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Use of the Pentax-AWS® in 293 Patients with Difficult Airways

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Background: **Several case reports have shown that the Pentax-AWS® (Hoya Corporation, Tokyo, Japan), a new video laryngoscope, is useful in patients with difficult airways.**

Methods: **We assessed the effectiveness of the Pentax-AWS® in two groups. Group 1 included 270 patients in whom direct laryngoscopy using a Macintosh laryngoscope had been difficult. Group 2 included 23 patients with predicted difficult intubation and difficult mask ventilation without previous use of the Macintosh laryngoscope.**

Results: **In group 1, the view of the glottis with the Macintosh laryngoscope was Cormack and Lehane grade 2 in 14 patients, grade 3 in 208 patients, and grade 4 in 48 patients. In 256 patients in whom the grade was 3 or 4 with the Macintosh laryngoscope, the view with the Pentax-AWS® was either grade 1 or 2 in 255 patients (99.6%; 95% confidence intervals 97.8–100%). Tracheal intubation was successful with the Pentax-AWS® in 268 of 270 patients (99.3%; 95% confidence interval 97.4–100%), and it failed (after two attempts) in two patients. In group 2, tracheal intubation was successful in 22 of 23 patients, and it failed in one patient. The reasons for failed intubation using the Pentax-AWS® were failure to position the blade toward the glottic side of the epiglottis, inability to maneuver the endotracheal tube away from the arytenoids and into the trachea, and bleeding and swelling of the oropharynx.**

Conclusion: **The success rate of tracheal intubation using the Pentax-AWS® was high in patients with difficult laryngoscopy with a Macintosh laryngoscope and in patients with predicted difficult intubation.**

THE Pentax-AWS® (Airway Scope; Hoya Corporation, Tokyo, Japan) (fig. 1), an indirect optical laryngoscope invented by a neurosurgeon Jun-ichi Koyama, M.D., Ph.D. (Department of Neurosugery, Shinshu University School of Medicine, Matsumoto, Japan) has been available in Japan since June 2006.[1] It consists of a disposable blade (PBlade®; Hoya Corporation), a 12-cm image tube with a charge-coupled device camera, and a handle with a 6-cm liquid crystal display (fig. 1). The image tube is inserted into the PBlade® so that the PBlade® completely encloses and protects the image tube and camera. The PBlade® has a transparent window through which the camera obtains images; the camera eye is 3 cm from the tip of the PBlade®.

Several studies have shown that the Pentax-AWS® provides full views of the glottis in the majority of patients.[2–5] There have been several anecdotal reports of successful tracheal intubation using the Pentax-AWS® in patients after failed intubation using a Macintosh laryngoscope.[6–9] In addition, tracheal intubation using the Pentax-AWS® has been shown to be easier than conventional tracheal intubation in patients whose heads and necks were immobilized to simulate difficult laryngoscopy conditions.[5] Suzuki *et al.* recently reported a high success rate of tracheal intubation using the Pentax-AWS® in 45 patients in whom a clear view of the glottis could not be obtained by using a Macintosh laryngoscope.[4] In their study, no external pressure to the neck was applied during laryngoscopy (to obtain a better view of the glottis), no endotracheal tube introducer was used, and no attempts were made to intubate the trachea with the Macintosh laryngoscope. Therefore, the usefulness of the Pentax-AWS® in patients in whom tracheal intubation using the Macintosh laryngoscope has failed is not known.

The main aim of this report was to obtain the success rate of tracheal intubation using the Pentax-AWS® in a large number of patients in whom difficult tracheal intubation using the Macintosh laryngoscope was experienced as a result of a variety of anatomical and pathologic changes. The second aim was to analyze the reasons for difficulty in tracheal intubation with the Pentax-AWS®.

Materials and Methods

We started to use the Pentax-AWS® after it had been licensed for use in clinical practice in 2006. The institutional research ethics committees of all participating institutions approved the study of summarizing data (from October 2006 to August 2008) and reporting the results. The committees stated that the nature of the study would not require written informed consent from each patient. Nine senior anesthesiologists with more

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Fig. 1. The Pentax-AWS® (Hoya Corporation, Tokyo, Japan). It consists of a disposable transparent blade (PBlade®; Hoya Corporation), a 12-cm image tube with a charge-coupled device (CCD) camera, and a handle with a 6-cm full-color liquid crystal device monitor display.

than 10-yr experience in anesthesia practice from seven hospitals participated in this project: Kansai Medical University (Takii and Otokoyama Hospitals), Jichi Medical University Hospital, Asahikawa Medical College Hospital, Showa University Hospital, Dokkyo Medical School, Koshigaya Hospital all in Japan, and National University Hospital in Singapore. Each anesthesiologist had practiced the Pentax-AWS® in mannequins and had used the device in more than ten patients without predicted difficult airways.

We prospectively collected cases of the Pentax-AWS® in two groups of patients. In patients in whom orotracheal intubation was indicated, we used a Macintosh laryngoscope after induction of general anesthesia and neuromuscular blockade, when neither difficult tracheal intubation nor difficult mask ventilation was predicted, or when difficult tracheal intubation was predicted but difficult mask ventilation was not predicted. We used the Pentax-AWS® when tracheal intubation using a Macintosh laryngoscope had been difficult (group 1). If both difficult tracheal intubation and difficult mask ventilation were predicted, we used the Pentax-AWS® (before induction of anesthesia and before neuromuscular blockade) without previous use of the Macintosh laryngoscope (group 2). We did not include patients in whom we had used the Pentax-AWS® for insertion of double-lumen tubes or bronchial blockers or for the exchange of tracheal tubes. Patients in whom nasotracheal intubation was required were also not included. To obtain a success rate of tracheal intubation with the Pentax -AWS®, we included 14 patients who have been reported previously.[4,6,8,10,11]

We recorded the patients' characteristics, preoperative view of the oropharynx (classification according to Mallampati *et al.*[12] and Samsoon and Young[13]), and the thyromental distance, and we predicted that tracheal intubation using a Macintosh laryngoscope would be difficult when Mallampati was 3 or 4, when the thyromental distance was less than 6 cm, or when the patient was severely or very severely obese (as 35.0 kg/m^2 or greater, according to the World Health Organization classification). We also recorded the presence of any other factors that might make tracheal intubation difficult.

Group 1

In the operating room, we monitored all patients with electrocardiography, pulse oximetry, and noninvasive blood pressure. The patient's head was placed on a pillow (height, 4–7 cm) unless there was a risk of cervical spinal cord injury. When there was a risk of cervical spinal cord injury, the patient's head was placed directly on the operating table, and the head and neck were stabilized either manually or by a stabilizer, such as a Halo vest.

After preoxygenation of the patient, we induced anesthesia with either propofol or thiopental. After we had confirmed adequate ventilation with a facemask, we produced a neuromuscular blockade with either vecuronium or atracurium. Each anesthesiologist attempted to intubate the trachea by using a conventional English-type Macintosh laryngoscope. We judged that tracheal intubation using the Macintosh laryngoscope was difficult when one of the participating senior anesthesiologists failed to intubate the trachea twice (with external pressure to the neck and with or without the use of an Eschmann endotracheal tube introducer) or when the senior anesthesiologist would have considered an alternative device (such as the McCoy laryngoscope, intubating laryngeal mask airway, or flexible bronchoscope) had the Pentax-AWS® not been available. When a senior anesthesiologist was called by a junior who had failed to intubate the trachea using a Macintosh laryngoscope, the senior anesthesiologist could limit the insertion of the Macintosh laryngoscope to only one attempt to minimize repeated attempts at laryngoscopy.

When the anesthesiologist judged that tracheal intubation was difficult, tracheal intubation using the Pentax-

Fig. 2. The Pentax-AWS® (Hoya Corporation, Tokyo, Japan) with an endotracheal tube attached to the blade. The *target symbol* indicates the approximate location of the endotracheal tube tip when the tube is advanced down the PBlade®.

AWS® was attempted. We prepared the Pentax-AWS® system by attaching the PBlade® to the handle and fitting a well-lubricated endotracheal tube (either a conventional polyvinylchloride tube or reinforced tube) into the tube groove on the PBlade®. We positioned the endotracheal tube such that its tip was just visible on the liquid crystal display screen without obstructing views of the airway (fig. 2). The PBlade® was inserted orally, with its tip toward the glottic side of the epiglottis, as with a Miller laryngoscope blade. We used the target symbol on the display to optimize alignment of the PBlade® with the glottis to facilitate insertion of the endotracheal tube.

We graded the laryngoscopy views for each device using a modified classification reported by Cormack and Lehane.[14] We made these modifications because the tip of the Pentax-AWS PBlade® is inserted toward the glottis (table 1). Nevertheless, the grading for the Macintosh laryngoscope with this modified method should be the same for the original grading reported by Cormack and Lehane.[14]

After obtaining a view of the glottis, we attempted to advance an endotracheal tube into the trachea, and we confirmed correct tracheal intubation by auscultation of the chest and by capnography. During the period of data collection, we noticed that the use of the Eschmann endotracheal tube introducer (SIMS Portex; Hythe, Kent, United Kingdom) might be useful to guide an endotracheal tube if there was difficulty in aligning the PBlade® with the glottis.[11] Since that time, if there was difficulty in advancing a tube into the trachea, each anesthesiologist was allowed to use the Eschmann tube introducer to guide entry of the endotracheal tube into the trachea. In brief, the introducer was passed through the endotracheal tube that was loaded on the PBlade®, and the angulated tip of the introducer was directed toward the glottis under vision. After insertion of the introducer into the trachea, the tube was advanced over the introducer into the trachea.

Table 1. A Modified Cormack and Lehane Classification for the Ease of Laryngoscopy

Grade 1	Most of glottis (with or without the epiglottis) is visible
Grade 2	Only the posterior extremity of the glottis is visible
Grade 3	No glottis is visible, but the larynx (such as the epiglottis) can be seen
Grade 4	No glottis is visible, and the larynx (such as the epiglottis) cannot be seen

We allowed up to two attempts with the Pentax-AWS®. Nevertheless, we abandoned its use if we judged that there was a high risk of trauma to the airway or if arterial hemoglobin oxygen saturation decreased to less than 95%. In such a case, we used an alternative device, such as a flexible bronchoscope. We recorded the number of attempts at tracheal intubation and the use of the Eschmann tube introducer. Due to ethical considerations, if it was impossible to see the glottis (particularly if the epiglottis was not seen), the anesthesiologist could judge that tracheal intubation had failed even when an endotracheal tube introducer or an endotracheal tube was not actually inserted. No patients were excluded from the data analyses after the Pentax-AWS® was used. Possible causes of difficult tracheal intubation with the Macintosh laryngoscope and with the Pentax-AWS® were recorded.

Group 2

In group 2, we used the Pentax-AWS® without previous use of the Macintosh laryngoscope in patients in whom both tracheal intubation and mask ventilation were predicted to be difficult.

As in group 1, the patient's head was placed on a pillow (height, 4–7 cm) unless there was a risk of cervical spine injury. When there was a risk of cervical spinal cord injury, the patient's head was placed directly on the operating table, and the head and neck were stabilized either manually or by a stabilizer, such as a Halo vest. Each anesthesiologist decided to give local anesthetics, sedatives, or analgesics on the basis of the patient's condition. After preoxygenation of the patient, the Pentax-AWS® was inserted and up to two attempts

Table 2. Patients Characteristics

	Group 1	Group 2
n	270	23
Male/female, n	187/83	15/8
Age, yr	58 (16)	55 (21)
Height, cm	162 (10)	161 (10)
Weight, kg	63 (14)	60 (13)
Body Mass Index, kg/m^2*	24 (5)	23 (4)
Normal weight/obese, n	171/99	17/6
Overweight/moderate/severe/very severe, n	81/6/10/2	3/3/0/0

Data are expressed as mean (SD) or numbers of patients (n).

* World Health Organization classification: overweight = 25.0–29.9 kg/m^2; moderate obesity = 30.0–34.9 kg/m^2; severe obesity = 35.0–39.9 kg/m^2; very severe obesity > 40.0 kg/m^2.

Group 1 = patients in whom there was difficulty with the Macintosh laryngoscope; Group 2 = patients in whom difficult airway management was predicted and the Macintosh laryngoscope had not been used before the Pentax-AWS® (Hoya Corporation, Tokyo, Japan).

were made to intubate the trachea. If it was impossible to intubate the trachea, alternative methods, such as fiberoptic intubation or tracheotomy, were used to secure the airway. The number of attempts at tracheal intubation and types of local anesthetics, sedatives, or analgesics used were recorded.

Statistical Analyses

The means and standard deviations of patients age, height, weight, and body mass index were calculated. The 95% confidence intervals (CI) for the proportion of having a clear view of the glottis (Cormack and Lehane grade 1 or 2) and the success rate of tracheal intubation using the Pentax-AWS® were calculated. Minitab release 13 (State College, PA) was used to for statistical analyses.

Results

Group 1

We used the Pentax-AWS® in 270 patients in whom laryngoscopy using a Macintosh laryngoscope had failed; characteristics are reported in table 2. The main predisposing factors (detected preoperatively) that made tracheal intubation using the Macintosh laryngoscope difficult included restricted neck movement (90 patients), Mallampati score 3 or 4 (91 patients), thyromental distance less than 6.0 cm (70 patients), retrognathia (56 patients), difficulty in opening the mouth (36 patients), and history of difficult intubation (19 patients) (table 3). Other factors included macrognathia (3 patients), pharyngeal tumor (2 patients), laryngeal tumor (1 patient), lingual tonsillar hypertrophy (1 patient), severe sleep apnea syndrome (1 patient), postpharyngectomy (2 patients), epiglottic cyst (2 patients), distortion of the larynx by a thyroid tumor (1 patient), scoliosis (1 patient), history of polio (1 patient), Treacher-Collins syndrome (1 patient), Crouzon syndrome (1 patient), Goldenhar syndrome (3 patients), and Marfan syndrome (1 patient). No predisposing factors were found in 59 patients.

Table 3. Predisposing Factors of Difficult Tracheal Intubation

	Group 1	Group 2
n	270	23
History of difficult intubation	19	1
Mallampati class 3 or 4	91	14
Severe or very severe obesity	6	0
Difficulty in opening the mouth	36	4
Thyromental distance < 6 cm	70	12
Loose teeth	13	1
Retrognathia	56	3
Short thick neck	13	1
Restricted head and neck movement	90	15
Neck stabilization by halo vest	2	2
Neck stabilization by manual in-line method	25	5
Other factors*	21	5
No predisposing factors found	59	0

* Other factors in Group 1 included macrognathia (3 patients), pharyngeal tumor (2 patients), laryngeal tumor (1 patient), lingual tonsillar hypertrophy (1 patient), severe sleep apnea syndrome (1 patient), postpharyngectomy (2 patients), epiglottic cyst (2 patients), distortion of the larynx by a thyroid tumor (1 patient), scoliosis (1 patient), history of polio (1 patient), Treacher-Collins syndrome (1 patient), Crouzon syndrome (1 patient), Goldenhar syndrome (3 patients), and Marfan syndrome (1 patient). Factors in Group 2 included deformity of the airway (by a tumor or by radiation) (2 patients), large pharyngeal tumor (1 patient), large epiglottic cyst (1 patient), and postcarotid endarectomy bleeding (1 patient).

Group 1 = patients in whom there was difficulty with the Macintosh laryngoscope; Group 2 = patients in whom difficult airway management was predicted and the Macintosh laryngoscope had not been used before the Pentax-AWS® (Hoya Corporation, Tokyo, Japan). Note: there may be more than one cause present in an individual patient.

The Cormack and Lehane grades of glottis view at laryngoscopy with the Macintosh laryngoscope are detailed in table 4. In 39 patients, it was not possible to elevate the epiglottis by a Macintosh blade sufficiently enough to expose the glottis. In 256 patients in whom the grade was 3 or 4 with the Macintosh laryngoscope, the view with the Pentax-AWS® was either grade 1 or 2 in 255 patients (99.6%; 95% CI 97.8–100%).

Tracheal intubation was successful with the Pentax-AWS® in 268 of 270 patients (99.3%; 95% CI 97.4–100%) (table 5). It was successful (without the use of the Eschmann endotracheal tube introducer) at the first attempt in 255 of 270 patients (94.4%), at the second attempt in 13 patients (4.8%; in seven and six patients with and without the aid of the Eschmann tube intro-

Table 4. The Cormack and Lehane Grade of Laryngoscopy View with the Macintosh Laryngoscope and Pentax-AWS® (Hoya Corporation, Tokyo Japan) Videolaryngoscope

Grade with Macintosh Laryngoscope	Grade with Pentax-AWS®				
	1	2	3	4	Total
1	0	0	0	0	0
2	14	0	0	0	14
3	203	4	1	0	208
4	43	5	0	0	48
Total	260	9	1	0	270

Table 5. Success Rates of Tracheal Intubation with the Pentax-AWS® (Hoya Corporation, Tokyo, Japan)

	Group 1	Group 2
n	270	23
Without the use of the Eschmann tube introducer, n (%)	261/263 (99.2%)	22 (95.7%)
With the use of the Eschmann tube introducer, n (%)	7/7 (100%)	
Total, n (%, 95% CI)	268/270 (99.3%, 97.4–100%)	22 (95.7%, 78.1–9.9%)
Number of attempts		
1, n	255	20
2, n	13	2
Failed, n	2	1

Group 1 = patients in whom there was difficulty with the Macintosh laryngoscope; Group 2 = patients in whom difficult airway management was predicted and the Macintosh laryngoscope had not been used before the Pentax-AWS® (Hoya Corporation, Tokyo, Japan); 95% CI = 95% confidence interval.

ducer, respectively). The success rate of tracheal intubation without the use of the Eschmann tube introducer was 96.7% (261 of 270 patients; 95% CI 93.8–98.5%).

In these two patients in whom tracheal intubation failed, it was impossible to maneuver the PBlade® of the Pentax-AWS® toward the glottic side of the epiglottis, and the glottis could be seen in one patient (grade 1) and it could not be seen (grade 3) in the other patient. In both patients, an Eschmann tube introducer was not used, and the epiglottis prevented insertion of an endotracheal tube. In these patients, the trachea was intubated with difficulty by using a fiberoptic bronchoscope.

The reasons for failed tracheal intubation using the Pentax-AWS® after the first attempt (in 15 patients) included failing to align the PBlade® to the glottis (9 patients), failing to elevate the epiglottis sufficiently (5 patients), and tongue obstruction of PBlade® insertion due to retrognathia and restricted jaw movement (1 patient). There were predisposing factors for difficult tracheal intubation in 13 of 15 patients, and no predisposing factors were detected in the remaining two patients. Predisposing factors included restricted head and neck movement (5 patients), retrognathia (4 patients), short thick neck (2 patients), severely or very severely obese (2 patients), and difficulty in mouth opening (1 patient).

Group 2

In group 2, we electively used the Pentax-AWS® in 23 patients with known or predicted difficult tracheal intubation and mask ventilation (tables 2, 3). The factors predicting difficult airway management included Mallampati grade 3 or 4 (14 patients), difficulty in mouth opening (4 patients), thyromental distance less than 6 cm (12 patients), retrognathia (3 patients), and restricted neck movement (15 patients), deformity of the airway by a tumor or by radiation (2 patients), large pharyngeal tumor (1 patient), large epiglottic cyst (1 patient), and postcarotid endarectomy bleeding (1 patient) (table 3).

Local anesthetics (lidocaine spray), sedatives, or analgesics were used in 21 patients, whereas none were used in the other two patients. For sedation, either midazolam (2–3 mg) plus fentanyl (50–100 μg) or remifentanil (0.1 mg $\cdot$ kg^{-1} $\cdot$ h^{-1}) was used. Incremental 10-mg doses of propofol were also used.

Tracheal intubation using the Pentax-AWS® was successful in 22 of 23 patients. It was successful at the first attempt in 20 patients and at the second attempt in 2 patients, and it failed in 1 patient (table 5). This patient in whom tracheal intubation failed had required airway management and anesthesia for emergency surgery to stop postcarotid endarterectomy bleeding. The bleeding was causing airway obstruction. No clear view of the glottis was obtained with the Pentax-AWS® due to tissue swelling and blood in the oropharynx. The patient needed an emergency tracheostomy after failed intubation with the Pentax-AWS®.

Discussion

We have found that the success rate of tracheal intubation using the Pentax-AWS® was high in patients in whom tracheal intubation with the Macintosh laryngoscope had been difficult, as well as in patients with known or predicted difficult laryngoscopy, mask ventilation, or both.

Suzuki *et al.* reported a high success rate of tracheal intubation using the Pentax-AWS® in 45 patients in whom a clear view of the glottis could not be obtained (Cormack and Lehane grade 3 or 4) using a Macintosh laryngoscope.[4] In their study, no external pressure to the neck was applied during laryngoscopy (to obtain a better view of the glottis), no endotracheal tube inroducer was used, and no attempts were made to intubate the trachea with the Macintosh laryngoscope. Because the reasons for difficult laryngoscopy and difficult tracheal intubation vary considerably between patients, a large number of patients with a variety of anatomical or pathologic changes to the airway would be required to assess the usefulness of any intubation device. We assessed the usefulness of the Pentax-AWS® in a large number of patients with difficult airways due to several different pathologic changes, such as restricted neck movement, deformity of the airway, tumors in the airways, and postendarectomy bleeding. Our results indicate that the Pentax-

AWS® is potentially useful in patients with difficult airways due to several different pathologic changes.

Indirect-optical laryngoscopes or videolaryngoscopes represent a major technological advancement in anesthesia practice.[15–17] The image of the glottis is captured near the tip of the laryngoscope; as a result, the glottis will be just a few centimeters from the "eye." Unlike conventional direct laryngoscopes, it is unnecessary to align the laryngeal, pharyngeal, and oral axes to view the glottis with videolaryngoscopes. Therefore, there is theoretically a higher likelihood of obtaining a full view of the glottis even when head and neck movement are restricted. In our patients, the Pentax-AWS® enabled good views of the glottis (Cormack and Lehane grade 1 or 2) in 255 of 256 patients (99.6%) in whom laryngoscopy view were grade 3 or 4 with a Macintosh laryngoscope.

There have been several reports of successful use of other videolaryngoscopes, such as GlideScope or TruView, in patients with difficult airways in whom tracheal intubation with a Macintosh laryngoscope had failed.[15–17] One major limitation of these videolaryngoscopes is that, even when a clear view of the glottis is obtained, it can be difficult to direct the endotracheal tube into view and into the trachea.[18,19] In contrast, there is no difficulty in locating the tube tip with the Pentax-AWS® because the tip of an endotracheal tube is already captured on the video screen before device insertion (fig. 2). The target symbol on the liquid crystal display screen enables optimal alignment of the PBlade® and loaded endotracheal tube with the glottis. The PBlade® design is such that it guides the loaded endotracheal tube toward the glottis when the tube is advanced down the PBlade tube groove, thus enabling a smooth tracheal intubation (fig. 1).

In our study, tracheal intubation was successful in 268 of 270 patients (99.3%) with difficult Macintosh laryngoscopy, and tracheal intubation failed in only two of these patients (0.7%). It is not possible to calculate the incidence of difficult intubation using the Pentax-AWS® in general population because we do have the denominator for the incidence of difficult laryngoscopy with Macintosh laryngoscopes. One meta-analysis has shown that the incidence for difficult laryngoscopy with a Macintosh laryngoscope (grade 3 or 4) is 5.8% (95% CI 4.5–7.5%).[20] If we estimate that the incidence of difficult laryngoscopy with the Macintosh blade at our hospitals was also 5.8%, we can calculate the incidence of difficult laryngoscopy with the Pentax-AWS® in the general population: $5.8\% \times 2/270 = 0.043\%$, which is about 1 in 2,300 patients.

Restricted neck movement is one major cause of difficulty in exposing the glottis with a Macintosh laryngoscope. In our report, tracheal intubation was successful with the Pentax-AWS® in 104 of 105 patients who had restricted neck movement or who needed manual inline stabilization to prevent cervical spinal cord injury. This high glottis visualization success rate is most likely because there is no need to place the head and neck in the sniffing position with the Pentax-AWS®, unlike with the Macintosh laryngoscope. Two radiographic studies have also shown less neck movement during laryngoscopy with the Pentax-AWS® compared to with a Macintosh laryngoscope.[21,22] In a study of laryngoscopy during the manual in-line stabilization of the cervical spine in 203 patients without neck pathology, the view of the glottis was obscured (Cormack and Lehane grade 3 or 4) in 22 patients with a Macintosh laryngoscope, whereas a full view of the glottis (Cormack and Lehane grade 1) was obtained with the Pentax-AWS® in all 203 patients.[5] Our results confirm the effectiveness of the Pentax-AWS® for laryngoscopy and tracheal intubation in patients with cervical spine pathology.

In some patients, failure of tracheal intubation with a Macintosh laryngoscope was the result of epiglottic cysts, laryngeal tumors, and deformity of the airways. The Pentax-AWS® facilitated tracheal intubation in these patients. We have found that the Pentax-AWS® was particularly useful in these patients because it was easier to observe the pathologic changes than with the Macintosh laryngoscope and because it was easier to confirm that the tube was not traumatizing the pathologic changes. The Pentax-AWS® was also useful in patients with several different syndromes, such as Treacher-Collins syndrome and Crouzon syndrome. Therefore, although the number of patients with each pathologic change was limited, the Pentax-AWS® appears to be useful in patients with difficult airways due to a variety of anatomical or pathologic changes.

Although we had high success rates of laryngoscopy with the Pentax-AWS®, there may be several limitations to its use. At an early stage, we found that there might be difficulty in advancing the endotracheal tube, with the tip of the endotracheal tube impinging on the arytenoids or the epiglottis, despite obtaining a clear view of the glottis. In our study, this was the main cause of difficulty in our patients (9 of 15 patients). We have found that it was useful to insert an Echmann endotracheal tube introducer through the endotracheal tube into the trachea and then advance the tube over the introducer.[11] We used this technique in seven patients, and it was always successful. In our report, tracheal intubation in one patient failed after two attempts. In this patient, the anesthesiologist did not use the introducer to guide the tube.

A second limitation is the difficulty in inserting the PBlade® tip toward the glottic or posterior surface of the epiglottis. In this situation, the epiglottis obstructs the insertion of the endotracheal tube into the trachea when it is advanced down the PBlade®. This problem can also be overcome by inserting an introducer through the endotracheal tube into the trachea, disengaging the

tube from the PBlade®, and then advancing the endotracheal tube over the introducer into the trachea. The entire procedure can be viewed on the Pentax-AWS®. Third, it may be difficult to insert the PBlade® in patients with limited mouth opening. However, it was possible to insert the PBlade® in one patient with interincisor distance of 2.1 cm, and tracheal intubation was successful at the first attempt. Fourth, the PBlade® is currently only available in one size and is not suitable for children. The PBlade® can accommodate tracheal tubes up to 8.0-mm internal diameter, and it cannot be used with larger double-lumen tubes.

In common with other videolaryngoscopes and with flexible bronchoscopes, blood, vomit, secretions in the oropharynx, and fogging of the PBlade® viewing window can cause failed laryngoscopy with the Pentax-AWS®. Bleeding into the oropharynx in one patient after carotid endarterectomy caused failed laryngoscopy and intubation with the Pentax-AWS®. The PBlade® has a suction channel through which a suction catheter can be passed to remove blood and secretions close to the PBlade® tip. A Yankauer catheter can also be separately inserted into the oral cavity to remove secretion, while the Pentax-AWS® is being used. Fogging of the PBlade® viewing window can be minimized by applying an antifog solution to the window or by immersing the PBlade® in warm water before its use.

A limitation of this study is that there might have been selection bias of patients. First, each anesthesiologist might have decided against using the Pentax-AWS® if its use was predicted to be difficult, for example, when mouth opening was severely restricted, or when there was a large mass in the oral cavity. Second, we did not include patients who required nasotracheal intubation or double lumen tracheal bronchial tubes. Third, we did not include patients who were at risk of pulmonary aspiration. Therefore, the true effectiveness and true incidence of failed tracheal intubation with the Pentax-AWS® in patients with difficult airways is not known. Lastly, because of the nature of the study, we always used the Pentax-AWS® after tracheal intubation using the Macintosh laryngoscope had failed in group 1. If the order of intubation procedures had been randomized, the results could have been different. Nevertheless, the difficulty in tracheal intubation would increase after repeated attempts at intubation; therefore, the success rate of tracheal intubation using the Pentax-AWS® would not have decreased if it had been used before insertion of the Macintosh laryngoscope.

In conclusion, the success rate of tracheal intubation using the Pentax-AWS® was high in patients with difficult tracheal intubation with a Macintosh laryngoscopy due to variety of different anatomical or pathologic reasons and in patients with known or predicted difficult intubation.

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