emergency department
35 36 37	10		
38 39 40			
41 42 43			
44 45			
46 47 48			
49 50			
51			
52 53			
54 55			
56 57			
58			
59 60			

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.

Funding: This work was supported by KAKENHI Grants from the Japan Society for the

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

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

1 2

3
4
5
0 7
/
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
20
30
21
21
3Z
33
34 25
35
36
3/
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
50
50
22
00

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)

10 **Consent for publication**: Not applicable.

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

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

References

1. Martin LD, Mhyre JM, Shanks AM, *et al.* 3,423 emergency tracheal intubations at a university hospital: airway outcomes and complications. *Anesthesiology* 2011;114:42-

48.

- Schmidt UH, Kumwilaisak K, Bittner E, *et al.* Effects of supervision by attending anesthesiologists on complications of emergency tracheal intubation. *Anesthesiology* 2008;109:973-977.
 - 3. Benedetto WJ, Hess DR, Gettings E, *et al.* Urgent tracheal intubation in general hospital units: an observational study. *J Clin Anesth.* 2007;19:20-24.
- Schwartz DE, Matthay MA, Cohen NH. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. *Anesthesiology* 1995;82:367-376.
 - 5. Simpson GD, Ross MJ, McKeown DW, *et al.* Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. *Br J Anaesth.*

2012;108:792-799.

6. Liu L, Tanigawa K, Kusunoki S, *et al.* Tracheal intubation of a difficult airway using Airway Scope, Airtraq, and Macintosh laryngoscope: a comparative manikin study of

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

2			
5 4 5 6			inexperienced personnel. Anesth Analg. 2010;110:1049-1055.
7 8 9		7.	Carlson JN, Brown CA. Does the use of video laryngoscopy improve intubation
10 11 12			outcomes? Ann Emerg Med. 2014;64:165-166.
13 14 15		8.	Teoh WH, Saxena S, Shah MK, et al. Comparison of three videolaryngoscopes:
16 17 18 19	5		Pentax Airway Scope, C-MAC, Glidescope vs the MacIntosh laryngoscope for
20 21 22			tracheal intubation. Anaesthesia 2010;65:1126-1132.
23 24 25		9.	Hirabayashi Y, Seo N. Tracheal intubation by non-anaesthetist physicians using the
26 27 28 20			Airway Scope. Emerg Med J. 2007;24:572-573.
29 30 31 32		10.	Taylor AM, Peck M, Launcelott S, et al. The McGrath® Series 5 videolaryngoscope
33 34 35	10		vs the Macintosh laryngoscope: a randomised, controlled trial in patients with a
36 37 38			simulated difficult airway. Anaesthesia 2013;68:142-147.
39 40 41 42		11.	Janz DR, Semler MW, Lentz RJ, et al. Randomized Trial of Video Laryngoscopy for
42 43 44 45			Endotracheal Intubation of Critically Ill Adults. Crit Care Med. 2016;44:1980-1987.
46 47 48		12.	Rombey T, Schieren M, Pieper D. Video versus direct laryngoscopy for inpatient
49 50 51	15		emergency intubation in adults: a systematic review and meta-analysis of randomized
52 53 54			controlled trials. Dtsch Arztebl Int. 2018;115:437-444.
55 56 57		12	Hasagawa K. Shigamitsu K. Hagiwara V. at al. Association between repeated
58 59 60		13.	masegawa K, Singennisu K, magiwara T, et al. Association between repeated

	intubation attempts and adverse events in emergency departments: An analysis of a
	multicenter prospective observational study. Ann Emerg Med. 2012;60:749-754.e2.
	14. Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when
	performing orotracheal intubation in the emergency department. Acad Emerg Med.
5	2013;20:71-78.
	15. Breckwoldt J, Klemstein S, Brunne B, <i>et al</i> . Difficult prehospital endotracheal
	intubation - predisposing factors in a physician based EMS. Resuscitation
	2011;82:1519-1524.
	16. Gaither JB, Spaite DW, Stolz U, et al. Prevalence of difficult airway predictors in
10	cases of failed prehospital endotracheal intubation. <i>J Emerg Med</i> 2014;47(3):294-300.
	17. Crewdson K, Lockey DJ, Røislien J, et al. The success of pre-hospital tracheal
	intubation by different pre-hospital providers: a systematic literature review and meta-
	analysis. <i>Crit Care</i> 2017;21:31.
	18. Koyama J, Aoyama T, Kusano Y, et al. Description and first clinical application of
15	AirWay Scope for tracheal intubation. J Neurosurg Anesth. 2006;18:247-250.
	19. Kotera A, Irie H, Iwashita S, et al. Comparison of the McGrath MAC video
	laryngoscope and the Pentax Airwayscope during chest compression: a manikin

1 2		2
3 4 5 6		study. J Intensive Care 2014;2:18.
7 8 9		20. Lascarrou JB, Boisrame-Helms J, Bailly A, et al. Video laryngoscopy vs direct
10 11 12		laryngoscopy on successful first-pass orotracheal intubation among ICU patients: a
13 14 15 16		randomized clinical trial. JAMA. 2017;317(5):483-493.
17 18 19	5	21. Jiang J, Ma D, Li B, et al. Video laryngoscopy does not improve the intubation
20 21 22		outcomes in emergency and critical patients - a systematic review and meta-analysis
23 24 25 26		of randomized controlled trials. Crit Care. 2017;21(1):288
27 28 29		22. Lewis SR, Butler AR, Parker J, et al. Video laryngoscopy versus direct laryngoscopy
30 31 32		for adult patients requiring tracheal intubation. Cochrane Database Syst Rev.
33 34 35 36	10	2016;11:CD011136
37 38 39		
40 41 42		
43 44 45		
40 47 48		
49 50 51		
52 53 54		
55 56 57		
58 59 60		

Table 1. Baseline and difficult airway characteristics

	All	Pentax-Airway Scope	King VISION	McGrath Mac	Macintosh	D
	(n=287)	(n=82)	(n=59)	(n=82)	(n=64)	1
Men	165 (57.5)	54 (65.9)	31 (52.5)	51 (62.2)	29 (45.3)	0.057
Age, years	65.4±20.5	60.7±24.8	69.0±16.2	67.4±17.1	65.7±21.4	0.457
Height, cm	158.1±14.4	156.9±19.3	159.3±9.0	160.9±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	0.400
Body mass index	22.0±3.7	22.3±3.8	22.1±3.6	21.7±3.2	22.1±4.2	0.794
Expert operators	131 (45.6)	36 (43.9)	27 (45.8)	45 (54.9)	23 (35.9)	0.149
Location of tracheal intubation (ED/ICU) Indications for tracheal intubation	162 (56.4)/125 (43.6)	49 (59.8)/33 (40.2)	37 (62.7)/22 (37.3)	37 (45.1)/45 (54.9)	39 (60.9)/25 (39.1)	0.111
Cardiopulmonary arrest	114 (39.7)	34 (41.5)	26 (44.1)	25 (30.5)	29 (45.3)	0.220
Airway obstruction	14 (4.9)	4 (4.9)	1 (1.7)	7 (8.5)	2 (3.1)	0.305
Respiratory failure	45 (15.7)	12 (14.6)	11 (18.6)	14 (17.1)	8 (12.5)	0.789
Hemodynamic instability	32 (11.1)	6 (7.3)	2 (3.4)	20 (24.4)	4 (6.3)	0.000
Altered mental status	82 (28.6)	26 (31.7)	19 (32.2)	16 (19.5)	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
Analgesics	91 (31.7)	22 (26.8)	15 (25.4)	36 (43.9)	18 (28.1)	0.053
Muscle relaxants	59 (20.6)	15 (18.3)	10 (16.9)	22 (26.8)	12 (18.8)	0.450
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)	0.925
Sedatives	116 (67.1)	33 (68.8)	24 (72.7)	35 (61.4)	24 (68.6)	0.722
Analgesics	91 (52.6)	22 (45.8)	15 (45.5)	36 (63.2)	18 (51.4)	0.250
Muscle relaxants	59 (34.1)	15 (31.3)	10 (30.3)	22 (38.6)	12 (34.3)	0.842
Difficult airway characteristics						
Obesity	16 (5.6)	6 (7.3)	3 (5.1)	3 (3.7)	4 (6.3)	0.793
Limited mouth opening	17 (5.9)	5 (6.1)	5 (8.5)	6 (7.3)	1 (1.6)	0.319
Restricted neck mobilization	39 (13.6)	19 (23.2)	6 (10.2)	7 (8.5)	7 (10.9)	0.040
Short neck	9 (3.1)	3 (3.7)	1 (1.7)	3 (3.7)	2 (3.1)	0.937
Facial trauma	13 (4.5)	7 (8.5)	1 (1.7)	4 (4.9)	1 (1.6)	0.171
Edema of glottis	7 (2.4)	2 (2.4)	0 (0.0)	4 (4.9)	1 (1.6)	0.390
Bloods, secretion, or vomitus in airway	123 (42.9)	36 (43.9)	23 (39.0)	38 (46.3)	26 (40.6)	0.821
Cases with difficult airway characteristics	161 (56.1)	47 (57.3)	31 (52.5)	48 (58.5)	35 (54.7)	0.897

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

Page 29 of 35

 BMJ Open

Values are numbers (%) of observations or means ± standard deviations. ED, emergency department; ICU, intensive care unit; CPA, cardiopulmonary arrest.

For peer review only

24 (67)

Macintosh

37 (58)

19 (46)

18 (78)

35 (78)

18 (67)

Р

0.004

0.00004

0.556

radie 2. First-pass intudation succ	ess rates of four laryingosc	copes		
	All laryngoscopes	Pentax-Airway Scope	King VISION	McGrath Mac
All operators, n	287	82	59	82
First-pass intubation success	199 (69)	64 (78)*	34 (58)	64 (78)†
Non-expert operators	156	46	32	37
First-pass intubation success	104 (67)	40 (87)‡	16 (50)	29 (78)§

Table ? First pass intubation success rates of four lawingescopes

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

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

95 (73)

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

Expert operators

First-pass intubation success

 For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

1	
2	
3	
4	
5	
6	
0	
/	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
10	
20	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
20	
20	
39	
40	
41	
42	
43	
44	
45	
46	

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

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	5		
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

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

BMJ Open

 For peer review only

Time to perform intubations, sec Difficulty score [†] Values are means ± standard de Difficulty was scored by visua <i>post hoc</i> analyses were perform	60 ± 31 (n=269) 39 ± 27 (n=258) eviations; *P=0.0 Il analogue scale,	63±34 (n=78) 39±26 (n=72) 27 vs. Macintosh. from very easy (0) to ver	63±31 (n=45) 43±26 (n=45)	62±31 (n=79) 32±27* (n=78)	52±27 (n=67) 45±26 (n=63)	0.043 0.009
Difficulty score [†] Talues are means ± standard de Difficulty was scored by visua <i>ost hoc</i> analyses were perform	39±27 (n=258) eviations; *P=0.0 Il analogue scale,	39±26 (n=72) 27 vs. Macintosh. from very easy (0) to very	43±26 (n=45)	32±27* (n=78)	45±26 (n=63)	0.009
alues are means \pm standard de Difficulty was scored by visua <i>ost hoc</i> analyses were perform	eviations; *P=0.0 Il analogue scale,	27 vs. Macintosh. from very easy (0) to ver				
	ieu using Tukey	s test for paired comparis	ry difficult (100).	copes.		

STROBE Statement—	Checklist o	f items	that	should	be	included	in	reports	of	cohort	studies
								1			

	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
		(b) Provide in the abstract an informative and balanced	2-3
		summary of what was done and what was found	20
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the	4-5
	-	investigation being renorted	10
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Mathada	5		
Study design	1	Present key elements of study design early in the paper	6-8
Study design	4	Describe the setting locations and relevant dates including	6
Setting	3	periods of recruitment exposure follow-up and data collection	0
Participants	6	(a) Give the eligibility criteria, and the sources and methods of	7
Participants	0	(a) Give the englotinty chiena, and the sources and methods of selection of participants. Describe methods of follow up	1
		(b) For matched studies, give matching aritaria and number of	
		(b) For matched studies, give matching criteria and number of	
Variables	7	Clearly define all outcomes, avecaures, predictors, notantial	7 0
Variables	/	clearly define an outcomes, exposures, predictors, potential	/-8
		confounders, and effect modifiers. Give diagnostic effectia, if	
Data gourgas/	0*	Ear and variable of interact, give sources of data and datails of	7 0
	8.	For each variable of interest, give sources of data and details of	/-8
measurement		of accomment methods if there is more than one group	
Diag	0	Describe any offerte to a dance networked sources of hiss	0
Blas	9	Describe any errors to address potential sources of blas	8
Study size	10	Explain now the study size was arrived at	9
Quantitative variables	11	Explain now quantitative variables were handled in the	/-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
		(b) Describe any methods used to examine subgroups and	0
		(b) Describe any methods used to examine subgroups and	9
		(a) Explain how missing data wara addrassed	0
		(c) Explain now missing data were addressed	9
		(a) In applicable, explain now loss to follow-up was addressed	
		(<u>e</u>) Describe any sensitivity analyses	
Results	12*		11
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	
D		(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

For peer review only - http://bmjopen!bmj.com/site/about/guidelines.xhtml

	variable of interest	
	(c) Summarise follow-up time (eg, average and total amount)	
15*	Report numbers of outcome events or summary measures over time	12-13, 26
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	
17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12, 26
18	Summarise key results with reference to study objectives	14
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
20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
21	Discuss the generalisability (external validity) of the study results	16
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
	15* 16 17 17 18 19 20 21 22	variable of interest (c) Summarise follow-up time (eg, average and total amount) 15* Report numbers of outcome events or summary measures over time 16 (a) 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 (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 17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses 18 Summarise key results with reference to study objectives 19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias 20 Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence 21 Discuss the generalisability (external validity) of the study results 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

*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.