Retrograde Light-guided Laryngoscopy for Tracheal Intubation

Clinical Practice and Comparison with Conventional Direct Laryngoscopy

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ABSTRACT

Background: Tracheal intubation with conventional laryngoscopy requires many trials until beginners are sufficiently skilled in intubating patients safely. To facilitate intubation, the authors used retrograde light-guided laryngoscopy (RLGL) and compared its feasibility with conventional direct laryngoscopy (DL).

Methods: Twenty operators participated in a prospective, randomized, open-label, parallel-arm study. These operators intubated 205 patients randomly according to a computer-generated procedure by using either DL or RLGL (five intubations with each technique). The primary outcome was the success rate of tracheal intubation. The authors evaluated the success rate of tracheal intubation, the time to glottic exposure and tracheal intubation, and the Cormack and Lehane grades.

Results: Compared with DL, the success rate was greater in the RLGL group for all five intubations (72% *vs.* 47%; rate difference, 25%; 95% CI [11.84–38.16%], $P < 0.001$). This was associated with a shorter time to glottic exposure (median [25th and 75th percentile]; 27 [15; 42] *vs.* 45 [30; 73] s, $P < 0.001$), shorter intubation time (66 [44; 120] *vs.* 120 [69; 120] s, $P < 0.001$), and decreased throat soreness (mean ± SD; visual analog scale, 2.1 ± 0.9 *vs.* 3.7 ± 1.0 cm, $P = 0.001$) in the RLGL group compared to the DL group.

Conclusion: RLGL is an alternative intubation technique. In our study, it enables beginners to intubate patients more successfully and quickly than conventional DL.

What We Already Know about This Topic

- Approximately 50 intubations are necessary for a beginner to reach a 90% success of conventional direct laryngoscopy

What This Article Tells Us That Is New

- The glottis was illuminated by using retrograde transtracheal light transmission from an external light source placed onto the skin of the caudal edge of the thyroid cartilage during direct laryngoscopy, instead of using antegrade direct illumination
- With using this technique, the beginners achieved greater success in tracheal intubation and faster intubation than the conventional technique

TRACHEAL intubation by direct laryngoscopy (DL) bears a certain risk of failure, and it takes providers many trials to acquire sufficient skill for the successful application of DL. Beginners in anesthesiology, for instance, may need between 47 and 56 intubations until they reach a success rate above 90%,[1,2] and their initial success rates range between 35 and 65%.[1–6]

To improve the success of intubation, various alternatives to conventional laryngoscopy have been described in recent years, such as the lighted stylet,[7] intubating laryngeal mask,[8,9] fiberoptic bronchoscope,[10] and video laryngoscope.[6] However, these alternatives are costly, technically complicated, and not available everywhere. Therefore, techniques that are

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Table 1. Patient Characteristics (n = 100 for Each Group)

	DL (n = 100)	RLGL (n = 100)	*P* Value
Age, yr	41.3 ± 9.5	43.6 ± 7.5	0.06
Sex (male/female)	39/61	36/64	0.77
Body weight, kg	63.7 ± 11.5	62.4 ± 10.6	0.41
Height, cm	165 ± 6	166 ± 7	0.83
Body mass index, kg/m^2	23.1 ± 3.3	22.7 ± 3.0	0.28
ASA score, Class I/II	83/17	78/22	0.37
Thyromental distance, cm	7.0 ± 0.5	6.8 ± 0.5	0.11
Mouth-open, cm	4.7 ± 0.6	4.5 ± 0.6	0.10
Mallampati score, I/II	71/29	68/32	0.76

Data are presented mean ± SD.

ASA = American Society of Anesthesiologists physical status classification; DL = direct laryngoscopy; RLGL = retrograde light-guided laryngoscopy.

inexpensive and easy to handle are still desired. With this in mind, we explored the usefulness of retrograde light-guided laryngoscopy (RLGL), which has been described in a recent case report.[11] The salient point of this method is that the glottis is visualized using retrograde transtracheal light transmission from an external light source attached to the skin, instead of antegrade illumination by DL. With this approach, the shining glottis can easily be tracked and identified.

Therefore, we hypothesized that the retrograde light helped beginners to intubate patients more effectively. The purpose of this study was to test the feasibility of RLGL by comparing it with conventional DL with regard to glottic exposure and intubation success.

Materials and Methods

This study was approved by the Ethics Committee of the Changhai Hospital of the Second Military Medical University in Shanghai, China; it was registered at www.clinicaltrials.gov (NCT01116999). This single-site study was conducted and all the patients were recruited in this university hospital.

Recruitment of Patients and Operators

In this prospective, randomized, open-label, parallel-arm superiority study, a total of 205 patients (demographics and patient characteristics are listed in table 1) admitted for surgery under general anesthesia were recruited from May 2010 to April 2011. They were informed of the experimental protocol and purpose of the study and had signed an informed consent form before receiving anesthesia. We used block randomization to ensure equal numbers of patients in each study group; all patients were allocated in a 1:1 ratio.

The inclusion criteria included a Mallampati score of I–II, thyromental distance ≥6 cm, mouth opening ≥3 cm, body mass index ≤30 kg/m^2, and the absence of temporomandibular joint disease, risks for regurgitation and pulmonary aspiration, and other apparent intubation obstacles. The exclusion criteria were C & L grade of III–IV, which was judged by qualified anesthesiologists, and critical situations with the patients, such as a significant decrease in the blood pressure or the heart rate.

Twenty operators who have never intubated a patient before were elected to intubate five patients each with either RLGL or DL. The operators were nine residents, six medical students, and five nurses. Before the start of the study, they received theoretical training on airway management, including C & L grades, bag-mask ventilation, and the theoretical background, indications, and the risks of both DL and RLGL. They practiced intubations on the airway management trainer manikin (Laerdal Medical, Stavanger, Norway) until they were able to use both techniques successfully to complete three consecutive intubations on the trainer manikin within 120 s.

RLGL

The essence of RLGL is the illumination of the glottis and pharynx by transtracheal light transmission from a light-emitting diode flashlight that is placed onto the skin of the caudal edge of the thyroid cartilage (fig. 1A–C), and the operator could adjust and optimize the location of the flashlight. Under conventional laryngoscopy with the anterior light off, the entrance of the glottis can then be viewed laryngoscopically as a bright spot against the dim red background of the pharynx. In addition, some structures surrounding the glottis, such as the vocal cord and the arytenoid cartilage, are also faintly visible (fig. 1D–E). Finally, the endotracheal tube can then be guided through the illuminated glottis and inserted into the trachea.

Experimental Design and Protocol

All intubations were conducted under the supervision of qualified anesthesiologists. The patient characteristics were documented preoperatively by the medical staff who were blinded to the design of this study. Immediately before each operation, a computer-generated instructions that were sealed in an envelope and assigned a patient to either DL or RLGL. Until the start of the intubation, the operators and supervisors were blind to the patient's identity and the technique to be used.

The patients were supine with their heads placed on a 7-cm-high pillow to ensure head stability. The patient's condition was monitored with the help of a standard electrocardiogram, pulse oxymetry, and noninvasive manometry of the arterial blood pressure. The patient breathed pure oxygen for at least 3 min before induction of general anesthesia with midazolam (0.08 mg/kg), propofol (2 mg/kg), fentanyl (2 μg/kg), and rocuronium bromide (0.8 mg/kg).

For RLGL, an assistant held the flashlight in place. The operator aligned the optical axis by lifting the base of the tongue with the help of the Macintosh blade (with the light switched off) and exposed the pharynx until the illuminated glottis was seen

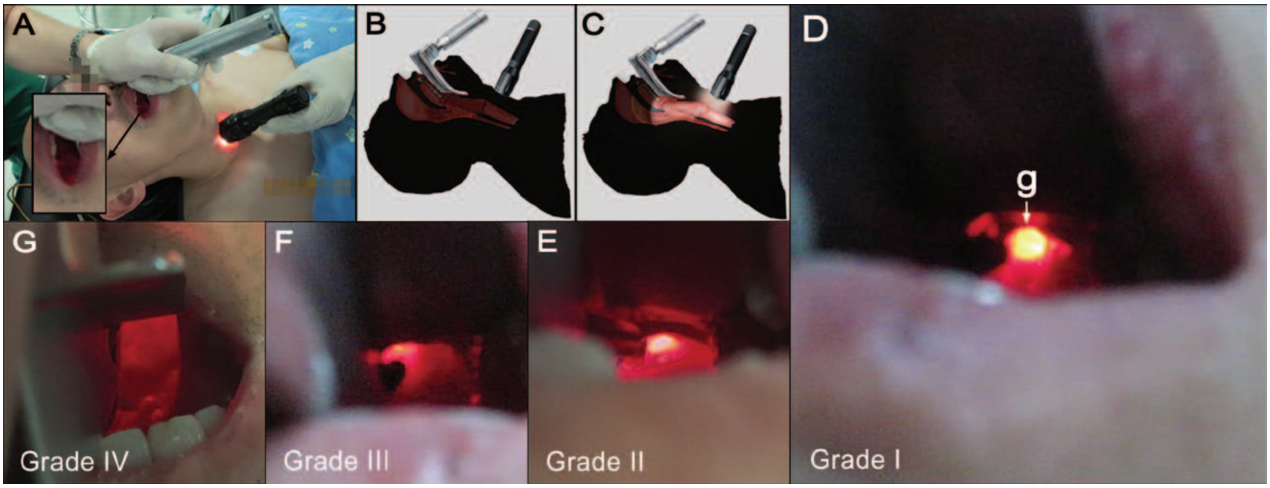

Fig. 1. Application of retrograde light-guided laryngoscopy (RLGL). (*A*) Macintosh laryngoscope with its light switched off in place and flashlight held by an assistant; Silhouettes (*B* and *C*) sketch the conditions before and after the light is switched on. (*D–G*) C & L grade I–IV as seen by an observer (original photographs). The retrograde transmitted light illuminates the glottis and the space cranial to it and marks the glottis as a yellow shining target against the dim light in the neighboring space (*D*). The glottis is seen fully and partially corresponds to C & L grade I (*D*) and II (*E*). Neither the glottis nor the epiglottis is seen corresponding to C & L grade IV (*G*). Finally, the glottis is invisible, but can still be localized by the yellow shining light in the background. We tentatively grouped such cases as C & L grade III (*F*), although one does not always see the epiglottis with RLGL. C & L = Cormack and Lehane grade; g = glottis.

against the dim red background (fig. 1D). Following the illuminated glottis as a target, the tracheal tube was eventually inserted into the trachea, and its cuff was finally inflated. The time for each intubation was limited to 120 s. The supervisors were not allowed to give instructions or assistance to the operators.

Exposure and intubation times were measured with a stopwatch. The assistant started the clock as soon as the patient's mouth was opened, stopped the watch when the operator reported his/her best view of the glottis, and stopped the watch again once the tube was in place and its cuff was inflated. Furthermore, the time lapse from mouth opening to the best glottic exposure was defined as the exposure time. The time required for the placement of the tube was defined as the intubation time.

The extent of glottic exposure was judged by the operators according to C & L[12] grades (fig. 1D–G). Failure of an attempt was defined by the following: (1) resistance to passing the tube; (2) withdrawal of the tube from the mouth in an attempt to reexpose the glottis; and (3) signs of an esophageal intubation. In the event of a failure, a new intubation attempt was immediately performed, and a total of two attempts were allowed for each patient.

The supervisors were obligated to discontinue the protocol and take over the intubation if one of the following situations occurred: (1) the time required for glottic exposure and tracheal intubation exceeded 120 s; (2) the intubation attempt failed twice; (3) the oxygen saturation decreased below 95%; (4) the blood pressure or heart rate fluctuated by more than 25%; or (5) airway injury, as evidenced by blood staining on the Macintosh blade or the head end of the tracheal tube, occurred.

Additionally, the incidence of sore throat was evaluated 24 h after intubation by staff members who were blind to the patient's grouping. A 0–10 cm visual analog scale was used for estimating pain intensity.

Statistical Analysis

The primary outcome was the success rate of tracheal intubation. The time to glottic exposure and tracheal intubation and the C & L grades were secondary outcomes. The sample size was estimated based on the primary test criterion: the success rate of tracheal intubation. The estimated success rate of tracheal intubation for the DL group was 50% in this study. A between-group difference of 20% in RLGL was considered clinically meaningful; 93 patients per group were required for a two-sided type I error of 0.05 and a power of 80%. We rounded the number to 100 patients in each group to balance the patient numbers (10 patients per operator) and intubation methods (5:5) for each operator.

The values were reported as percentage, rate difference with a 95% CI, mean ± SD, or median (25th and 75th percentiles), as appropriate. Untrained performers might fail "quickly" in one technique and succeed "slowly" in the other technique, which may increase the mean time of the successful technique without any effect on the failed one, resulting in a negative bias. Therefore, the elapsed time of all failed intubations was recorded as 120 s, regardless of the actual duration. The demographic characteristics were compared using a two-sample *t* test for continuous data and a Pearson chi-square test for categorical data. For continuous data, Levene test was used to test the equality of variances. When the variances were not equal, a separate-variances *t* test was used instead. The tracheal intubation time and glottic exposure time between the two techniques were compared using a log-rank test. Kaplan–Meier plots were created to compare the time to successful tracheal intubation between the two different groups. All reported *P* values were two-sided, and *P* values less than 0.05 were considered

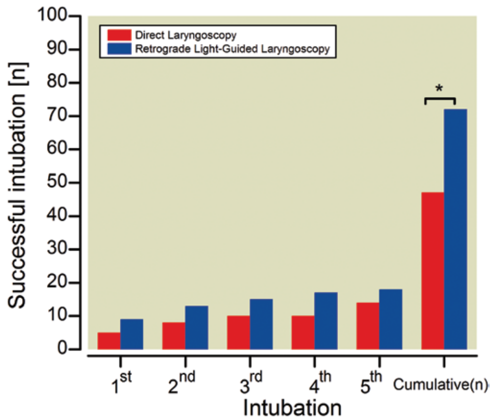

Fig. 2. Successful intubations (n) with consecutive intubations and cumulative numbers by direct laryngoscopy and retrograde light-guided laryngoscopy. Note the tendency of the intubation success rate to increase with the number of intubations, and the significant differences in the cumulative date between methods. * $P < 0.001$.

significant. The statistical analyses were performed using SPSS Statistics 17.0 software (SPSS Inc., Chicago, IL) and SAS 9.13 software (SAS Institute Inc., Cary, IN).

Results

A total of 205 tracheal intubations were performed. According to the exclusion criteria, five patients were excluded from the analysis. One patient developed an unexpected 40% decrease in blood pressure, and the other four patients were C & L grade III according to the supervising anesthesiologists. No participants experienced complications, adverse events, or observable harm as a result of the protocol.

Patient anthropometric data, particularly the anesthesia-related variables in table 1, did not differ significantly between the two groups. Therefore, patient randomization yielded two homogeneous study groups.

Success Rates

As shown in figure 2, the successful intubation numbers increased from the first to the fifth intubation with either method, with a tendency to increase more in the RLGL group compared to the DL group. Compared to the DL group, the overall success rate (72% *vs.* 47%; rate difference, 25%; 95% CI [11.84%–38.16%], $P < 0.001$) was higher in the RLGL group.

Time to Glottic Exposure and Tracheal Intubation

The exposure times in the first intubation were not significantly different, neither were the intubation times in the first and fifth intubations, but both times decreased with consecutive intubations for both groups (table 2). It is noteworthy that exposure of the glottis and intubation were accomplished faster by using RLGL than DL. These method-related differences were also apparent in the exposure time (27 [15; 42] *vs.* 45 [30; 73] s, $P < 0.001$) and intubation time (66 [44; 120] *vs.* 120 [69; 120] s, $P < 0.001$), which were both significantly shorter in the RLGL group than in the DL group.

In light of the decreasing intubation time with consecutive intubations (table 2), one would expect a close relationship

Table 2. Times to Glottic Exposure and Tracheal Intubation with DL and RLGL

	DL	RLGL	*P* Value
First intubation (n = 20)			
Glottic exposure (s)	47 (35; 82)	37 (27; 61)	0.317
Tracheal intubation (s)	120 (116; 120)	120 (65; 120)	0.145
Second intubation (n = 20)			
Glottic exposure (s)	46 (35; 78)	31 (18; 43)	0.030
Tracheal intubation (s)	120 (95; 120)	73 (58; 120)	0.029
Third intubation (n = 20)			
Glottic exposure (s)	45 (26; 72)	20 (13; 37)	0.014
Tracheal intubation (s)	102 (62; 120)	55 (38; 101)	0.038
Fourth intubation (n = 20)			
Glottic exposure (s)	42 (21; 62)	22(13; 35)	0.007
Tracheal intubation (s)	90 (45; 120)	47 (35; 73)	0.013
Fifth intubation (n = 20)			
Glottic exposure (s)	36 (23; 57)	21 (14; 31)	0.042
Tracheal intubation (s)	52 (66; 120)	47 (39; 76)	0.063
Cumulative (n = 100)			
Glottic exposure (s)	45 (30; 73)	27 (15; 42)	<0.001
Tracheal intubation (s)	120 (69; 120)	66 (44; 120)	<0.001

Data are presented as medians (25th and 75th percentiles).
DL = direct laryngoscopy; RLGL = retrograde light-guided laryngoscopy.

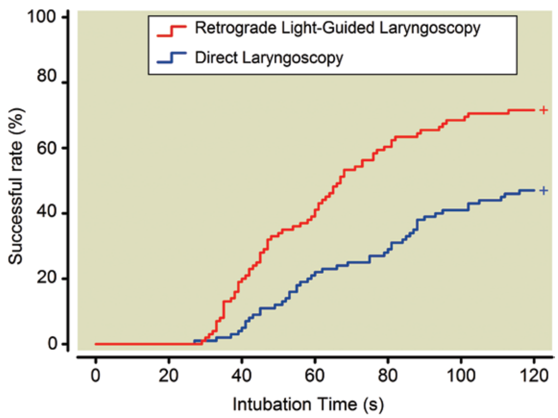

Fig. 3. Relationship between intubation time and intubation success (percent of all intubations) by direct laryngoscopy and retrograde light-guided laryngoscopy (Kaplan-Meier analysis).

between intubation time and intubation success. This relationship is evident from the Kaplan–Meier curves in figure 3. For a given intubation time, the success rates were greater with RLGL than with DL. The median intubation time with RLGL was 66 (44; 120) s, compared to 120 (69; 120) s with DL (log-rank test, $P < 0.001$).

Exposure of the Glottis

The extent of glottic exposure was judged by the operators according to C & L grades,[12] as detailed in table 3; the classification in the RLGL group is exemplified by the photographs in figures 1D–G. A total of 80 exposures in the RLGL group and 57 exposures in the DL group were graded I and II. Moreover, in the RLGL group, about half as many exposures were grade IV compared to the DL group (7 *vs.* 16). Therefore, the exposure of the glottis using RLGL was apparently better than using DL.

Of note, the operators failed to intubate 28 and 53 patients in the RLGL group and the DL group, respectively. The supervisors, who eventually intubated all of these patients, judged the patients' C & L grades as I and II (table 3).

Table 3. Assessment of Exposure of the Glottis According to C & L Grade of All Intubations by the Operators and the Supervisors for the Failed Intubations

	Operators		Supervisors	
C & L	RLGL (n = 100)	DL (n = 100)	RLGL (n = 28)	DL (n = 53)
I	51	31	13	28
II	29	26	15	25
III	13	27	0	0
IV	7	16	0	0

C & L = Cormack and Lehane grade; DL = direct laryngoscopy; RLGL = retrograde light-guided laryngoscopy.

Postoperative Sore Throat

At 24 h after intubation, a total of nine patients intubated using RLGL complained of a sore throat, which was less than the 21 patients intubated using DL ($P = 0.017$). The intensity of the throat soreness was also less in the RLGL group (visual analog scale, 2.1 ± 0.9 *vs.* 3.7 ± 1.0 cm, $P = 0.001$) compared to that in the DL group.

Discussion

Compared to DL, RLGL enables beginners to intubate patients faster and with greater success. These differences could not have resulted from bias with regard to patient recruitment because the randomized allocation of patients to the intubation methods yielded two homogeneous study groups without differences in the anesthesia-related variables, such as body size, American Society of Anesthesiologists classification, or potential intubation difficulties (table 1).

For comparing the effectiveness of the two intubation techniques, we recruited beginners who had never intubated a patient before but who had handled both techniques on manikins. By randomizing patients to one of the two intubation techniques, we avoided bias related to the operator's choice of intubation method. Furthermore, by recruiting 20 beginners, each of whom performed 10 intubations (five with either method), we also minimized the potential influence of individual technical skill. It is, therefore, safe to say that our study provides an appropriate comparison of the effectiveness of the two intubation techniques.[5,6]

Because each operator performed 10 intubations, one may wonder if they still can be qualified as beginners. The answer is most likely yes because it takes approximately 50 intubations for a beginner to reach a success rate of 90%.[1,2] Our operator success rates are in the lower range of the intubation learning curve. Therefore, the differences in the results between our patient groups are likely explained by our choice of the intubation technique rather than by the biases of the operators.

Exposure of the glottis is a critical step for tracheal intubation.[6,7,13] Many of our operators found it easier to track the intensely "red glowing"[11] glottis by using RLGL (fig. 1) than by using DL. Moreover, the disappearance of the illuminated glottis around the tube after intubation is evidence for successful intubation by RLGL, which makes the whole intubation process effective and time saving. This result suggests that different light conditions in the target area may explain the advantage of RLGL over DL. Principally, the effectiveness of both techniques rests on only two preconditions. First, the proper alignment of the optical axis between the observer and glottis is critical and is a requirement for both methods. Second, the light intensity must be appropriate to identify the glottis. DL usually provides visibility conditions sufficient for viewing structures in the neighborhood of the glottis as important landmarks for localizing the glottis if it is initially not visible. By retrograde light transmission, these structures, although only faintly visualized, can also be used for initial orientation in the pharynx/larynx. However, these structures are not essential for exposing the glottis with RLGL because the technique relies primarily on illumination of the glottis and the structures cranial to it as a guide (fig. 1D–F). This is analogous to the orientation in a tunnel, where the light at the exit marks the destination. Regardless of these considerations, RLGL does improve the intubation conditions as shown by the shift of the C & L grades to lower categories (table 3), by the shorter exposure and shorter intubation times (table 2), and, most importantly, by the greater success rates (fig. 3) compared to DL. Our average success rate of 47% in the DL group is within the range of reported values (between 35 and 65%).[1–6]

As the first study to employ this new technique and test its effectiveness against that of conventional DL, we are aware of the several limitations and shortcomings of our study. First, compared with the standard airway management trainer manikin used for training in the DL group, the trainer manikin for the RLGL group was a revised model that did not adequately imitate the scenario encountered in the case of a real patient, which required more attempts to meet the success requirement (complete three consecutive intubations) of the training process. Second, this study could not be blinded because the operators were aware of both intubation methods just prior to the start of intubation. Third, our observations apply to a select group of subjects who were healthy and had no apparent obstacles to intubation. Therefore, it remains to be seen if RLGL may also be helpful for difficult intubations. A combination of RLGL and DL may facilitate intubation in such cases. Fourth, the light intensity of the flashlight used in the RLGL group had been pre-tested for our select group of patients by our anesthesiologist before this study; the proper light intensity could guarantee the best view in the laryngeal cavity. Fifth, RLGL required an additional assistant to hold the flashlight in place. In the future, the manpower needed for RLGL could be reduced by developing a light source that is fixed on the skin. Sixth, C & L grades were better with RLGL, but it should be mentioned that, with the different light sources and light conditions in the laryngeal cavity between these two groups, the glottic exposures in the RLGL group could not be evaluated with the standard C & L grading system[12]; instead, they were evaluated with a revised version (fig. 1D–G) in this study. Seventh, the incidence of postoperative sore throat was lower and the pain intensity was less severe with RLGL. However, these observations must be interpreted with caution because of the small sample size and the lack of a standardized approach to detect laryngeal sequelae.

In conclusion, RLGL is an alternative approach for intubation. It is a simple, inexpensive, and easy-to-learn technique that may supplement conventional laryngoscopy. With this method in our study, intubation is more effective than with conventional DL. In addition, RLGL is a new assistant technique for tracheal intubation that has been reported recently. Its proper operation and effectiveness need to be further explored.

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