

Can Video Laryngoscopy Enhance Direct Laryngoscopy Skills in Novice Medical Students? A Randomized Crossover Trial (ViDiLa)

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Abstract

Background:

Video laryngoscopy (VL) has demonstrated superiority over direct laryngoscopy (DL) in emergency airway management. During VL, the shared screen view enables supervisors to observe the learner's technique in real time and provide targeted feedback on glottic visualization and laryngoscope positioning, which may facilitate the acquisition of skills transferable to subsequent DL performance. Whether this teaching advantage translates into measurable carry-over effects in novice learners remains unknown.

Methods:

In this two-sequence crossover pilot trial, fifth-semester medical students were randomized by lot within four practice groups to VL training first, followed by DL (Group A), or DL first, followed by VL (Group B). Supervised practice with feedback preceded the recorded attempt only for the first device. The second technique was recorded immediately after a demonstration. All attempts used a standardized airway simulator and identical equipment. Blinding was not feasible. The primary outcome was time to intubation (TTI) at the first DL attempt, compared between sequences. Secondary outcomes included first-pass success (FPS), time to view, time to tube passage, and TTI compared between VL and DL. Follow-up took place 1 to 4 weeks later, and self-assessed competence was surveyed before training and at follow-up.

Results:

We enrolled 64 students (Group A 33, Group B 31). At the first DL attempt, Group B had shorter TTI than Group A (median 25s vs. 32s; Hodges-Lehmann estimate 8s, 95% CI 3-13s; $p = 0.004$) and higher FPS (96.8% vs. 75.0%; $p = 0.03$). At the first attempt, VL showed longer TTI (median 35s vs. 25s; $p = 0.03$) and lower FPS (54.5% vs. 96.8%) than DL. At follow-up, TTI improved significantly with VL but not with DL. Pre-training self-assessed competence did not correlate with performance. In an exploratory mixed-effects model, VL was associated with 18% longer TTI (ratio 1.18, 95% CI 1.01–1.38).

Conclusions:

Supervised training with VL did not substitute for device-specific training with DL in novice medical students. VL appeared more challenging and may require repeated dedicated training to achieve proficiency.

Trial registration

Background

Tracheal intubation is a core competency in emergency and perioperative medicine (1, 2). Failed or difficult airway management is associated with severe complications, including hypoxia, aspiration, cardiac arrest, and death (3–5). Moreover, the risk of adverse events increases substantially with each additional intubation attempt (6). Direct laryngoscopy (DL) requires a direct line of sight to the glottis, whereas video laryngoscopy (VL) provides an indirect view using a camera or optical system (7). Over the past two decades, VL has been increasingly adopted in clinical practice (8). A Cochrane review including 222 trials demonstrated fewer failed intubations and improved glottic visualization with VL. These findings were reinforced by the DEVICE trial, which reported a higher first-pass success rate with VL than with DL (85.1% vs. 70.8%), and by a randomized trial of rapid sequence induction (9–11). Consequently, current guidelines recommend that VL should be immediately available wherever tracheal intubation is performed (12). This clinical evidence derives almost entirely from trained operators who had already achieved procedural competence and therefore does not address how novices acquire either technique. Direct laryngoscopy nevertheless remains relevant because its mechanics underpin Macintosh-style video laryngoscopy, and these devices permit an immediate switch to a direct view when the lens is obscured, or the device fails, a fallback available only to operators competent in the direct technique (13–15). Accordingly, authors continue to emphasize the importance of teaching DL; this is reflected in national guidelines that define minimum training requirements (14, 16). Achieving competence requires substantial hands-on experience, with studies suggesting that between 50 and more than 100 supervised intubations may be necessary to attain reliable proficiency (17–20). Simulation-based training in undergraduate medical education provides the foundation for initial skill acquisition. Competence is subsequently developed through supervised clinical practice and maintained through continuous procedural exposure, as the skill fades without regular practice (21). VL itself has been proposed as a teaching tool. A recent systematic review and meta-analysis of Macintosh-style VL for teaching DL reported a higher first-attempt success rate (risk ratio 1.16, 95% CI 1.07 to 1.25), but no significant difference in overall intubation success or time to intubation. Notably, nearly all studies that were included were judged to be at risk of bias in at least one domain (22). Two distinct applications of VL should be distinguished: using VL as an instructional tool, in which the instructor guides a trainee performing DL, and using VL as the primary intubation technique in which the trainee performs the procedure independently under indirect visualization. In most published studies, the video image serves as a feedback tool for the instructor while the trainee performs conventional DL (23–26). The reported benefits therefore primarily reflect enhanced supervision of DL rather than improved independent VL performance. Evidence of the subsequent use, novices intubating under indirect visualization themselves, remains limited. Some studies involving medical students have reported higher first-attempt success rates and more rapid early skill acquisition with VL-based training. By contrast, a randomized crossover manikin study involving inexperienced participants found that the advantages of VL were

largely confined to difficult airway scenarios and hyperangulated blades (27–29). Furthermore, visualization of the glottis alone does not guarantee successful tracheal intubation. Under indirect visualization, the endotracheal tube must be advanced along a trajectory that the operator cannot directly observe, representing a distinct psychomotor challenge that improved visualization alone does not overcome (30).

How these techniques interact when both are incorporated into airway training remains largely unknown. Prior training in DL supports the subsequent acquisition of video laryngoscopy skills, whereas the reverse has rarely been investigated. In short crossover studies, sequence effects may be difficult to distinguish from period effects. Furthermore, epiglottis loading has not been quantified in novice learners, and self-reported confidence correlates poorly with actual performance (31–33).

At the same time, a distinctly educational argument favors early VL exposure. During VL, the instructor and trainee share the same video image, allowing the instructor to observe the learner's technique in real time and provide targeted feedback on glottic visualization and laryngoscope positioning. In contrast, DL does not offer a shared view, as the line of sight is available only to the operator. This shared visualization may facilitate the acquisition of technical skills that transfer to subsequent DL performance. However, whether such transfer occurs in novice learners has not been directly investigated.

We conducted a randomized crossover trial in novice medical students to determine whether initial training with video laryngoscopy improves subsequent performance with direct laryngoscopy and to compare procedural performance between both techniques during repeated simulator-based training.

Methods

Aim of the Study

This study aimed to investigate whether initial training with VL improves subsequent DL performance in medical students with limited or no prior intubation experience, and to compare time to intubation (TTI) and first-pass success (FPS) rates between VL and DL across two simulator-based training sessions in a randomized crossover design.

Study Design

The ViDiLa study was designed as a prospective, randomized, controlled, two-sequence crossover pilot study conducted at the Skills Lab of the Brandenburg Medical School in Neuruppin, Germany. The practical training sessions took place in April 2026, and the follow-up assessments took place in April and May 2026. The study was approved by the Ethics committee of the Brandenburg Medical School (MHB) (396022026-NMF-E). The trial was registered retrospectively in the German Clinical Trials Register (DRKS00041720, <https://drks.de/search/en/trial/DRKS00041720>, registered 23 September 2026). Trial

results are reported in accordance with the CONSORT 2025 statement and the CONSORT extension for randomized crossover trials (34, 35). The completed checklist is provided as Additional file 2. Eligible participants were fifth-semester medical students who provided written informed consent before participation. Lack of consent was the only exclusion criterion. A two-period crossover design was chosen so that every participant performed both techniques within a single teaching session and so that sequence and carry-over effects could be quantified. No washout period was scheduled between the two periods, since the carry-over of VL training onto DL performance was itself an object of study. Participants were allocated to one of two training sequences: Group A performed video laryngoscopy (VL) first and direct laryngoscopy (DL) second, whereas Group B performed DL first and VL second. Throughout this report, Group A and Group B denote these two sequences. All attempts were performed on a standardized airway management trainer P73 (3B Scientific GmbH, Germany) using identical equipment throughout the study. DL was performed with a size 3 Macintosh blade (KaWe, Germany), whereas VL was performed using the ProVu videolaryngoscope (Flexicare Medical, United Kingdom) fitted with a size 3 Macintosh blade. A cuffed endotracheal tube with an internal diameter of 7.5 mm (RÜSCH, Germany) was used for all attempts. A malleable stylet was available for every attempt and was preformed together with the tube to an identical predefined curvature using reusable templates; participants were free to use it or not. The manikin head was kept in the neutral position throughout. Follow-up assessments were conducted 1 to 4 weeks later under the same standardized conditions. As all procedures were performed on a manikin, harms to participants were not assessed. Students, patients, or members of the public were not involved in the design, conduct, or reporting of the study.

Randomization and blinding

Participants were individually randomized to Group A or Group B by drawing lots, stratified by the four pre-existing practice groups, with a fixed number of lots per sequence in each group to ensure balanced (1:1) allocation. A study team member who was not involved in recruitment, instruction, or data collection drew the lots after written informed consent had been obtained, so that the allocation was unknown at enrollment. Participants, instructors, observers, and the data analyst were not blinded.

Endpoint measurement

The primary outcome was time to intubation (TTI), defined as the time from picking up the laryngoscope to the first effective ventilation of the simulator. All procedural times were measured prospectively with a stopwatch by independent, trained observers. Esophageal intubation was identified by inflation of the gastric reservoir bag of the trainer. Additional procedural time variables included time to view (TTV), defined as the time from passage of the laryngoscope blade beyond the teeth to the moment the participant reached for the tube, and time to tube passage (TTTP), defined as the time from reaching for the tube to inflation of the cuff. TTV thus represents the time until the participant judged the glottic view sufficient to proceed, and TTTP the time required to place the tube. Further outcomes included first-pass success (FPS), esophageal intubation, tooth contact, stylet use, and glottic view. Glottic view was graded

by the participants themselves immediately after each attempt using a printed reference chart depicting the grades of the Cormack-Lehane classification (36, 37). No independent assessment of the glottic view was performed. In the protocol, the comparison of TTI between VL and DL at the first attempt of each period was defined as the primary endpoint, and the effect of the training sequence on the first DL attempt (Group A, T2 vs. Group B, T1) as a secondary objective. As this pilot study was designed to assess feasibility and was not powered for a formal hypothesis test, we considered the transfer of VL training to DL performance the more informative question and report the sequence comparison as the primary analysis. The comparison between VL and DL is reported as a secondary analysis.

Data collection and study procedure

Before the intervention, participants completed a baseline survey including demographic characteristics and prior airway management experience. One week before the practical session, all participants completed a 90-minute theoretical session on airway management. At the beginning of the practical session, an instructor demonstrated the intubation procedure using the device allocated to the first period. Participants then received 10 minutes of supervised free practice with that device only, during which instructors provided individualized feedback, followed by one recorded intubation attempt on an adult airway simulator. Participants subsequently crossed over to the alternative technique. The instructor demonstrated the second device, but no hands-on practice, familiarization, feedback or unrecorded trial attempt with it was permitted, and the recorded attempt followed immediately. Device-specific preparation was therefore asymmetric by design: supervised hands-on practice was provided only for the device used in the first period. An instructor demonstration preceded the recorded attempt in both periods, whereas the 10 minutes of supervised practice with individualized feedback preceded it in the first period and followed it in the second. After the crossover attempt, participants received a further 10 minutes of supervised practice with individualized feedback using the second device, so that by the end of the session all participants had practised both techniques under supervision. All instruction and feedback were delivered by the same two instructors throughout the study, both anesthesiologists and certified simulation instructors, who followed an identical checklist for the demonstration and for the feedback given during the practice periods. Both instructors demonstrated and supervised both techniques, so that instructor identity was not systematically linked to a technique or to a sequence. Procedural times were recorded by four medical students who had been trained and standardized as observers, applied identical timing definitions, and used identical stopwatches.

At follow-up, both groups again performed DL and VL under standardized conditions without instruction or feedback. In Group A, two participants performed the follow-up attempts in the reversed order; therefore, follow-up comparisons were conducted by technique rather than by sequence. No structured airway training took place between the two sessions. A detailed illustration of the experimental setup and study workflow, as well as the participants' survey, is provided in the Supplement. Study data were pseudonymized using participant-specific study IDs.

Statistical analysis

All continuous data are reported as median with interquartile ranges (IQR). Categorical data are reported as numbers and percentages. All analyses were performed according to the allocated sequence and included all randomized participants with available data for the respective outcome (Fig. 1). Intubation success was defined as successful placement without esophageal intubation within 120 seconds. First-pass success (FPS) was defined as successful intubation on the first attempt without prior repositioning. As this was a pilot study, no formal power calculation was performed. The sample size was determined by the cohort size of the fifth-semester medical students invited to participate. For the primary endpoint, the first DL attempt in Group A (following prior VL training, T2) was compared with the first DL attempt in Group B (without prior VL training, T1). Among successful intubations, between-group differences in TTI were assessed using the Mann-Whitney U test. Effect sizes and Hodges-Lehmann estimates with 95% confidence intervals (CIs) are reported. Categorical outcomes were compared using Fisher's exact test, and the risk difference and the relative risk of first-pass success are reported with 95% CIs. In addition, time-to-event analyses including all attempts were performed using Kaplan-Meier methods and log-rank tests, with unsuccessful intubations censored at 120 seconds. Secondary analyses compared VL and DL performance at T1 (baseline, naive conditions) using the same approach. At follow-up (T3 and T4 combined), TTI and FPS were compared between methods using the Mann-Whitney U test. To assess within-participant learning, paired Wilcoxon signed-rank tests were applied to participants with data available at both the initial session and follow-up, separately for DL and VL.

In an exploratory analysis, independent predictors of TTI across all time points were identified using a linear mixed-effects model with log-transformed TTI as the dependent variable, restricted to successful intubations. The model included intubation technique, training phase (first attempt vs. follow-up), self-reported Cormack-Lehane grade, number of prior simulator intubations, pre-training self-assessed competence, age, and prior airway course attendance as fixed effects. Each participant contributed several intubation attempts, so the observations were not independent. A participant-specific random intercept was therefore included to account for this within-subject correlation, allowing each participant an individual baseline intubation time while the fixed effects were estimated across the whole cohort. Exponentiated coefficients are reported as TTI ratios with 95% confidence intervals. All models were fitted on complete cases; missing covariate values were not imputed. The association between pre-training self-assessed competence and TTI was additionally examined using Spearman's rank correlation, stratified by method.

As a sensitivity analysis, the primary carry-over comparison was repeated using an accelerated failure time model with a lognormal distribution, including all attempts with unsuccessful intubations censored at 120 seconds and adjusting for self-reported Cormack-Lehane grade, prior simulator experience, self-assessed competence, age, and prior airway course attendance. To further contextualize the method comparison across all time points, an adjusted Cox proportional hazards model including the same covariates was fitted and visualized as covariate-adjusted cumulative intubation curves. The comparisons between sequences and between techniques, the time-to-event analyses, and the

association between self-assessed competence and performance were prespecified in the protocol. The specification of the mixed-effects model, the accelerated failure time and Cox models, and the paired comparisons between the initial session and follow-up were defined during the analysis.

All tests were two-sided, and a p-value < 0.05 was considered statistically significant. All analyses were conducted in R (version 4.5.0; R Core Team, 2025). A complete list of packages used is provided in the Supplement.

Results

From a total of 69 fifth-semester medical students who were invited to participate, 64 provided written informed consent and were enrolled in the study (Fig. 1). Participants had a median age of 23.0 years (IQR, 21.5–26.0), 37 of 62 participants with sex recorded (60%) were female. The majority had no prior experience with direct or video laryngoscopy, and fewer than 10% had previously performed tracheal intubation in a patient.

Following randomization within the four practice groups, 33 participants were allocated to Group A (VL first) and 31 participants to Group B (DL first). Baseline characteristics were balanced between groups, with no statistically significant differences in age, sex, prior airway management experience, or self-assessed competence (**see Table 1**). Baseline data were incomplete for a minority of participants (age n = 8, sex n = 2, prior airway course n = 6, prior device experience n = 7 to 8, prior simulator intubation counts n = 6, self-assessed competence n = 7 to 8); percentages refer to participants with available data.

Across all time points, first-pass success rates were consistently higher with DL than with VL; across all attempts, however, esophageal intubation occurred exclusively with DL (9/99, 9.1%) and never with VL (0/99; p = 0.003), and the glottic view was better with VL (Cormack-Lehane grade I in 51% vs. 20%; p < 0.001; Table S1); detailed results are provided in **Figure S1**.

Procedural outcomes for the first DL attempt are summarized in Table 2. Group B showed a higher first-pass success rate than Group A (30/31 (96.8%) vs. 24/32 (75.0%); p = 0.03) and, among successful intubations, a shorter time to intubation (median (IQR) 25 s (18–28) vs. 32 s (26–41); p = 0.004). Time to view and time to tube passage were likewise shorter in Group B (TTV 18 s (12–24) vs. 24 s (20–35), p = 0.004; TTTP 19 s (14–22) vs. 23 s (18–28), p = 0.014). Esophageal intubation occurred in 7/33 (21%) participants in Group A and 1/31 (3.2%) in Group B (p = 0.054). Tooth contact, stylet use, and the distribution of self-reported Cormack–Lehane grade were comparable between groups.

Table 2
Procedural outcomes at the first direct laryngoscopy attempt

Outcome	Group A ¹	Group B ¹	p-value ²
TTI (s)	32 (26, 41)	25 (18, 28)	0.004
TTV (s)	24 (20, 35)	18 (12, 24)	0.004
TTTP (s)	23 (18, 28)	19 (14, 22)	0.014
First-pass success	24 (75%)	30 (97%)	0.03
Esophageal intubation	7 (21%)	1 (3.2%)	0.054
Tooth contact	14 (44%)	13 (43%)	> 0.9
Stylet use	26 (79%)	29 (94%)	0.15
Self-reported Cormack-Lehane grade			0.3
I	4 (13%)	6 (20%)	
II	20 (63%)	20 (67%)	
II–III	2 (6.3%)	3 (10%)	
III	4 (13%)	0 (0%)	
III-IV	1 (3.1%)	0 (0%)	
IV	1 (3.1%)	1 (3.3%)	
¹ Median (Q1, Q3); n (%)			
² Wilcoxon rank sum test; Fisher's exact test			
Group A performed DL after prior VL training (T2, n = 33 randomized); Group B performed DL without prior training (T1, n = 31 randomized). Continuous: median (IQR); categorical: n (%). Percentages refer to participants with data available for the respective variable, so denominators differ between rows. Time variables (TTI, TTV, TTTP) refer to successful intubations. TTI = time to intubation; TTV = time to view; TTTP = time to tube passage; FPS = first-pass success; DL = direct laryngoscopy; VL = video laryngoscopy.			

Carry-Over Effect of Video Laryngoscopy Training on Direct Laryngoscopy Performance

At the first DL attempt, Group A achieved a first-pass success rate of 75.0% (24/32), compared to 96.8% (30/31) in Group B (risk difference 21.8 percentage points, 95% CI 4.3 to 39.1; relative risk 1.29, 95% CI 1.05 to 1.59; p = 0.03). Among participants with first-pass success, median TTI was 32s (IQR, 26-41s; n = 24) in Group A and 25s (IQR, 19-28s; n = 30) in Group B. TTI was significantly longer in Group A than Group B, with a Hodges-Lehmann estimated difference of 8s (95% CI 3-13s; p = 0.004; Fig. 2). Including

all attempts with failed intubations censored at 120 seconds, Group B reached a higher cumulative success rate more rapidly compared to Group A ($p < 0.001$, Fig. 3).

Baseline Performance of Video and Direct Laryngoscopy

At T1, first-pass success was achieved in 18/33 participants (54.5%) with VL (Group A) and 30/31 (96.8%) with DL (Group B). Among participants with first-pass success, median TTI was 35s (IQR, 24-44s; $n = 18$) with VL and 25s (IQR, 19-28s; $n = 30$) with DL. TTI was significantly longer with VL than with DL, with a Hodges-Lehmann estimated difference of 8s (95% CI 1-16s; $p = 0.03$; **Figure S2**). Including all attempts with failed intubations censored at 120 seconds, DL reached a higher cumulative success rate more rapidly compared to video laryngoscopy at T1 ($p < 0.001$; Fig. 4).

Follow-Up Performance

At follow-up, first-pass success was achieved in 29/35 (82.9%) with VL and 32/35 (91.4%) with DL. Among participants with first-pass success, median TTI was 25s (IQR, 21-38s; $n = 29$) with VL and 27s (IQR, 23-34s; $n = 32$) with DL, with no significant difference between techniques ($p = 0.81$), **Figure S3**. Among the 27 participants who provided data for both methods at follow-up, 15 were faster with DL, 10 with VL, and 2 showed identical times with both techniques, **Figure S4**. Among participants with paired data from both the initial session and follow-up, VL showed a significant reduction in TTI from 31s (IQR, 24-44s) to 24s (IQR, 20-29s) ($n = 16$; $p = 0.01$). DL showed no significant change, with 28s (IQR, 24-41s) at the initial session and 27s (IQR, 23-35s) at follow-up ($n = 27$; $p = 0.61$), **Figure S5**.

Exploratory Analysis of Predictors of Time to Successful Intubation

In the exploratory mixed-effects model, video laryngoscopy was the only variable independently associated with TTI and was associated with an 18% longer time to intubation compared with direct laryngoscopy (TTI ratio 1.18, 95% CI 1.01–1.38). None of the other examined predictors reached statistical significance (**Figure S6**).

Self-Assessed Competence

All 64 enrolled participants completed the pre-training self-assessment questionnaire. Follow-up questionnaire data were available for 31 participants. Before training, most participants rated themselves as not confident or rather unsure across all assessed airway management skills, particularly for procedures on patients (**Table S2, Figure S7**). At follow-up, self-assessed competence had markedly increased across all items, with most participants reporting being rather confident or very confident in manikin-based procedures (**Figure S8**). Confidence ratings for patient-based procedures also improved but remained lower than those for manikin-based skills. In an exploratory analysis, pre-training self-assessed competence in endotracheal intubation was not associated with TTI for either DL ($r = -0.16$, p

= 0.171) or VL ($r = 0.04$, $p = 0.76$). A breakdown by perceived confidence level and method (DL or VL) is shown in **Figure S9**.

Sensitivity Analyses

The group difference in TTI at the first DL attempt remained significant after adjustment for self-reported Cormack-Lehane grade, prior simulator experience, self-assessed competence, age, and prior airway course training (TTI ratio for Group B versus Group A 0.62, 95% CI 0.47–0.82, $p < 0.001$; **Figure S10**). In a covariate-adjusted Cox proportional hazards model, DL was associated with faster intubation compared with VL across the observed time range (**Figure S11**).

Discussion

Key findings

We conducted a randomized crossover study comparing video laryngoscopy and direct laryngoscopy among novice medical students and identified five key findings. First, DL achieved higher first-pass success rates and shorter intubation times than VL in naive intubation attempts. Second, pre-training self-assessed competence did not reliably correlate with observed intubation performance for either method. Third, a VL-first sequence did not compensate for the absence of device-specific DL practice, with Group A showing both lower first-pass success and longer intubation times at their first DL attempt compared with Group B. Fourth, repeated exposure to VL was associated with a significant improvement in intubation time at follow-up, whereas DL performance remained stable, suggesting that VL proficiency may be more sensitive to training frequency than DL. Finally, VL appeared more challenging for novice learners overall, remaining independently associated with longer intubation times even after covariate adjustment, suggesting that it may require a distinct set of psychomotor and visuospatial skills compared with DL.

Relationship to prior studies

The clinical superiority of VL is well documented: A Cochrane review of 222 randomized trials and the DEVICE trial in critically ill adults both favored VL over DL (9, 10). This evidence, however, derives almost entirely from operators who had already achieved procedural competence, so it informs how VL performs once proficiency has been achieved rather than how novices learn. For our research question, studies of novice learners under simulation-based conditions are therefore the more informative comparators.

Studies of novice learners suggest that VL may facilitate the acquisition of DL skills. A recent systematic review and meta-analysis reported improved first-pass success with VL-based instruction, supporting VL as an effective teaching modality for DL (22).

In our simulation-based randomized controlled trial of novice fifth-semester medical students with limited prior intubation experience, we found no evidence that a VL-first sequence improved subsequent

DL performance. Participants assigned to the VL-first sequence showed lower first-pass success (75.0% vs 96.8%) and longer intubation times (median 32s vs 25s) at their first DL assessment than participants assigned to the DL-first sequence. Two features of the design qualify this comparison. Group A performed their DL assessment in the second period, after general familiarization with the manikin and the testing procedure, which would be expected to benefit rather than to disadvantage them; the observed difference is therefore unlikely to be explained by a period effect alone. Conversely, only Group B received supervised hands-on practice with DL before the assessment. The finding is best interpreted as showing that supervised practice with VL did not substitute for device-specific practice with DL, rather than as evidence of negative transfer from VL to DL. The comparison between techniques at T1 is not affected by this asymmetry. At that point, both groups had received the same amount of supervised hands-on practice with their allocated device, so the better performance observed with DL than with VL at T1 cannot be explained by unequal device-specific preparation.

Interestingly, preliminary clinical data are consistent with our findings. In a preliminary randomized trial, 20 novice trainees each performed 20 intubations in patients in one of two teaching orders. In the VL-first group, performance did not improve when trainees switched to DL, whereas in the DL-first group, the second series was significantly faster than the first, and the DL-first group reached an 80% success rate after 18 attempts compared with more than 20 attempts in the VL-first group (38). This pattern is consistent with the sequence-associated difference observed in our study and with the previous observation that DL training supports the acquisition of VL skills (31).

One possible explanation is that the psychomotor skills required for VL are not fully transferable to DL. Although both techniques achieve tracheal intubation, VL relies on indirect, screen-guided hand-eye coordination. Early training with VL may therefore reinforce motor strategies that are specific to indirect visualization rather than directly applicable to conventional DL. This may also explain why novice learners achieved higher FPS with DL. Our own data illustrate this dissociation as follows: across all attempts, VL produced a markedly better glottic view and not a single esophageal intubation, yet a lower first-pass success rate than DL. The limiting step for novices therefore appears to be tube delivery rather than visualization. Although VL reliably improves the laryngeal view, converting that view into successful tube placement requires distinct psychomotor skills that novices may not yet have developed (30).

This is further supported by a randomized manikin crossover study in inexperienced participants, in which the benefit of VL was largely confined to difficult airways and hyperangulated blades, whereas a standard Macintosh blade performed best in normal airway anatomy (29). Our study used a normal airway manikin and a Macintosh-style VL, representing precisely the setting in which little benefit from VL would be expected.

These considerations reconcile our findings with the broader clinical literature. The established superiority of VL in patients should not be assumed to translate to independent first attempts by novice learners under standardized simulation conditions. Where VL has been shown to benefit beginners, this advantage appears to arise primarily from its value as a teaching tool, enabling real-time supervision

through a shared laryngeal view, rather than from superior independent VL performance (22). This teaching perspective leads directly to the question of how quickly each technique is acquired when novices perform it themselves. Acquiring proficiency in DL requires substantial training, with systematic review evidence suggesting that at least 50 supervised intubations are needed to achieve a 90% success rate (19).

VL has been proposed to facilitate early skill acquisition, and simulation studies have reported rapid improvements in intubation performance, including higher FPS and shorter intubation times, particularly in difficult-airway scenarios or when hyperangulated devices are used (27, 29).

Our findings provide a cautious signal in this direction. Although novice learners initially performed worse with a Macintosh-style VL than with DL, median VL TTI decreased from 31 to 24 seconds at follow-up among participants with paired successful attempts ($n = 16$; $p = 0.01$). No statistically significant within-participant change was observed for DL ($n = 27$; $p = 0.61$). Given the small paired samples and differential attrition, these longitudinal findings should be considered exploratory.

Implications of study findings

While VL has demonstrated superiority in emergency airway management in experienced hands, the pathway to achieving reliable VL proficiency remains incompletely understood, particularly in novice learners (9, 10).

Our data suggest that VL and DL may engage partly distinct psychomotor and visuospatial demands and that the VL-first sequence used in this simulation-based setting did not confer a measurable immediate advantage for subsequent DL performance. Among participants with paired data at both time points, TTI decreased with VL, whereas no statistically significant change was observed with DL. However, differential attrition and the limited number of participants with two successful VL attempts preclude conclusions as to whether this reflects a true difference in skill acquisition between the two techniques.

These findings support further investigation of the optimal sequencing and amount of deliberate practice required when VL is introduced to novices, while DL skills should not be assumed to follow automatically from prior VL training. Notably, pre-training self-assessed competence did not correlate with measured performance for either technique in our cohort. This is consistent with substantial evidence that self-assessment aligns poorly with externally observed competence: A systematic review concluded that clinicians have a limited ability to self-assess accurately, and meta-analytic work focused specifically on medical students reached similar conclusions (32, 33). Our finding extends this literature to a procedural, simulation-based task and cautions against using learner confidence as a proxy for procedural readiness when deciding how much supervised practice novices need. Future studies with larger samples, longitudinal follow-up, and assessments of clinical transfer are needed to determine the optimal sequencing and dosing of VL and DL training for novice medical students.

Strengths and Limitations

This study has several strengths. We conducted a randomized crossover study in predominantly novice practitioners to examine whether a video-laryngoscopy-first training sequence was associated with subsequent direct laryngoscopy performance in learners with minimal or no prior intubation experience. Both, objective performance outcomes and self-assessed competence were systematically captured across multiple time points, enabling a more comprehensive characterization of the learning trajectory than performance measures alone would permit. The simulation setting provided a high degree of standardization, with all participants using identical laryngoscopes and the same manikin model. The inclusion of a predominantly novice population was supported by our cohort characteristics, with fewer than 10% of participants reporting any prior experience with tracheal intubation in patients, allowing assessment of early skill acquisition while minimizing confounding from pre-existing procedural competence.

Several limitations must be acknowledged. The sample size was small, which limits statistical power, particularly for subgroup and follow-up analyses. However, as this was explicitly designed as a pilot study, the primary aim was to establish feasibility and generate preliminary effect estimates rather than to draw definitive conclusions; the sample size was determined by the available cohort rather than by a formal power calculation. Analyses of TTI were restricted to successful intubations, while time-to-event analyses partially addressed this limitation through censoring of failed attempts at 120 seconds, so selection bias cannot be fully excluded. Furthermore, only the first intubation attempt per time point was analyzed, and performance on subsequent attempts within a session was not captured. Baseline covariates were incomplete for up to eight participants, and because the exploratory and adjusted models were fitted on complete cases, these analyses are based on a smaller sample than the primary comparison.

Procedural times were measured in real time with a stopwatch, and the attempts were not video recorded. Attempts could therefore not be re-measured, agreement between the four observers could not be quantified, and the timing endpoints retain an element of observer judgement.

Follow-up attendance was incomplete, with performance data available for 35 of 64 participants and self-assessment questionnaire data for only 31, some of whom had missing individual items. This limits the interpretability of both learning trajectory and competence analyses and introduces the possibility of attrition bias. Attrition was also differential, with 67% of Group A but only 42% of Group B attending follow-up, so selective loss to follow-up cannot be excluded. Blinding of participants and assessors to the technique was not possible. All VL attempts used a single Macintosh-style device, so the findings cannot be extrapolated to hyperangulated blades, and the study was conducted at a single center within one curriculum, which limits generalizability.

The two periods were not matched for device-specific preparation. Participants received supervised hands-on practice only with the device allocated to the first period, whereas the second technique was performed after demonstration alone. The primary comparison therefore contrasts a first DL attempt preceded by supervised DL practice (Group B) with a first DL attempt preceded by supervised VL practice

and a DL demonstration only (Group A). It addresses whether supervised practice with VL can substitute for device-specific practice with DL, and not whether VL exposure confers a benefit over and above equivalent DL practice. The design does not allow these two questions to be separated. The comparison is additionally confounded with period, in that Group A performed the assessment in the second period; this would be expected to favor Group A through general familiarization with the setting and therefore acts against, rather than in the direction of, the observed difference. This limitation applies to the sequence comparison only. The between-technique comparison at T1 was made after equivalent supervised practice with the allocated device and is therefore unaffected.

Glottic view was graded by participants themselves using a reference chart rather than by an independent assessor. The reliability of novice self-assessment of the laryngeal view is unknown, and the conditions differ systematically between techniques: during VL the glottic image is displayed on a shared screen, whereas during DL the view is available to the operator alone. Cormack-Lehane grade should therefore be interpreted as a self-reported measure, and the adjusted analyses including it as a covariate should be read with this in mind.

Finally, the manikin setting limits external validity, as clinical intubation conditions differ substantially with respect to patient anatomy and the demands of real-world settings. However, a controlled simulation environment is particularly appropriate for novice learners who have not yet acquired sufficient competence for clinical exposure.

Conclusion

Compared with DL, VL appeared more challenging for novice learners and may require a distinct set of psychomotor and visuospatial skills. These differences raise questions about the direct comparability of learning curves between the two techniques and suggest that proficiency in one modality may not automatically translate into competence in the other.

Abbreviations

CI	Confidence interval
CONSORT	Consolidated Standards of Reporting Trials
DL	Direct laryngoscopy
DRKS	Deutsches Register Klinischer Studien (German Clinical Trials Register)
FPS	First-pass success
IQR	

Interquartile range
T1, T2, T3, T4
Study timepoints
TTI
Time to intubation
TTTP
Time to tube passage
TTV
Time to view
VL
Video laryngoscopy

Declarations

Ethics approval and consent to participate

This study was conducted following the guidelines of the Declaration of Helsinki and approved by the Ethics committee of the Brandenburg Medical School (MHB) 396022026-NMF-E. All participants provided written informed consent prior to study participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available. The ethics approval obtained for this study and the informed consent provided by participants cover the use of pseudonymized data for the present analysis only and do not extend to public deposition or transfer to third parties. In addition, the cohort comprises a single class year at one institution, so the combination of demographic characteristics and repeated individual performance measures would carry a realistic risk of re-identification even after removal of direct identifiers. In accordance with the study protocol and the participants' informed consent, individual participant data are not made available to third parties. The study protocol is available online at DRKS, and the statistical analysis plan and the R code used for the analyses are available from the corresponding author on reasonable request.

Competing interests

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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Authors' contributions

JS, MKK, PV and JN conceptualized the study and developed the methodology. JS, NS, LL, and PV collected the data. JN performed the formal analysis. JN and JS prepared the original draft of the manuscript. LL, JN, MKK, NS, PV, SKK, and JS reviewed and edited the manuscript. JS and MKK acquired funding and provided resources. JN and JS supervised the study. All authors read and approved the final manuscript.

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Table 1

Table 1 is available in the Supplementary Files section.

Figures

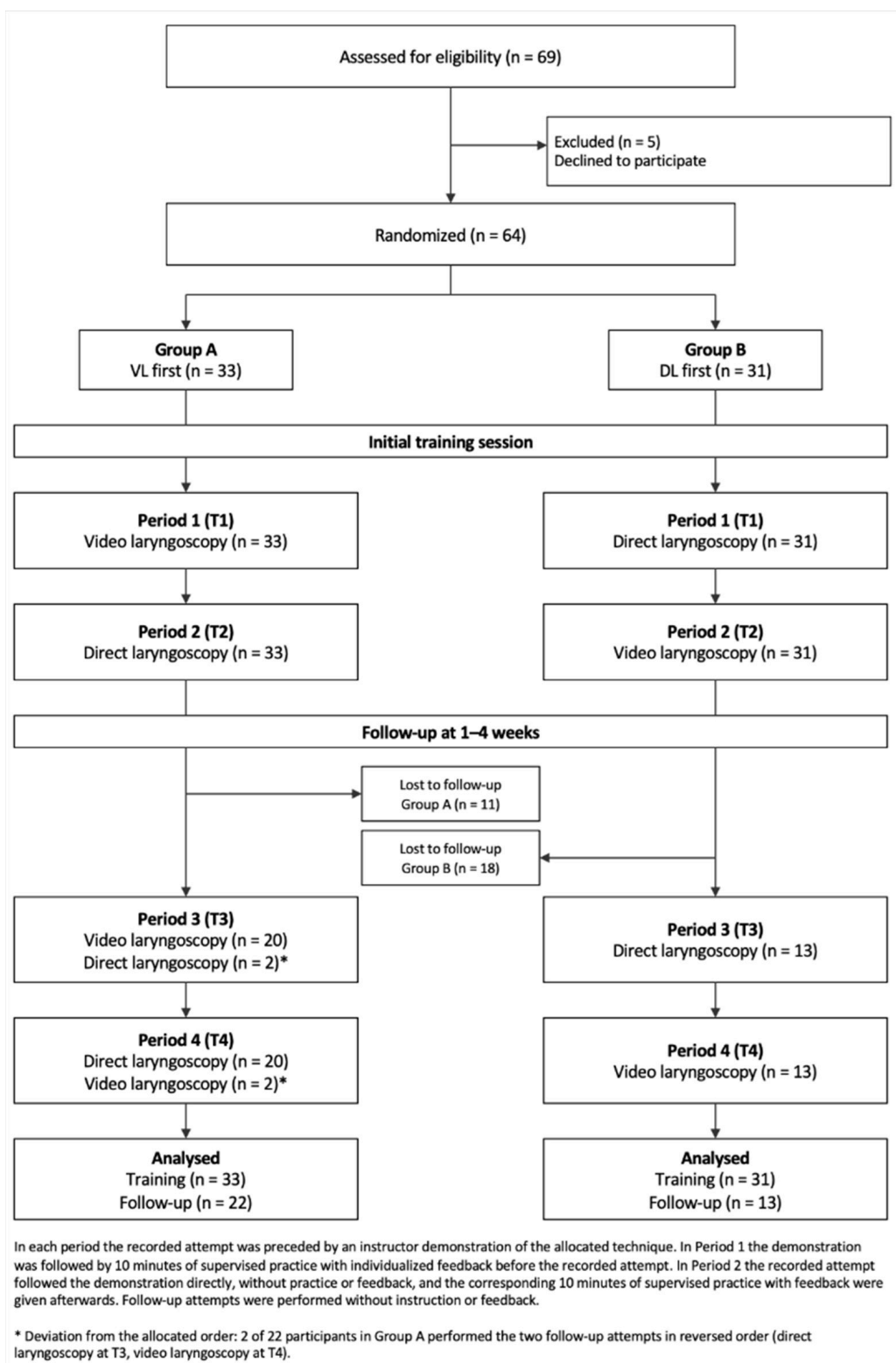


Figure 1

Participant Flow

Flow diagram of participant enrolment, randomization, and follow-up in the ViDiLa trial. Of 69 fifth-semester medical students assessed for eligibility, 64 were enrolled and randomized to a training sequence beginning either with video laryngoscopy (VL; Group A) or with direct laryngoscopy (DL; Group

B). At T1, 33 participants in Group A performed VL and 31 participants in Group B performed DL. At T2, after crossover, the same 33 and 31 participants performed DL and VL, respectively. At T3, 22 participants in Group A and 13 in Group B completed the follow-up assessment (11 and 18 participants, respectively, were lost to follow-up), and the same participants were assessed again at T4. In Group A, two participants performed the follow-up attempts in the reversed order (DL at T3, VL at T4); follow-up comparisons were therefore made by technique rather than by timepoint. All available data were analysed according to the study protocol.

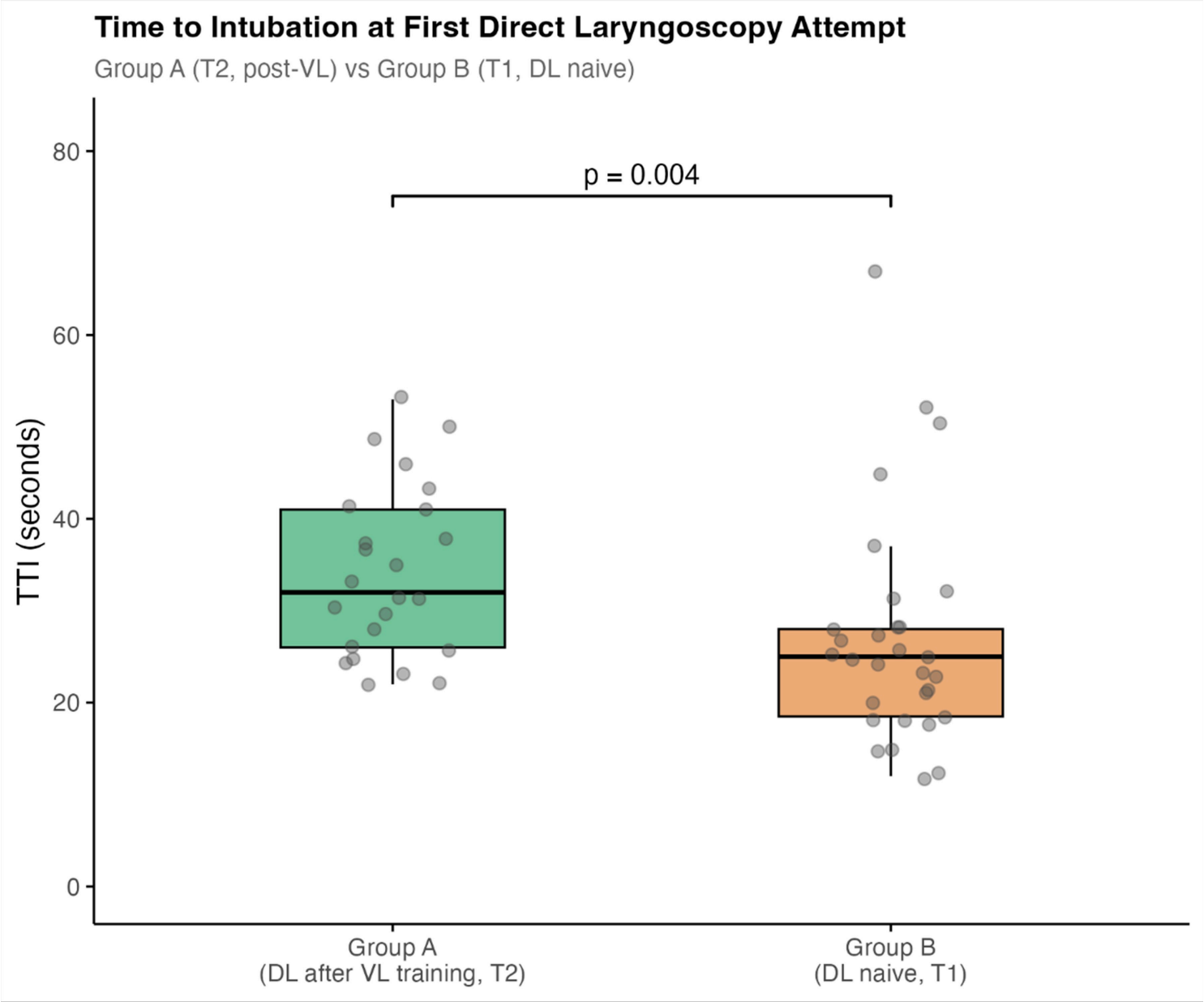


Figure 2

Time to intubation at first direct laryngoscopy attempt

Box plots show median (IQR) with individual TTI data points. Analysis is restricted to participants with first-pass success. Group A performed direct laryngoscopy after prior video laryngoscopy training (T2,

n=24); Group B performed direct laryngoscopy without prior training (T1, n=30). Group A showed a significantly longer time to intubation compared to Group B (median 32s vs. 25s; Hodges–Lehmann estimate 8s (95% CI 3-13s); p=0.004).

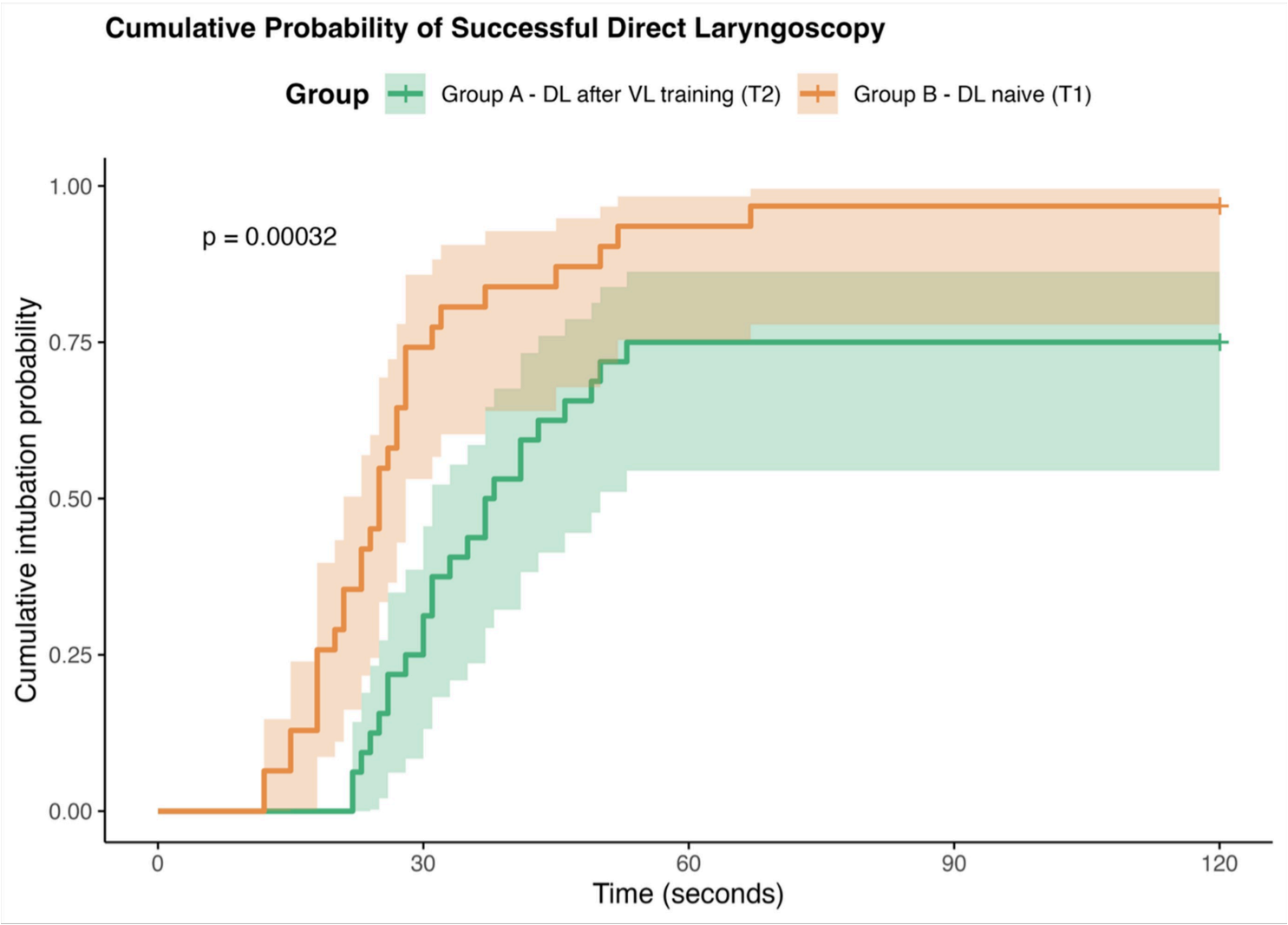


Figure 3

Cumulative probability of successful intubation at first direct laryngoscopy attempt

Kaplan-Meier curves show the cumulative probability of successful first-pass intubation within 120 seconds. Group A performed direct laryngoscopy after prior video laryngoscopy training (T2, n=32 with data available); Group B performed direct laryngoscopy without prior training (T1, n=31). Failed attempts were censored at 120 seconds. Shaded areas represent 95% confidence intervals. Group B reached a higher cumulative success rate more rapidly than Group A, with a final success rate of 96.8% versus 75.0% at 120 seconds (p<0.001).

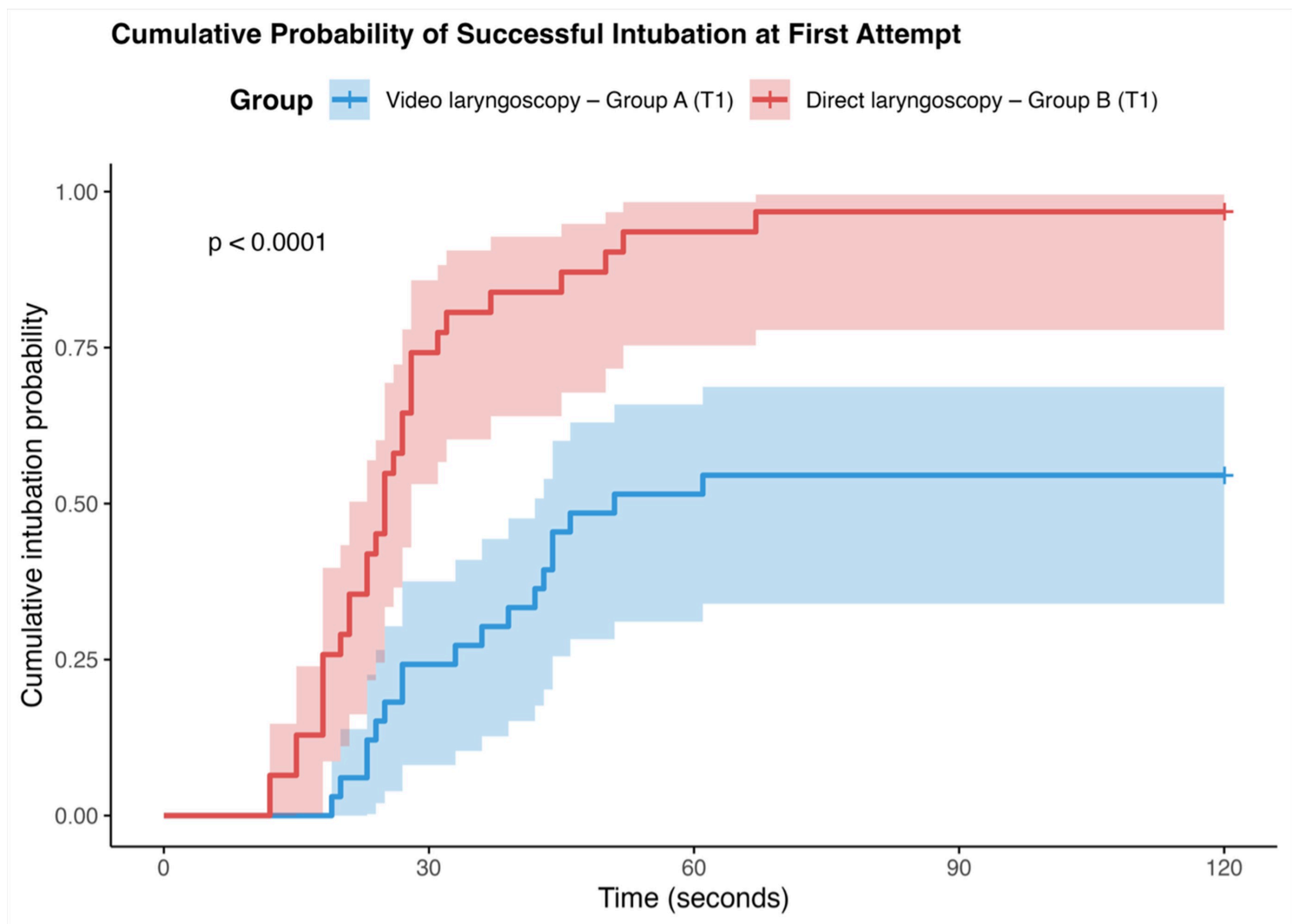


Figure 4

Cumulative probability of successful intubation at first attempt

Kaplan-Meier curves compare video laryngoscopy (Group A, n=33) and direct laryngoscopy (Group B, n=31) at the first intubation attempt (T1). Both groups had received an instructor demonstration and 10 minutes of supervised practice with their allocated device and had no prior experience with it, so this comparison is not affected by the asymmetric device-specific preparation that applies to the crossover attempt. Direct laryngoscopy achieved a higher cumulative success rate within 120 seconds (96.8% vs. 54.5%; $p < 0.001$). Failed attempts were censored at 120 seconds. Shaded areas represent 95% confidence intervals.

Supplementary Files

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