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Original Article

Comparative Hemodynamic Stability and Physiologic Stress During Difficult Airway Intubation: Video Laryngoscopy Versus Direct Macintosh Laryngoscopy

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ABSTRACT

Background: Direct laryngoscopy can provoke marked sympathetic stimulation, and this effect may be amplified in difficult airway scenarios where laryngoscopic force and procedural complexity increase. Evidence suggests videolaryngoscopy may attenuate physiologic stress responses during intubation, but comparative data in difficult airways remain clinically important. Objective: To compare hemodynamic variability and physiologic responses during intubation using Macintosh laryngoscopy versus video laryngoscopy in patients with difficult airway predictors. Methods: A comparative clinical study was conducted among adults with difficult airway features. Participants underwent intubation using Macintosh or a video laryngoscope, and peri-intubation heart rate, blood pressure, mean arterial pressure, oxygen saturation, $ETCO_2$ categories, and ECG findings were recorded and compared between devices. Results: Sixty-eight participants were analyzed. Videolaryngoscopy demonstrated more stable peri-intubation physiology with significant between-device differences favoring video laryngoscopy for heart rate (mean difference 0.48; 95% CI 0.22–0.74; $p<0.001$), blood pressure (1.18; 0.58–1.78; $p<0.001$), mean arterial pressure (2.12; 1.50–2.74; $p<0.001$), and SpO_2 (0.74; 0.43–1.05; $p<0.001$). Extreme responses and ECG abnormalities were observed predominantly with Macintosh laryngoscopy. Conclusion: In difficult airway conditions, videolaryngoscopy is associated with reduced hemodynamic variability and fewer extreme physiologic responses compared with Macintosh laryngoscopy. Keywords: difficult airway; videolaryngoscopy; Macintosh laryngoscope; hemodynamic response; intubation; mean arterial pressure.

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INTRODUCTION

Endotracheal intubation remains a high-stakes component of general anesthesia, and the hemodynamic response provoked by laryngoscopy and tracheal tube passage is clinically relevant because acute sympathetic surges can precipitate tachyarrhythmias, myocardial ischemia, and cerebrovascular complications in susceptible patients. This stress response is mediated by intense stimulation of the supraglottic and infraglottic structures, and it may be amplified when airway visualization is limited, laryngoscopic force increases, and intubation attempts are prolonged. Modern perioperative medicine therefore emphasizes not only technical success but also "physiologic intubation," prioritizing device selection and technique to reduce oxygenation failure and cardiovascular instability during airway management.

Difficult airway prediction and preoperative assessment remain imperfect despite established bedside screening tests, and the presence of multiple predictors frequently clusters in the same patient, increasing the likelihood of difficult laryngoscopy and physiologic perturbation during airway instrumentation (1). In this context, videolaryngoscopy has become increasingly integrated into routine and difficult airway practice because it improves glottic visualization, reduces the need for line-of-sight alignment, and may decrease laryngoscopic force relative to direct laryngoscopy. Prior comparative

studies have reported attenuated hemodynamic responses during videolaryngoscopy compared with Macintosh laryngoscopy in mixed surgical populations and in selected higher-risk groups, supporting a plausible physiologic advantage during airway manipulation (2–6). Moreover, rescue-device literature and comparative trials of video-enabled platforms suggest that improved visualization can reduce failed attempts and facilitate more controlled tube delivery, which may translate into fewer complications and more stable peri-intubation physiology (7,8). Contemporary difficult airway guidance further supports the role of videolaryngoscopy within structured airway strategies that prioritize first-pass success and minimization of adverse physiologic events, reflecting the transition of airway management toward protocolized, safety-oriented, and outcome-driven practice (9). This transition is also reflected in national practice patterns demonstrating broad adoption of videolaryngoscopy in modern anesthesia systems, reinforcing its relevance as a standard-of-care tool in many settings (10).

Despite this evolving evidence base, clinically grounded data from diverse real-world settings remain valuable because airway management outcomes depend on patient risk profile, difficult airway burden, institutional practice, and operator familiarity. In resource-variable environments, it remains important to define whether videolaryngoscopy provides measurable physiologic benefit in patients with difficult airway predictors undergoing routine surgical care, beyond technical visualization advantages alone. Therefore, the present study compared hemodynamic stability and physiologic stress during difficult airway intubation using video laryngoscopy versus direct Macintosh laryngoscopy among adult surgical patients managed at a tertiary-care center in Lahore, Pakistan. We hypothesized that videolaryngoscopy would be associated with reduced hemodynamic variability—reflected by smaller peri-intubation perturbations in heart rate, blood pressure, mean arterial pressure, and oxygen saturation—and fewer extreme physiologic responses compared with Macintosh laryngoscopy (2–6,9).

MATERIALS AND METHODS

A comparative clinical study was conducted at Mayo Hospital, Lahore, Pakistan, among adult patients undergoing surgery requiring endotracheal intubation under general anesthesia. Participants were enrolled based on preoperative identification of difficult airway predictors using standard airway assessment measures, including Mallampati classification, mouth opening, thyromental distance, interincisor distance, and neck circumference, and were included when findings were consistent with anticipated difficult airway. Patients were allocated to intubation using either direct Macintosh laryngoscopy or video laryngoscopy as the primary device approach according to the institutional airway management plan and intraoperative assignment. Written informed consent was obtained prior to participation, and all procedures were conducted in accordance with internationally accepted ethical principles for human research (11).

Peri-intubation physiologic measurements were collected using standard operating room monitoring. Heart rate, noninvasive blood pressure, and mean arterial pressure were recorded using multiparameter monitors, and oxygen saturation was measured continuously by pulse oximetry. End-tidal carbon dioxide was recorded following ventilation and categorized into predefined ranges (20–22 mmHg, 23–25 mmHg, and >25 mmHg). Continuous ECG monitoring was used to document rhythm status and the occurrence of peri-intubation abnormalities, categorized as normal sinus rhythm, bradycardia, tachycardia, atrial flutter, atrial fibrillation, ventricular tachycardia, or ventricular fibrillation. Airway assessment variables and clinical baseline characteristics were documented on a structured proforma at enrollment, and procedural details were recorded during intubation.

The primary outcomes were device-associated differences in peri-intubation hemodynamic responses, operationalized as the observed changes and comparative differences in heart rate, blood pressure, mean arterial pressure, and oxygen saturation between Macintosh and video laryngoscope groups. Secondary outcomes included distribution of clinically relevant response categories for heart rate, blood pressure, mean arterial pressure, oxygen saturation, $ETCO_2$ category distribution, and ECG abnormalities during

intubation. To reduce measurement bias, physiologic parameters were recorded using standardized monitors and uniform category thresholds, and data collection was performed in real time during the intubation period using consistent definitions derived from clinical monitoring standards. Potential confounding related to baseline airway difficulty burden was addressed by applying consistent eligibility criteria based on difficult airway predictors, and device-related comparisons were interpreted in the context of physiologic extremes and clinically meaningful categories rather than relying solely on central tendency.

A total sample size of 68 participants was analyzed. Statistical analysis was performed using standard statistical software. Continuous outcomes were summarized using mean and standard deviation where appropriate, while categorical variables were summarized as frequencies and percentages. Between-device comparisons for key hemodynamic outcomes were evaluated using inferential testing with reporting of mean differences and 95% confidence intervals, and statistical significance was interpreted at a two-sided alpha level of 0.05. Missing data were minimized through point-of-care recording during intubation; analyses were conducted on available observations for each parameter with consistent denominators reported in the results tables. Ethical approval was obtained through the institutional process, and confidentiality was maintained by using anonymized data extraction sheets and restricted-access storage for study records in line with ethical research conduct principles (11).

RESULTS

A total of 68 participants were included. The sample was nearly gender-balanced, with 35 females (51.5%) and 33 males (48.5%). The most common age category was 31–40 years (18/68, 26.5%), followed by 51–60 years (15/68, 22.1%) and 41–50 years (14/68, 20.6%), while 8 participants (11.8%) were aged ≥61 years. Educational attainment was dominated by secondary education (24/68, 35.3%), and higher education was reported in 20/68 (29.4%), whereas 16/68 (23.5%) were uneducated. Most participants were married (46/68, 67.6%), and the socioeconomic profile showed a larger proportion classified as rich (33/68, 48.5%) compared with middle class (26/68, 38.2%) and poor (9/68, 13.2%). The most frequent individual surgical procedures were thyroidectomy, laminectomy, appendectomy, and laparoscopic cholecystectomy, each accounting for 5 cases (7.4%), followed by rhinoplasty (4/68, 5.9%) and percutaneous nephrolithotomy (4/68, 5.9%).

Airway evaluation confirmed a high burden of difficult airway predictors. Mallampati class III was present in 54/68 (79.4%), and Mallampati class IV in 14/68 (20.6%). Markers of restricted airway access were common, including interincisor distance <3 cm in 41/68 (60.3%) and neck circumference >17 inches in 42/68 (61.8%). Nearly half of participants had mouth opening <3 fingers (33/68, 48.5%) and thyromental distance <4 cm (33/68, 48.5%), supporting the classification of this cohort as anticipated difficult airway.

For comparative outcomes, 34 participants were managed with Macintosh laryngoscopy and 34 with video laryngoscopy. Video laryngoscopy demonstrated significantly more favorable physiologic stability across all primary hemodynamic endpoints. Compared with video laryngoscopy, Macintosh laryngoscopy was associated with a significantly greater response in heart rate (mean difference 0.48, 95% CI 0.22–0.74, $p<0.001$), blood pressure response (mean difference 1.18, 95% CI 0.58–1.78, $p<0.001$), and mean arterial pressure (mean difference 2.12, 95% CI 1.50–2.74, $p<0.001$). Oxygenation also favored video laryngoscopy, with SpO_2 differing significantly between groups (mean difference 0.74, 95% CI 0.43–1.05, $p<0.001$). Consistent with these inferential findings, the Macintosh group showed a higher incidence of tachycardia (59%) and more hypertensive and elevated MAP responses, whereas the video laryngoscope group was characterized predominantly by normal heart rate responses (79%) and more stable pressure patterns.

Ventilatory and electrophysiologic observations further supported device-associated differences. The Macintosh group demonstrated a higher proportion of $ETCO_2$ >25 mmHg (32%), while the video

laryngoscope group remained largely within $ETCO_2$ 20–25 mmHg (97%). ECG disturbances were observed only with Macintosh laryngoscopy, where arrhythmias occurred in 6 cases, while no arrhythmias were reported in the video laryngoscope group. Collectively, these findings indicate that in patients with difficult airway predictors, video laryngoscopy was associated with significantly reduced hemodynamic perturbation and fewer adverse physiologic responses compared with direct Macintosh laryngoscopy.

Table 1. Baseline Characteristics, Surgical Procedures, and Airway Assessment of Participants

Characteristic	Category	n (%)
Gender	Male	33 (48.5)
	Female	35 (51.5)
Age group (years)	21–30	13 (19.1)
	31–40	18 (26.5)
	41–50	14 (20.6)
	51–60	15 (22.1)
	≥61	8 (11.8)
Education level	Uneducated	16 (23.5)
	Primary	8 (11.8)
	Secondary	24 (35.3)
	Higher education	20 (29.4)
Marital status	Married	46 (67.6)
	Single	21 (30.9)
	Widowed	1 (1.5)
Socioeconomic status	Poor	9 (13.2)
	Middle class	26 (38.2)
	Rich	33 (48.5)
Common surgical procedures	Thyroidectomy	5 (7.4)
	Laminectomy	5 (7.4)
	Appendectomy	5 (7.4)
	Laparoscopic cholecystectomy	5 (7.4)
	Rhinoplasty	4 (5.9)
	Percutaneous nephrolithotomy	4 (5.9)
Airway assessment parameters	Mallampati class III	54 (79.4)
	Mallampati class IV	14 (20.6)
	Mouth opening <3 fingers	33 (48.5)
	Thyromental distance <4 cm	33 (48.5)
	Interincisor distance <3 cm	41 (60.3)
	Neck circumference >17 inches	42 (61.8)

Table 2. Hemodynamic Changes and Physiological Responses During Intubation Using Macintosh and Video Laryngoscope

Parameter	Macintosh (n = 34)	Video Laryngoscope (n = 34)	Mean Difference	95% CI	p-value
Heart Rate (beats/min)	**Higher incidence of tachycardia (59%)**	**Predominantly normal HR (79%)**	**0.48**	**0.22–0.74**	**<0.001**
Blood Pressure Response	**More hypertensive responses**	**More stable BP readings**	**1.18**	**0.58–1.78**	**<0.001**
Mean Arterial Pressure (mmHg)	**Greater variability with elevated MAP**	**More stable MAP**	**2.12**	**1.50–2.74**	**<0.001**
SpO_2 (%)	**Occasional desaturation observed**	**100% maintained ≥96% saturation**	**0.74**	**0.43–1.05**	**<0.001**
$ETCO_2$ (mmHg)	**Higher proportion >25 mmHg (32%)**	**Majority 20–25 mmHg (97%)**			
ECG abnormalities	**Arrhythmias observed in 6 cases**	**No arrhythmias reported**			

DISCUSSION

This study evaluated hemodynamic variability during endotracheal intubation in anticipated difficult airways and demonstrated that video laryngoscopy was associated with more stable peri-intubation physiology than Macintosh laryngoscopy. In a cohort characterized by a high prevalence of difficult airway predictors—Mallampati III/IV predominance and restrictive mouth opening and interincisor distance—the video laryngoscope group showed fewer extreme heart rate and blood pressure responses and a cleaner electrophysiologic profile, while the Macintosh group concentrated a higher burden of tachycardia, high MAP categories, and observed arrhythmias. These findings align with the core airway assessment literature emphasizing that difficult airway predictors cluster and amplify procedural stress and sympathetic stimulation during laryngoscopy, particularly when airway visualization is challenging and intubation time and force may increase (1). Across the primary hemodynamic endpoints, the direction and precision of the estimated effects consistently favored video laryngoscopy, with statistically

significant between-device differences for heart rate, blood pressure, mean arterial pressure, and oxygen saturation (all $p < 0.001$). Although the absolute mean differences were modest, the pattern is clinically relevant because intubation-related sympathetic surges are not interpreted solely by mean change; rather, clinicians prioritize avoidance of extremes (severe tachycardia, hypertensive spikes, and high MAP bands) that can precipitate myocardial ischemia, cerebral hemorrhage, dysrhythmias, and perioperative instability—especially in patients with limited physiologic reserve. Prior comparative studies similarly report attenuated cardiovascular responses with videolaryngoscopic techniques versus direct laryngoscopy, plausibly reflecting reduced lifting force, improved glottic visualization, and a more controlled intubation trajectory (2–6). The present distributional data reinforce that interpretation: severe heart rate elevation occurred only in the Macintosh group, whereas the video laryngoscope group clustered within the normal heart rate band, indicating a shift away from clinically hazardous peaks rather than merely a small change in central tendency (2,3).

Oxygenation and ventilatory markers further support a stability advantage with video laryngoscopy in difficult airway conditions. The video laryngoscope group maintained higher SpO_2 categories with no low-saturation strata represented, while the Macintosh group showed multiple tiers of desaturation, including a small subset falling below 70%. Even short desaturation episodes can be consequential in difficult airway management because rescue options and re-oxygenation windows may narrow rapidly; therefore, strategies that reduce repeated attempts and minimize airway manipulation time are prioritized. Rescue-device literature underscores that improved visualization and simplified tube delivery can reduce failed attempts and facilitate recovery pathways after direct laryngoscopy difficulty (7,8). In parallel, $ETCO_2$ findings suggested more favorable ventilation patterns in the video laryngoscope group, with far fewer readings in the >25 mmHg category, consistent with smoother airway control and fewer physiologic perturbations during the intubation interval.

From a safety and implementation standpoint, the findings are congruent with contemporary difficult airway guidance that emphasizes preparation, device selection, and techniques that maximize first-pass success and minimize physiological stress (9). The observed preference toward videolaryngoscopy also reflects evolving practice trends in high-resource systems, where adoption has increased as clinicians seek both technical and physiologic advantages in routine and difficult airways (10). Importantly, physiologic benefit does not eliminate the need for operator competence and standardized protocols; rather, it strengthens the case for training frameworks, device familiarization, and structured airway plans, especially in tertiary centers managing higher-risk surgical populations.

This work should be interpreted in light of standard clinical research considerations. Hemodynamic outcomes can be influenced by anesthetic induction agents, depth of anesthesia, pre-existing cardiovascular disease, and peri-intubation timing of measurement; therefore, rigorous protocolization of measurement timepoints and adjustment for key confounders are essential for maximal causal clarity. Nonetheless, the consistency across endpoints, the clinically interpretable shift away from extremes, and the safety-aligned ECG pattern collectively support the inference that video laryngoscopy may offer a physiologic buffering effect during difficult airway intubation. Future studies with clearly prespecified primary endpoints, standardized timing (e.g., baseline, post-induction pre-laryngoscopy, immediate post-tube confirmation, and 1–5 minute intervals), and stratification by comorbidity burden would further strengthen generalizability and align reporting with modern ethical and transparency expectations for human research (11).

CONCLUSION

In adults with predictors of difficult airway, video laryngoscopy was associated with more stable peri-intubation physiology than Macintosh laryngoscopy, demonstrating significantly lower hemodynamic variability across heart rate, blood pressure, mean arterial pressure, and oxygen saturation and fewer

extreme physiologic responses, supporting videolaryngoscopy as a preferred approach when the clinical objective is to minimize intubation-related cardiovascular and oxygenation perturbations.

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