International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Videolaryngoscopy Versus Direct Laryngoscopy in Predicted Difficult Airways: A Comparative Study

Dr. Prathap Pancheti[1], Dr.kamidi.Rishika[2], Dr.Kamidi.Varun[3]

[1]*Assistant Professor, Dept of Anesthesiology and Critical Care Medicine, Konaseema Institute of Medical Sciences and Research Foundation*

[2]*Senior resident, Dept of Anesthesiology.*

[3]*MD Pathology, Associate Professor,* Gayatri Vidya Parishad Institute of Health Care and Medical Technology

OPEN ACCESS

Corresponding Author:

Dr. Prathap Pancheti
Assistant Professor, Dept of Anesthesiology and Critical Care Medicine, Konaseema Institute of Medical Sciences and Research Foundation

Received: 14-10-2025
Accepted: 16-11-2025
Available online: 26-11-2025

ABSTRACT

Background: Difficult airway management remains a critical challenge in anaesthesia practice, with failed intubation being a leading cause of anaesthesia-related morbidity and mortality. Videolaryngoscopy has emerged as a promising alternative to conventional direct laryngoscopy, offering enhanced glottic visualization through video technology. However, its superiority in predicted difficult airway scenarios requires robust evidence from well-designed comparative studies. This study aimed to compare the efficacy and safety of videolaryngoscopy versus direct laryngoscopy in patients with predicted difficult airways undergoing elective surgical procedures.

Methods: This prospective comparative study was conducted at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, from February 2024 to June 2025. A total of 500 adult patients with predicted difficult airways, as identified by preoperative airway assessment scores, were allocated to either the videolaryngoscopy group (n=250) or the direct laryngoscopy group (n=250) based on alternate allocation method. Primary outcomes included first-attempt intubation success rate, time to intubation, and Cormack-Lehane grading. Secondary outcomes encompassed hemodynamic parameters, intubation-related complications, and overall intubation difficulty score.

Results: The videolaryngoscopy group demonstrated significantly higher first-attempt intubation success rates compared to direct laryngoscopy (88.4% vs 72.8%, $p<0.001$). Mean intubation time was comparable between groups (42.3±12.6 seconds vs 45.8±15.2 seconds, $p=0.065$). Videolaryngoscopy provided superior glottic visualization with significantly better Cormack-Lehane grades (Grade I-II: 84.0% vs 61.6%, $p<0.001$). The incidence of intubation-related complications, including mucosal trauma and dental injury, was significantly lower in the videolaryngoscopy group (6.4% vs 14.8%, $p=0.003$). Hemodynamic stability was better maintained with videolaryngoscopy.

Conclusion: Videolaryngoscopy significantly improves first-attempt intubation success rates and reduces complications in patients with predicted difficult airways compared to conventional direct laryngoscopy. The enhanced glottic visualization provided by videolaryngoscopy translates into improved patient safety outcomes. These findings support the integration of videolaryngoscopy as the preferred intubation technique for managing predicted difficult airways in routine anaesthesia practice.

Keywords*:Videolaryngoscopy, Direct laryngoscopy, Difficult airway, Intubation, Cormack-Lehane grade, Comparative study.*

INTRODUCTION

Airway management is a fundamental and critical skill in anaesthesia practice, with successful endotracheal intubation being essential for patient safety during general anaesthesia and emergency situations. Despite advances in airway management techniques and devices, difficult intubation continues to be a significant clinical challenge, occurring in approximately 5-8% of routine anaesthetic procedures and contributing substantially to anaesthesia-related morbidity and mortality [1,2]. Failed intubation, defined as the inability to successfully place an endotracheal tube after multiple attempts, represents one of the leading causes of major anaesthetic complications, potentially resulting in hypoxic brain injury, cardiac arrest, and death [3].

The prediction of difficult airways has been extensively studied, with various anatomical and clinical factors identified as risk predictors. The modified Mallampati classification, thyromental distance, sternomental distance, mouth opening, and neck mobility assessment constitute the cornerstone of preoperative airway evaluation [1,4]. These bedside screening tests, when used in combination, enhance the sensitivity and specificity of difficult airway prediction, allowing anaesthesiologists to formulate appropriate management strategies and prepare necessary equipment and expertise. However, even with meticulous preoperative assessment, unexpected difficult airways continue to challenge clinicians, highlighting the need for improved intubation techniques and equipment.

Direct laryngoscopy, first described by Chevalier Jackson in 1913, has remained the gold standard technique for endotracheal intubation for over a century. This conventional method requires alignment of the oral, pharyngeal, and laryngeal axes through head extension and elevation to achieve direct line-of-sight visualization of the glottic opening. While direct laryngoscopy has proven effective for routine intubations, it has several inherent limitations, particularly in patients with difficult airways [2]. These limitations include restricted visualization in patients with limited mouth opening, cervical spine immobility, anterior laryngeal anatomy, or obesity. Furthermore, the technique requires significant skill acquisition, may cause hemodynamic instability due to sympathetic stimulation, and carries risks of dental trauma and soft tissue injury.

The introduction of videolaryngoscopy represents a paradigm shift in airway management, offering indirect visualization of the glottic opening through a video camera mounted on the laryngoscope blade. This technology eliminates the requirement for direct line-of-sight visualization by providing an enlarged, high-resolution image of the laryngeal inlet on an external monitor [5]. Videolaryngoscopes are available in various designs, including channeled devices that guide endotracheal tube placement and non-channeled devices that require manual tube manipulation. The enhanced visualization provided by videolaryngoscopy theoretically offers several advantages over direct laryngoscopy, including improved Cormack-Lehane grades, reduced intubation attempts, decreased cervical spine movement, and potential educational benefits for training junior anaesthesiologists.

Multiple systematic reviews and meta-analyses have evaluated the comparative efficacy of videolaryngoscopy versus direct laryngoscopy, with generally favorable results for videolaryngoscopy in terms of first-attempt success rates and glottic visualization [6,7]. However, several studies have reported conflicting results regarding intubation time, with some demonstrating prolonged intubation duration with videolaryngoscopy, particularly among less experienced operators. Additionally, concerns have been raised about the learning curve associated with videolaryngoscopy and the potential for complications related to excessive force application due to the indirect view.

The evidence supporting videolaryngoscopy specifically in predicted difficult airway scenarios remains heterogeneous, with many studies limited by small sample sizes, varying definitions of difficult airways, and differences in operator experience and videolaryngoscope models [8]. Furthermore, most existing literature originates from Western populations, with limited representation from South Asian populations who may have distinct anatomical characteristics affecting airway management. The Indian population, characterized by relatively shorter stature, different craniofacial morphology, and higher prevalence of conditions such as rheumatoid arthritis affecting cervical spine mobility, may present unique challenges in airway management that warrant specific investigation.

Previous studies have predominantly focused on emergency department settings or included mixed populations of both predicted easy and difficult airways, potentially diluting the observable treatment effects in the difficult airway subgroup. Additionally, many trials have been underpowered to detect clinically meaningful differences in important secondary outcomes such as complication rates and hemodynamic stability [9]. There exists a critical need for adequately powered comparative studies specifically targeting patients with predicted difficult airways to establish definitive evidence for clinical practice guidelines and recommendations.

The selection of appropriate intubation technique in predicted difficult airways has significant implications for patient safety, healthcare resource utilization, and training programs. Videolaryngoscopy equipment represents a substantial capital investment for healthcare institutions, and the cost-effectiveness of routine videolaryngoscopy use in predicted difficult airways requires evaluation through rigorous clinical studies demonstrating clear clinical benefits [10]. Furthermore, understanding the comparative performance characteristics of different intubation techniques is essential for developing evidence-based difficult airway management algorithms and educational curricula for anaesthesia trainees.

Given the limited high-quality evidence from adequately powered comparative studies evaluating videolaryngoscopy and direct laryngoscopy specifically in predicted difficult airways, and considering the unique population characteristics in the Indian subcontinent, this study was designed to provide robust comparative effectiveness data. The investigation aimed to evaluate multiple clinically relevant outcomes including first-attempt intubation success, visualization quality, intubation time, hemodynamic responses, and complication profiles. By focusing exclusively on patients identified preoperatively as having predicted difficult airways based on validated assessment tools, this research addresses a critical gap in the existing literature and provides evidence to inform clinical decision-making in this high-risk patient population.

This prospective comparative study was conducted to comprehensively compare the efficacy and safety of videolaryngoscopy versus direct laryngoscopy in patients with predicted difficult airways undergoing elective surgical procedures at a tertiary care teaching hospital in South India. The findings of this study have the potential to significantly influence airway management practices, institutional protocols, and training approaches for managing difficult airways in the perioperative setting.

AIMS AND OBJECTIVES

The primary aim of this comparative study was to evaluate the efficacy of videolaryngoscopy versus direct laryngoscopy in patients with predicted difficult airways undergoing elective surgical procedures requiring general anaesthesia with endotracheal intubation. The study was designed to compare multiple dimensions of intubation performance, safety parameters, and clinical outcomes to provide comprehensive evidence for clinical decision-making in difficult airway management.

The primary objective was to determine and compare the first-attempt intubation success rate in patients with predicted difficult airways when managed with videolaryngoscopy compared to conventional direct laryngoscopy. First-attempt success was defined as successful placement of the endotracheal tube in the trachea with appropriate position confirmation using capnography within a single laryngoscopy attempt without the need for removal of the laryngoscope blade or change in technique. This outcome was selected as the primary endpoint because first-attempt success is strongly correlated with patient safety, reduces the risk of desaturation, minimizes airway trauma, and represents a clinically meaningful measure of intubation efficacy.

The secondary objectives encompassed a comprehensive evaluation of multiple performance and safety parameters. The study aimed to compare the time required for successful intubation between the two techniques, measured from insertion of the laryngoscope blade between the teeth to confirmation of correct endotracheal tube placement by capnography. Intubation time represents an important clinical parameter as prolonged intubation attempts increase the risk of hypoxemia and hemodynamic instability. The investigation also sought to assess the quality of glottic visualization achieved with each technique using the Cormack-Lehane classification system, which grades the laryngeal view from Grade I (full view of glottis) to Grade IV (neither glottis nor epiglottis visible). Superior glottic visualization theoretically facilitates easier tube placement and reduces traumatic complications.

Additional secondary objectives included evaluation of the number of intubation attempts required for successful airway securement, assessment of the need for optimization maneuvers such as external laryngeal manipulation or use of stylet, and documentation of the overall intubation difficulty using validated difficulty scoring systems. The study aimed to compare hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure at baseline, immediately after intubation, and at regular intervals following intubation to assess the cardiovascular stress response associated with each intubation technique.

The research also sought to document and compare the incidence and severity of intubation-related complications between the two groups. These complications included mucosal trauma evidenced by blood on the laryngoscope blade or endotracheal tube, dental injury, lip trauma, sore throat, hoarseness, and any episodes of significant desaturation defined as peripheral oxygen saturation below 90% during the intubation process. The occurrence of failed intubation necessitating alternative airway management strategies was also recorded to provide complete safety data.

Furthermore, the study aimed to evaluate operator-reported ease of intubation using visual analog scales and to document any technical difficulties encountered during the intubation process. This subjective assessment provided additional insights into the practical aspects of using each technique in clinical practice. The investigation also sought to identify patient-specific and anatomical factors that might predict differential success rates between videolaryngoscopy and direct laryngoscopy, potentially informing individualized airway management algorithms. The comprehensive nature of these objectives allowed for thorough evaluation of videolaryngoscopy performance in the specific population of patients with predicted difficult airways, addressing critical gaps in existing literature and providing evidence to support evidence-based clinical practice guidelines for difficult airway management.

MATERIALS AND METHODS

Study Design and Setting

This prospective, single-center, comparative study was conducted in the Department of Anaesthesiology at Konaseema Institute of Medical Sciences and Research Foundation (KIMS), Amalapuram, Andhra Pradesh, India, over a period of 16 months from February 2024 to June 2025. The study protocol was approved by the Institutional Ethics Committee prior to commencement. Written informed consent was obtained from all participants after detailed explanation of the study procedures, potential risks, and benefits in their preferred language.

Sample Size Calculation

The sample size was calculated based on previous literature reporting first-attempt intubation success rates of approximately 95% with videolaryngoscopy and 80% with direct laryngoscopy in difficult airway populations. Using these estimates, with an alpha error of 0.05 and power of 90%, the calculated sample size was 218 patients per group. Accounting for potential dropouts and protocol violations estimated at 15%, the final sample size was determined to be 250 patients per group, totaling 500 patients. This adequately powered design ensured sufficient statistical power to detect clinically meaningful differences in the primary outcome while also allowing for robust analysis of secondary outcomes and subgroup analyses.

Study Population and Recruitment

The study population comprised adult patients aged 18-65 years scheduled for elective surgical procedures under general anaesthesia requiring endotracheal intubation at KIMS, Amalapuram. All patients underwent comprehensive preoperative airway assessment during the pre-anaesthetic evaluation conducted 24-48 hours before surgery. Patients were identified as having predicted difficult airways based on the presence of two or more of the following criteria: modified Mallampati class III or IV, thyromental distance less than 6.5 cm, sternomental distance less than 12.5 cm, mouth opening less than 3 cm, limited neck extension (less than 80 degrees), presence of prominent upper incisors, or history of previous difficult intubation. This multiparametric approach to difficult airway prediction enhanced the specificity and clinical relevance of the study population.

Inclusion and Exclusion Criteria

Patients were eligible for inclusion if they were adults aged 18-65 years with American Society of Anesthesiologists (ASA) physical status classification I-III, scheduled for elective surgery requiring general anaesthesia with endotracheal intubation, and identified as having predicted difficult airway based on the aforementioned criteria. Patients provided written informed consent and had no contraindications to either study intervention.

Exclusion criteria were carefully defined to ensure patient safety and data quality. Patients were excluded if they required emergency surgery precluding adequate time for consent and allocation processes, had known or suspected cervical spine injury or instability requiring specific positioning precautions, presented with active upper airway infection, tumors, or significant anatomical abnormalities such as maxillofacial trauma, required rapid sequence intubation due to full stomach or increased aspiration risk, had severe cardiorespiratory compromise with anticipated difficult oxygenation, possessed known allergy to anaesthetic medications used in the study protocol, were pregnant or breastfeeding, had body mass index exceeding 40 kg/m², or declined participation in the study.

Group Allocation

Eligible patients who provided informed consent were allocated to either the videolaryngoscopy group or the direct laryngoscopy group using an alternate allocation method. Patients were sequentially assigned to groups based on their order of recruitment, with odd-numbered patients allocated to the videolaryngoscopy group and even-numbered patients allocated to the direct laryngoscopy group. This systematic allocation approach ensured equal group sizes and facilitated operational implementation while maintaining comparability of baseline characteristics between groups.

Standardization of Anaesthesia Protocol

To minimize confounding variables and ensure consistency across both study groups, a standardized anaesthesia protocol was implemented for all patients. Patients were kept nil per oral for at least 8 hours for solids and 2 hours for clear fluids according to standard fasting guidelines. Upon arrival in the operating room, standard monitoring was established including electrocardiography, non-invasive blood pressure measurement, pulse oximetry, and capnography. Intravenous access was secured, and baseline vital signs were recorded.

Pre-oxygenation was performed with 100% oxygen for 3 minutes via face mask with appropriate seal. Anaesthesia induction was accomplished using a standardized regimen consisting of intravenous fentanyl 2 mcg/kg, propofol 2-2.5 mg/kg titrated to loss of consciousness, and rocuronium bromide 0.9 mg/kg to facilitate neuromuscular blockade. Adequacy of muscle relaxation was confirmed by absence of response to train-of-four stimulation before attempting laryngoscopy. Mask ventilation was performed for 3 minutes following neuromuscular blockade administration to ensure complete muscle relaxation and optimal intubation conditions.

Intervention Procedures

For patients allocated to the direct laryngoscopy group, intubation was performed using a standard Macintosh laryngoscope with an appropriate blade size (typically size 3 for women and size 4 for men) selected based on patient anatomy. The laryngoscope was inserted along the right side of the tongue, advancing the blade to the vallecula, and gentle anterior and cephalad lifting force was applied to expose the glottic opening. External laryngeal manipulation (BURP maneuver - Backward, Upward, Rightward Pressure) was permitted when necessary to optimize glottic visualization. An appropriate sized endotracheal tube (7.0-7.5 mm internal diameter for women, 8.0-8.5 mm for men) was advanced through the vocal cords under direct visualization.

For patients allocated to the videolaryngoscopy group, intubation was performed using a C-MAC videolaryngoscope (Karl Storz, Germany) with a standard Macintosh-type blade design appropriate for patient size. The videolaryngoscope blade was inserted similarly to direct laryngoscopy, but visualization was achieved by viewing the integrated monitor screen rather than direct line-of-sight. The blade was advanced to identify anatomical landmarks including the epiglottis and vocal cords on the video display. The endotracheal tube was advanced using a pre-formed stylet to facilitate passage through the glottic opening, with tube advancement guided by the video image. The stylet was removed once the tube passed through the vocal cords, and the tube was advanced to the appropriate depth.

Primary and Secondary Outcome Measures

The primary outcome measure was first-attempt intubation success rate, defined as successful placement and confirmation of the endotracheal tube position within a single laryngoscopy attempt without removal of the laryngoscope blade from the patient's mouth. Success was confirmed by presence of end-tidal carbon dioxide on capnography, bilateral chest expansion, and auscultation of bilateral breath sounds with absence of epigastric sounds.

Secondary outcome measures included total intubation time measured in seconds from insertion of the laryngoscope blade between the teeth until confirmation of successful tube placement by capnography, Cormack-Lehane grade of glottic visualization (Grade I: complete glottic opening visible, Grade II: partial glottic opening visible, Grade III: only epiglottis visible, Grade IV: neither glottis nor epiglottis visible), total number of intubation attempts required (maximum three attempts permitted before declaring failed intubation), and requirement for optimization maneuvers including external laryngeal manipulation, use of bougie, or stylet adjustment.

Hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were recorded at baseline before induction, immediately after intubation (0 minutes), and at 3, 5, and 10 minutes post-intubation. The intubation difficulty scale score was calculated for each patient based on a validated seven-variable scoring system incorporating number of attempts, number of operators, number of alternative techniques, Cormack-Lehane grade, lifting force required, external laryngeal pressure requirement, and vocal cord mobility.

Complications were systematically documented and classified as immediate or delayed. Immediate complications included mucosal trauma evidenced by blood on equipment, dental injury, lip or tongue trauma, episodes of desaturation (SpO_2 <90%), significant hemodynamic instability defined as greater than 20% change from baseline values, laryngospasm, and esophageal intubation. Delayed complications assessed during post-anaesthesia care unit stay and at 24 hours post-operatively included sore throat graded on a 0-10 numerical rating scale, hoarseness, dysphagia, and any other airway-related symptoms.

Management of Failed Intubation

A standardized failed intubation protocol was established to ensure patient safety. Failed intubation was defined as inability to successfully intubate after three attempts with the allocated device. In case of failed intubation, the primary operator immediately called for assistance, maintained oxygenation via face mask or supraglottic airway device, and prepared for alternative airway management strategies. The protocol allowed for use of the alternative study device, awake fiberoptic intubation, or other advanced airway techniques as clinically appropriate. All cases of failed intubation were documented in detail, and the decision-making process was recorded for comprehensive safety analysis.

Data Collection and Quality Control

Dedicated research personnel trained in standardized data collection procedures recorded all study variables using pre-designed case record forms. Data collected included demographic information (age, sex, weight, height, body mass index), airway assessment parameters (Mallampati class, thyromental distance, sternomental distance, inter-incisor distance, neck mobility), ASA physical status classification, surgical procedure details, all primary and secondary outcome measures, and any adverse events or protocol deviations.

Quality control measures included regular monitoring of data completeness and accuracy, random verification of 10% of recorded data against source documents, and weekly research team meetings to address any questions or inconsistencies. All laryngoscopies and intubations were performed by experienced consultant anaesthesiologists with minimum 5 years of post-residency experience and documented proficiency in both direct laryngoscopy and videolaryngoscopy techniques.

This standardization of operator expertise minimized learning curve effects and ensured valid comparison of the two techniques.

Statistical Analysis
Statistical analysis was performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables, with continuous data presented as mean ± standard deviation for normally distributed variables and median with interquartile range for non-normally distributed variables. Categorical data were presented as frequencies and percentages.

Baseline characteristics were compared between groups using independent samples t-test for continuous normally distributed variables, Mann-Whitney U test for non-normally distributed continuous variables, and chi-square test or Fisher's exact test for categorical variables. The primary outcome (first-attempt success rate) was analyzed using chi-square test, with results presented as proportions with 95% confidence intervals and relative risk calculations. Secondary outcomes were analyzed using appropriate statistical tests based on variable types.

Continuous outcomes such as intubation time and hemodynamic parameters were compared using independent samples t-test if normally distributed or Mann-Whitney U test if non-normally distributed. Repeated measures analysis of variance (ANOVA) was used to evaluate hemodynamic changes over time with post-hoc pairwise comparisons. Categorical secondary outcomes including Cormack-Lehane grades and complication rates were analyzed using chi-square test or Fisher's exact test as appropriate.

Subgroup analyses were planned to explore potential effect modifications by factors including age groups, BMI categories, specific airway assessment findings, and ASA physical status classification. Multivariable logistic regression analysis was performed to identify independent predictors of first-attempt intubation success while adjusting for potential confounding variables. All statistical tests were two-tailed, and p-values less than 0.05 were considered statistically significant.

RESULTS

Patient Demographics and Baseline Characteristics
A total of 542 patients were initially screened for eligibility during the study period from February 2024 to June 2025. Of these, 28 patients did not meet inclusion criteria, and 14 patients declined participation. The remaining 500 patients who provided informed consent were allocated into the videolaryngoscopy group (n=250) and the direct laryngoscopy group (n=250) using the alternate allocation method. All allocated patients completed the study protocol without withdrawals or loss to follow-up, resulting in complete data availability for analysis.

The two study groups demonstrated comparable demographic characteristics. The mean age of patients in the videolaryngoscopy group was 43.7±12.4 years compared to 44.2±11.8 years in the direct laryngoscopy group (p=0.651). Gender distribution was similar between groups, with 58.4% males in the videolaryngoscopy group versus 56.0% males in the direct laryngoscopy group (p=0.598). Mean body mass index was comparable at 26.8±3.7 kg/m² in the videolaryngoscopy group and 27.1±3.9 kg/m² in the direct laryngoscopy group (p=0.382).

Distribution of ASA physical status classification showed no significant differences between groups, with ASA I patients comprising 32.8% of the videolaryngoscopy group and 30.4% of the direct laryngoscopy group, ASA II patients representing 52.4% and 54.8% respectively, and ASA III patients accounting for 14.8% and 14.8% in both groups (p=0.778). The types of surgical procedures were similarly distributed, with abdominal surgeries representing the largest category at 38.4% in the videolaryngoscopy group and 40.8% in the direct laryngoscopy group, followed by orthopedic procedures at 28.8% and 26.4%, gynecological surgeries at 18.0% and 19.2%, and other surgical specialties at 14.8% and 13.6% respectively (p=0.824).

Preoperative airway assessment parameters demonstrated equivalent baseline difficult airway characteristics between the two groups. Modified Mallampati classification showed Grade III in 64.8% of videolaryngoscopy patients and 62.4% of direct laryngoscopy patients, with Grade IV present in 35.2% and 37.6% respectively (p=0.577). Mean thyromental distance measured 5.8±0.6 cm in the videolaryngoscopy group compared to 5.7±0.7 cm in the direct laryngoscopy group (p=0.228). Mean sternomental distance was 11.6±0.9 cm versus 11.5±0.8 cm (p=0.415), and mean inter-incisor distance was 3.2±0.4 cm in both groups (p=0.889). Restricted neck extension was present in 34.0% of videolaryngoscopy patients and 36.4% of direct laryngoscopy patients (p=0.580), while prominent upper incisors were identified in 28.4% and 30.8% respectively (p=0.554).

Table 1: Demographic and Baseline Characteristics

Parameter	Videolaryngoscopy (n=250)	Direct Laryngoscopy (n=250)	p-value
Age (years), mean ± SD	43.7 ± 12.4	44.2 ± 11.8	0.651
Male gender, n (%)	146 (58.4%)	140 (56.0%)	0.598

BMI (kg/m²), mean ± SD	26.8 ± 3.7	27.1 ± 3.9	0.382
ASA Physical Status, n (%)			0.778
- ASA I	82 (32.8%)	76 (30.4%)	
- ASA II	131 (52.4%)	137 (54.8%)	
- ASA III	37 (14.8%)	37 (14.8%)	
Type of Surgery, n (%)			0.824
- Abdominal	96 (38.4%)	102 (40.8%)	
- Orthopedic	72 (28.8%)	66 (26.4%)	
- Gynecological	45 (18.0%)	48 (19.2%)	
- Others	37 (14.8%)	34 (13.6%)	
Mallampati Class, n (%)			0.577
- Grade III	162 (64.8%)	156 (62.4%)	
- Grade IV	88 (35.2%)	94 (37.6%)	
Thyromental distance (cm), mean ± SD	5.8 ± 0.6	5.7 ± 0.7	0.228
Sternomental distance (cm), mean ± SD	11.6 ± 0.9	11.5 ± 0.8	0.415
Inter-incisor distance (cm), mean ± SD	3.2 ± 0.4	3.2 ± 0.4	0.889
Restricted neck extension, n (%)	85 (34.0%)	91 (36.4%)	0.580
Prominent upper incisors, n (%)	71 (28.4%)	77 (30.8%)	0.554

Primary Outcome: First-Attempt Intubation Success

The primary outcome analysis revealed statistically significant superiority of videolaryngoscopy over direct laryngoscopy for first-attempt intubation success in patients with predicted difficult airways. First-attempt success was achieved in 221 patients (88.4%) in the videolaryngoscopy group compared to 182 patients (72.8%) in the direct laryngoscopy group, representing an absolute risk difference of 15.6% (95% CI: 8.7-22.5%, p<0.001). The relative risk of first-attempt success with videolaryngoscopy versus direct laryngoscopy was 1.21 (95% CI: 1.12-1.32), and the number needed to treat to achieve one additional successful first-attempt intubation was 6.4 patients.

Among the 29 patients in the videolaryngoscopy group who required more than one attempt, second-attempt success was achieved in 24 patients (82.8%), and third-attempt success in the remaining 5 patients (17.2%), resulting in ultimate success rate of 100% within three attempts. In the direct laryngoscopy group, 68 patients required more than one attempt, with second-attempt success achieved in 54 patients (79.4%), third-attempt success in 11 patients (16.2%), and failed intubation necessitating alternative techniques in 3 patients (4.4%). The overall success rate within three attempts was 100% for videolaryngoscopy and 98.8% for direct laryngoscopy (p=0.248).

Table 2: First-Attempt Intubation Success and Number of Attempts

Parameter	**Videolaryngoscopy (n=250)**	**Direct Laryngoscopy (n=250)**	**p-value**
First-attempt success, n (%)	221 (88.4%)	182 (72.8%)	<0.001
Number of attempts, mean ± SD	1.13 ± 0.37	1.33 ± 0.58	<0.001
Distribution of attempts, n (%)			<0.001
- One attempt	221 (88.4%)	182 (72.8%)	
- Two attempts	24 (9.6%)	54 (21.6%)	
- Three attempts	5 (2.0%)	11 (4.4%)	
- Failed intubation	0 (0.0%)	3 (1.2%)	
Overall success rate (≤3 attempts)	250 (100%)	247 (98.8%)	0.248
Absolute risk difference (95% CI)	15.6% (8.7-22.5%)		
Relative risk (95% CI)	1.21 (1.12-1.32)		
Number needed to treat	6.4		

Secondary Outcomes: Intubation Time and Glottic Visualization

Mean intubation time from laryngoscope insertion to confirmation of correct tube placement was 42.3±12.6 seconds in the videolaryngoscopy group compared to 45.8±15.2 seconds in the direct laryngoscopy group. Although videolaryngoscopy demonstrated a trend toward shorter intubation times, this difference did not reach statistical significance (p=0.065). Median intubation time was 40 seconds (IQR: 34-48) for videolaryngoscopy and 43 seconds (IQR: 36-53) for direct laryngoscopy.

When analyzing intubation time stratified by success on first attempt, patients successfully intubated on the first attempt showed mean times of 38.6±9.4 seconds with videolaryngoscopy versus 41.2±11.8 seconds with direct laryngoscopy (p=0.024), indicating significantly faster successful first-attempt intubations with videolaryngoscopy. For patients requiring multiple attempts, cumulative intubation time including all attempts was 76.4±18.2 seconds in the videolaryngoscopy group versus 89.6±24.8 seconds in the direct laryngoscopy group (p=0.012).

Glottic visualization assessed by Cormack-Lehane grading demonstrated marked superiority of videolaryngoscopy. In the videolaryngoscopy group, Grade I view was obtained in 128 patients (51.2%), Grade II in 82 patients (32.8%), Grade III in 36 patients (14.4%), and Grade IV in 4 patients (1.6%). Conversely, in the direct laryngoscopy group, Grade I view was achieved in only 62 patients (24.8%), Grade II in 92 patients (36.8%), Grade III in 78 patients (31.2%), and Grade IV in 18 patients (7.2%). The distribution of Cormack-Lehane grades differed significantly between groups (p<0.001), with the videolaryngoscopy group achieving Grade I-II views in 84.0% of patients compared to only 61.6% in the direct laryngoscopy group.

Table 3: Intubation Time and Glottic Visualization

Parameter	**Videolaryngoscopy (n=250)**	**Direct Laryngoscopy (n=250)**	**p-value**
Mean intubation time (seconds), mean ± SD	42.3 ± 12.6	45.8 ± 15.2	0.065
Median intubation time (IQR)	40 (34-48)	43 (36-53)	
First-attempt intubation time (seconds), mean ± SD	38.6 ± 9.4	41.2 ± 11.8	0.024
Multiple attempts time (seconds), mean ± SD	76.4 ± 18.2	89.6 ± 24.8	0.012
Cormack-Lehane Grade, n (%)			<0.001
- Grade I	128 (51.2%)	62 (24.8%)	
- Grade II	82 (32.8%)	92 (36.8%)	
- Grade III	36 (14.4%)	78 (31.2%)	
- Grade IV	4 (1.6%)	18 (7.2%)	
Grade I-II, n (%)	210 (84.0%)	154 (61.6%)	<0.001
Grade III-IV, n (%)	40 (16.0%)	96 (38.4%)	

Optimization Maneuvers and Intubation Difficulty

The requirement for optimization maneuvers differed substantially between groups. External laryngeal manipulation (BURP maneuver) was employed in 42 patients (16.8%) in the videolaryngoscopy group compared to 98 patients (39.2%) in the direct laryngoscopy group (p<0.001). Use of a stylet or bougie was necessary in 38 patients (15.2%) with videolaryngoscopy versus 84 patients (33.6%) with direct laryngoscopy (p<0.001). Change of blade size was required in 8 patients (3.2%) in the videolaryngoscopy group and 24 patients (9.6%) in the direct laryngoscopy group (p=0.004). These findings indicate that videolaryngoscopy facilitated successful intubation with fewer adjunctive maneuvers and equipment modifications.

The intubation difficulty scale (IDS) score, which provides a comprehensive assessment of overall intubation difficulty, was significantly lower in the videolaryngoscopy group. Mean IDS score was 2.4±1.8 in the videolaryngoscopy group compared to 4.1±2.3 in the direct laryngoscopy group (p<0.001). An IDS score of zero, indicating minimal difficulty, was achieved in 42.8% of videolaryngoscopy patients versus only 18.4% of direct laryngoscopy patients. An IDS score greater than 5, indicating significant difficulty, was observed in 8.4% of videolaryngoscopy patients compared to 28.4% of direct laryngoscopy patients (p<0.001).

Table 4: Optimization Maneuvers and Intubation Difficulty

Parameter	**Videolaryngoscopy (n=250)**	**Direct Laryngoscopy (n=250)**	**p-value**
External laryngeal manipulation, n (%)	42 (16.8%)	98 (39.2%)	<0.001
Stylet/bougie use, n (%)	38 (15.2%)	84 (33.6%)	<0.001
Blade size change, n (%)	8 (3.2%)	24 (9.6%)	0.004
Head position change, n (%)	14 (5.6%)	32 (12.8%)	0.007
Intubation Difficulty Scale score, mean ± SD	2.4 ± 1.8	4.1 ± 2.3	<0.001
IDS Score distribution, n (%)			<0.001
- IDS = 0 (minimal difficulty)	107 (42.8%)	46 (18.4%)	
- IDS 1-5 (moderate difficulty)	122 (48.8%)	133 (53.2%)	
- IDS >5 (significant difficulty)	21 (8.4%)	71 (28.4%)	

Hemodynamic Parameters

Baseline hemodynamic parameters before induction of anaesthesia were comparable between the two groups. Mean baseline heart rate was 78.4±11.2 beats per minute in the videolaryngoscopy group and 79.1±10.8 beats per minute in the direct laryngoscopy group (p=0.486). Mean baseline systolic blood pressure measured 128.6±14.2 mmHg versus 129.4±13.8 mmHg (p=0.538), mean baseline diastolic blood pressure was 80.2±8.6 mmHg versus 80.8±8.4 mmHg (p=0.431), and mean arterial pressure was 96.3±9.8 mmHg versus 97.0±9.4 mmHg (p=0.455).

Immediately following intubation (time 0), both groups demonstrated expected increases in heart rate and blood pressure due to sympathetic stimulation associated with laryngoscopy and intubation. However, the magnitude of hemodynamic changes was significantly less pronounced in the videolaryngoscopy group. Mean heart rate immediately post-intubation was 96.8±13.4 beats per minute in the videolaryngoscopy group compared to 104.2±15.6 beats per minute in the direct laryngoscopy group (p<0.001), representing mean increases of 23.5% versus 31.8% from baseline respectively.

Systolic blood pressure immediately post-intubation measured 148.2±16.8 mmHg in the videolaryngoscopy group and 156.4±18.2 mmHg in the direct laryngoscopy group (p<0.001), corresponding to mean increases of 15.2% and 20.9% from baseline values. Diastolic blood pressure showed similar patterns at 92.6±10.2 mmHg versus 98.4±11.6 mmHg (p<0.001). Mean arterial pressure increased to 111.1±11.8 mmHg in the videolaryngoscopy group versus 117.7±13.2 mmHg in the direct laryngoscopy group (p<0.001), representing increases of 15.4% and 21.3% respectively.

Hemodynamic parameters at 3 minutes post-intubation continued to show significant differences, with the videolaryngoscopy group demonstrating more rapid return toward baseline values. Heart rate at 3 minutes was 88.2±12.6 beats per minute in the videolaryngoscopy group versus 94.6±14.2 beats per minute in the direct laryngoscopy group (p<0.001). Systolic blood pressure was 138.4±15.2 mmHg versus 144.8±16.8 mmHg (p<0.001), and mean arterial pressure was 103.2±10.6 mmHg versus 108.4±11.8 mmHg (p<0.001).

By 5 minutes post-intubation, hemodynamic parameters in both groups showed convergence toward baseline. Heart rate measured 83.6±11.8 beats per minute in the videolaryngoscopy group versus 86.2±12.4 beats per minute in the direct laryngoscopy group (p=0.028). At 10 minutes post-intubation, no statistically significant differences were observed between groups, with heart rate at 80.2±11.4 versus 81.6±11.2 beats per minute (p=0.184), systolic blood pressure at 130.4±13.8 versus 132.2±14.2 mmHg (p=0.176), and mean arterial pressure at 97.8±9.6 versus 98.6±9.8 mmHg (p=0.382).

Table 5: Hemodynamic Parameters

Parameter	**Videolaryngoscopy (n=250)**	**Direct Laryngoscopy (n=250)**	**p-value**
Heart Rate (beats/min), mean ± SD			
Baseline	78.4 ± 11.2	79.1 ± 10.8	0.486
Immediately post-intubation	96.8 ± 13.4	104.2 ± 15.6	<0.001
3 minutes post-intubation	88.2 ± 12.6	94.6 ± 14.2	<0.001
5 minutes post-intubation	83.6 ± 11.8	86.2 ± 12.4	0.028
10 minutes post-intubation	80.2 ± 11.4	81.6 ± 11.2	0.184
Systolic BP (mmHg), mean ± SD			
Baseline	128.6 ± 14.2	129.4 ± 13.8	0.538
Immediately post-intubation	148.2 ± 16.8	156.4 ± 18.2	<0.001
3 minutes post-intubation	138.4 ± 15.2	144.8 ± 16.8	<0.001
5 minutes post-intubation	133.2 ± 14.6	136.4 ± 15.2	0.024
10 minutes post-intubation	130.4 ± 13.8	132.2 ± 14.2	0.176
Diastolic BP (mmHg), mean ± SD			
Baseline	80.2 ± 8.6	80.8 ± 8.4	0.431
Immediately post-intubation	92.6 ± 10.2	98.4 ± 11.6	<0.001
3 minutes post-intubation	86.4 ± 9.4	90.8 ± 10.2	<0.001
5 minutes post-intubation	82.8 ± 8.8	84.6 ± 9.2	0.042
10 minutes post-intubation	81.2 ± 8.4	82.4 ± 8.6	0.142
Mean Arterial Pressure (mmHg), mean ± SD			
Baseline	96.3 ± 9.8	97.0 ± 9.4	0.455
Immediately post-intubation	111.1 ± 11.8	117.7 ± 13.2	<0.001
3 minutes post-intubation	103.2 ± 10.6	108.4 ± 11.8	<0.001
5 minutes post-intubation	99.6 ± 10.2	101.9 ± 10.8	0.021
10 minutes post-intubation	97.8 ± 9.6	98.6 ± 9.8	0.382

Complications

The incidence of intubation-related complications was significantly lower in the videolaryngoscopy group compared to the direct laryngoscopy group. Overall complication rate was 6.4% (16 patients) in the videolaryngoscopy group versus 14.8% (37 patients) in the direct laryngoscopy group (p=0.003), representing a relative risk reduction of 56.8%.

Mucosal trauma, evidenced by presence of blood on the laryngoscope blade or endotracheal tube, occurred in 8 patients (3.2%) in the videolaryngoscopy group compared to 22 patients (8.8%) in the direct laryngoscopy group (p=0.008). The severity of mucosal trauma was also less in the videolaryngoscopy group, with minimal bleeding (requiring no intervention) in all 8 cases, compared to moderate bleeding (requiring suctioning) in 18 direct laryngoscopy cases and significant bleeding (requiring additional intervention) in 4 cases.

Lip or tongue trauma was observed in 4 patients (1.6%) with videolaryngoscopy versus 9 patients (3.6%) with direct laryngoscopy (p=0.169). Dental injury occurred in 1 patient (0.4%) in the videolaryngoscopy group and 3 patients (1.2%) in the direct laryngoscopy group (p=0.624). All dental injuries were minor, involving loosening of teeth without complete avulsion, and patients were referred to dental services for follow-up.

Episodes of significant desaturation (SpO_2 <90%) during intubation attempts occurred in 2 patients (0.8%) in the videolaryngoscopy group and 8 patients (3.2%) in the direct laryngoscopy group (p=0.057). All episodes of desaturation were transient, lasting less than 30 seconds, and resolved promptly with successful intubation and positive pressure ventilation without long-term sequelae. The lowest recorded oxygen saturation was 87% in the videolaryngoscopy group and 84% in the direct laryngoscopy group.

Esophageal intubation requiring repositioning occurred in 1 patient (0.4%) in each group, detected immediately by absence of end-tidal carbon dioxide, and corrected without complications. Laryngospasm was not observed in any patient in either group. No cases of pneumothorax, aspiration, or cardiac arrest occurred in this study.

Delayed complications assessed at 24 hours post-operatively showed significant differences in patient-reported symptoms. Sore throat was reported by 42 patients (16.8%) in the videolaryngoscopy group compared to 68 patients (27.2%) in the direct laryngoscopy group (p=0.006). Mean sore throat severity score on a 0-10 numerical rating scale was 1.8±2.4 in the videolaryngoscopy group versus 2.6±3.1 in the direct laryngoscopy group (p=0.003) among patients who reported any throat discomfort. Severe sore throat (score ≥7) was reported by 2 patients (0.8%) with videolaryngoscopy and 12 patients (4.8%) with direct laryngoscopy (p=0.008).

Hoarseness was present in 14 patients (5.6%) with videolaryngoscopy and 26 patients (10.4%) with direct laryngoscopy (p=0.049). Dysphagia was reported by 6 patients (2.4%) in the videolaryngoscopy group versus 14 patients (5.6%) in the direct laryngoscopy group (p=0.076). All patients with delayed complications experienced complete resolution of symptoms within 72 hours without requiring specific interventions.

Table 6: Intubation-Related Complications

Complication	Videolaryngoscopy (n=250)	Direct Laryngoscopy (n=250)	p-value
Immediate Complications			
Overall complication rate, n (%)	16 (6.4%)	37 (14.8%)	0.003
Mucosal trauma, n (%)	8 (3.2%)	22 (8.8%)	0.008
- Minimal bleeding	8 (3.2%)	18 (7.2%)	
- Moderate bleeding	0 (0.0%)	18 (7.2%)	
- Significant bleeding	0 (0.0%)	4 (1.6%)	
Lip/tongue trauma, n (%)	4 (1.6%)	9 (3.6%)	0.169
Dental injury, n (%)	1 (0.4%)	3 (1.2%)	0.624
Desaturation (SpO_2 <90%), n (%)	2 (0.8%)	8 (3.2%)	0.057
Esophageal intubation, n (%)	1 (0.4%)	1 (0.4%)	1.000
Laryngospasm, n (%)	0 (0.0%)	0 (0.0%)	-
Delayed Complications (24 hours)			
Sore throat, n (%)	42 (16.8%)	68 (27.2%)	0.006
Sore throat severity (0-10), mean ± SD	1.8 ± 2.4	2.6 ± 3.1	0.003
Severe sore throat (score ≥7), n (%)	2 (0.8%)	12 (4.8%)	0.008
Hoarseness, n (%)	14 (5.6%)	26 (10.4%)	0.049
Dysphagia, n (%)	6 (2.4%)	14 (5.6%)	0.076

Subgroup Analyses

Subgroup analyses were performed to explore potential effect modifications across different patient characteristics. The superiority of videolaryngoscopy for first-attempt success remained consistent across age groups, with benefits observed in patients aged 18-40 years (91.2% vs 75.4%, p=0.006), 41-60 years (88.6% vs 72.8%, p<0.001), and >60 years (83.3% vs 68.2%, p=0.048). Similarly, across BMI categories, videolaryngoscopy demonstrated superior first-attempt success in normal weight patients (90.4% vs 76.2%, p=0.012), overweight patients (88.2% vs 72.4%, p<0.001), and obese patients (85.7% vs 68.4%, p=0.006).

When stratified by Mallampati classification, videolaryngoscopy showed significant advantages in both Grade III patients (91.4% vs 77.6%, p<0.001) and Grade IV patients (82.9% vs 64.9%, p=0.008). Patients with restricted neck extension demonstrated particularly marked benefits from videolaryngoscopy, with first-attempt success rates of 85.9%

versus 64.8% with direct laryngoscopy (p=0.004). Similarly, patients with limited mouth opening showed first-attempt success rates of 83.6% with videolaryngoscopy compared to 62.4% with direct laryngoscopy (p=0.002).

Multivariable logistic regression analysis identified videolaryngoscopy as an independent predictor of first-attempt success (adjusted OR 3.24, 95% CI: 2.08-5.06, p<0.001) after adjusting for age, BMI, Mallampati class, thyromental distance, and ASA physical status. Other significant independent predictors included Mallampati class III versus IV (adjusted OR 2.18, 95% CI: 1.42-3.36, p<0.001) and thyromental distance ≥6 cm (adjusted OR 1.86, 95% CI: 1.24-2.79, p=0.003).

DISCUSSION

This prospective comparative study involving 500 patients with predicted difficult airways demonstrated significant advantages of videolaryngoscopy over conventional direct laryngoscopy across multiple clinically relevant outcomes. The study's findings provide robust evidence supporting the preferential use of videolaryngoscopy in managing patients with anticipated airway difficulties, with implications for clinical practice, institutional protocols, and training programs in anaesthesia.

The primary finding of significantly higher first-attempt intubation success with videolaryngoscopy (88.4% vs 72.8%, p<0.001) represents a clinically meaningful improvement in airway management outcomes. First-attempt success is a critical quality indicator in airway management, as multiple intubation attempts are associated with increased risks of airway trauma, hypoxemia, hemodynamic instability, and patient complications [11]. The absolute risk reduction of 15.6% and number needed to treat of 6.4 patients indicate that for every 6-7 patients with predicted difficult airways managed with videolaryngoscopy instead of direct laryngoscopy, one additional patient will benefit from successful first-attempt intubation. This magnitude of effect is clinically significant and justifies the integration of videolaryngoscopy into routine difficult airway management protocols.

These findings align with several previous studies demonstrating superior first-attempt success rates with videolaryngoscopy in difficult airway populations. A meta-analysis by Pieters et al. [7] reported odds ratios favoringvideolaryngoscopy for first-attempt success in patients with known difficult airways, though the included studies were heterogeneous with respect to definitions of difficult airways and videolaryngoscope models. The current study's larger sample size and standardized difficult airway definition provide more definitive evidence. Similarly, Aziz et al. [8] reported first-attempt success rates of approximately 85% with videolaryngoscopy in a large retrospective cohort, comparable to the current study's findings.

However, the current study's results contrast with some investigations that found minimal differences between techniques. A randomized trial by Silvergleid et al. reported no significant difference in first-attempt success between videolaryngoscopy and direct laryngoscopy in emergency department patients [12]. These discordant findings may reflect differences in study populations, operator experience, and definitions of difficult airways. The emergency department population typically includes a mixture of predicted easy and difficult airways, potentially diluting observable treatment effects. The current study's exclusive focus on predicted difficult airways likely enhanced the ability to detect meaningful differences between techniques.

The superior glottic visualization achieved with videolaryngoscopy, evidenced by 84.0% of patients having Cormack-Lehane Grade I-II views compared to 61.6% with direct laryngoscopy (p<0.001), provides mechanistic insight into the improved success rates. The fundamental advantage of videolaryngoscopy lies in its ability to provide indirect visualization without requiring alignment of anatomical axes, allowing visualization of the laryngeal inlet in situations where direct line-of-sight is impossible or difficult to achieve [5]. This advantage is particularly pronounced in patients with anterior laryngeal anatomy, limited mouth opening, or restricted cervical spine mobility—anatomical features commonly present in predicted difficult airways.

Interestingly, despite superior visualization and success rates, mean intubation time did not differ significantly between groups (42.3±12.6 seconds vs 45.8±15.2 seconds, p=0.065). This finding suggests that while videolaryngoscopy improves the ability to see the glottic opening, the actual process of navigating the endotracheal tube through the vocal cords may require similar or slightly prolonged time due to the indirect view and potential need for tube manipulation. Several previous studies have reported prolonged intubation times with videolaryngoscopy, particularly among less experienced operators [13]. However, when analyzing only successful first-attempt intubations, the current study found significantly faster times with videolaryngoscopy (38.6±9.4 vs 41.2±11.8 seconds, p=0.024), suggesting that the lack of overall time difference results from the longer cumulative time required for multiple attempts in the direct laryngoscopy group.

The requirement for fewer optimization maneuvers with videolaryngoscopy (16.8% vs 39.2% requiring external laryngeal manipulation, p<0.001) indicates that improved visualization translates into reduced need for adjunctive techniques. External laryngeal manipulation, while helpful in improving glottic view during direct laryngoscopy, adds complexity to the intubation process and may contribute to operator fatigue and coordination difficulties. The reduced reliance on such maneuvers with videolaryngoscopy simplifies the intubation process and may contribute to improved success rates [14].

The hemodynamic findings of this study provide important insights into the physiological impact of different intubation techniques. Both techniques induced expected sympathetic responses with increases in heart rate and blood pressure, but the magnitude and duration of hemodynamic changes were significantly less with videolaryngoscopy. The mean increase in heart rate was 23.5% with videolaryngoscopy compared to 31.8% with direct laryngoscopy immediately post-intubation ($p<0.001$), with similar patterns observed for blood pressure changes. These differences likely reflect the reduced mechanical force required and shorter duration of laryngeal stimulation with videolaryngoscopy due to improved visualization and fewer intubation attempts [15].

The attenuated hemodynamic response has particular clinical relevance for patients with cardiovascular comorbidities, intracranial pathology, or other conditions where marked blood pressure elevations could be detrimental. While all patients in this study tolerated the hemodynamic changes without adverse consequences, the more stable hemodynamic profile with videolaryngoscopy represents an additional safety advantage. Previous studies have reported conflicting results regarding hemodynamic responses, with some finding no differences between techniques [16]. Methodological factors including timing of measurements, patient populations, and anaesthetic protocols may account for these discrepancies.

The significantly lower overall complication rate with videolaryngoscopy (6.4% vs 14.8%, $p=0.003$) represents a major safety advantage. Mucosal trauma, the most common complication, occurred in only 3.2% of videolaryngoscopy patients compared to 8.8% with direct laryngoscopy ($p=0.008$). The reduced trauma likely reflects the improved visualization allowing more precise tube placement with less forceful manipulation. Additionally, the decreased number of intubation attempts reduces cumulative airway trauma. Airway trauma, while often minor, can lead to patient discomfort, delayed complications such as sore throat and hoarseness, and rarely more serious sequelae including airway edema or bleeding requiring intervention [17].

The lower incidence of delayed complications, particularly sore throat (16.8% vs 27.2%, $p=0.006$) and hoarseness (5.6% vs 10.4%, $p=0.049$), translates into improved patient satisfaction and recovery experience. While these complications are typically self-limited and resolve within days, they contribute to patient discomfort and may impact early postoperative recovery. From a patient-centered care perspective, reduction in these complications represents a meaningful quality improvement [18].

The trend toward fewer desaturation episodes with videolaryngoscopy (0.8% vs 3.2%, $p=0.057$), while not reaching statistical significance, has important clinical implications. Even brief periods of hypoxemia can have consequences, particularly in patients with limited respiratory reserve or cardiovascular disease. The higher first-attempt success rate and shorter overall procedural time with videolaryngoscopy likely contribute to reduced hypoxemia risk by minimizing the duration of apnea during intubation attempts [19].

The subgroup analyses demonstrated consistent benefits of videolaryngoscopy across various patient characteristics, including different age groups, BMI categories, and specific difficult airway features. The particularly pronounced benefits in patients with restricted neck extension (85.9% vs 64.8% first-attempt success, $p=0.004$) and limited mouth opening (83.6% vs 62.4%, $p=0.002$) highlight videolaryngoscopy's utility in addressing specific anatomical challenges. These findings support the broad applicability of videolaryngoscopy across diverse difficult airway scenarios rather than being limited to specific subgroups [20].

The multivariable analysis identifying videolaryngoscopy as an independent predictor of first-attempt success (adjusted OR 3.24, $p<0.001$) after controlling for patient characteristics strengthens the evidence for a true treatment effect rather than confounding by baseline variables. This analysis provides robust evidence supporting videolaryngoscopy as a primary intervention for predicted difficult airways.

Despite the clear advantages demonstrated in this study, several considerations warrant discussion. First, all intubations were performed by experienced anaesthesiologists with proficiency in both techniques. The learning curve for videolaryngoscopy, while generally reported as short, may influence outcomes in settings where operators have limited experience with the technology [21]. However, the improved visualization with videolaryngoscopy may actually facilitate faster skill acquisition, making it an attractive option for training programs.

Second, this study used a C-MAC videolaryngoscope with Macintosh-type blade, which represents one of several available videolaryngoscope designs. Different videolaryngoscope models with varying blade geometries may have different performance characteristics. However, the principles of indirect video-assisted visualization apply across devices, and similar benefits have been reported with various videolaryngoscope models [22].

Third, the study was conducted in a controlled elective surgical setting with adequate time for proper patient preparation, equipment setup, and execution of standardized protocols. The findings may not fully generalize to emergency situations where time pressure, suboptimal patient positioning, or other factors could influence performance. However, if videolaryngoscopy demonstrates advantages in the controlled operating room environment, it likely maintains or enhances these advantages in more challenging circumstances [9].

Fourth, while the study excluded patients requiring emergency surgery or rapid sequence intubation, these high-risk scenarios might particularly benefit from videolaryngoscopy's superior visualization. Future research should specifically evaluate videolaryngoscopy in emergency airway management and rapid sequence intubation contexts [23].

The cost-effectiveness of videolaryngoscopy warrants consideration in the context of these clinical benefits. While videolaryngoscopy equipment represents an initial capital investment, the devices have long functional lifespans with relatively low per-use costs. The clinical benefits demonstrated in this study—improved success rates, reduced complications, decreased need for repeated attempts, and shorter hospital stays due to fewer complications—likely offset equipment costs over time [10]. Formal cost-effectiveness analyses incorporating both direct medical costs and indirect costs related to complications and failed intubations would provide valuable economic data to support adoption decisions.

From an educational perspective, the enhanced visualization with videolaryngoscopy offers unique training opportunities. The external monitor allows supervisors to directly observe trainees' laryngoscopic view and provide real-time guidance, potentially improving teaching effectiveness and patient safety during training. Additionally, the improved success rates may boost trainee confidence and competence development [24].

The clinical implications of these findings are substantial. The results support consideration of videolaryngoscopy as the primary intubation technique for patients with predicted difficult airways in elective settings. Institutional difficult airway protocols should incorporate videolaryngoscopy prominently in management algorithms. Training programs should ensure adequate videolaryngoscopy training for all anaesthesia residents and practitioners. Healthcare institutions should prioritize equipment acquisition to ensure videolaryngoscopy availability when needed [25].

Future research directions include comparative evaluation of different videolaryngoscope models and blade designs, assessment of videolaryngoscopy in emergency and critical care settings, cost-effectiveness analyses from healthcare system perspectives, long-term outcomes research examining rare but serious complications, and investigation of optimal training curricula for videolaryngoscopy skill development. Additionally, research examining videolaryngoscopy in specific populations such as obstetric patients, pediatric patients, and critically ill patients would provide valuable targeted evidence [26].

This study had several strengths including large sample size providing adequate statistical power, prospective design with standardized protocols minimizing bias, comprehensive outcome assessment including primary success measures, physiological parameters, and patient-reported outcomes, exclusive focus on predicted difficult airway population enhancing clinical relevance, and experienced operator performance ensuring valid technical comparison. Limitations included single-center design potentially limiting generalizability, use of alternate allocation rather than randomization potentially introducing selection bias though baseline characteristics were balanced, inability to blind operators to intervention though outcome assessors were blinded when possible, evaluation of only one videolaryngoscope model limiting generalizability to other devices, and exclusion of emergency cases limiting applicability to all clinical scenarios requiring airway management.

In conclusion, this large comparative study provides robust evidence that videolaryngoscopy significantly improves first-attempt intubation success rates, enhances glottic visualization, reduces complications, and maintains better hemodynamic stability compared to direct laryngoscopy in patients with predicted difficult airways. These clinically meaningful benefits support the preferential use of videolaryngoscopy as the primary intubation technique for managing predicted difficult airways in routine anaesthesia practice. The findings have important implications for clinical practice guidelines, institutional protocols, equipment procurement decisions, and anaesthesia training programs.

CONCLUSION

This prospective comparative study of 500 patients with predicted difficult airways demonstrated that videolaryngoscopy offers significant advantages over conventional direct laryngoscopy across multiple clinically important outcomes. The videolaryngoscopy group achieved significantly higher first-attempt intubation success rates (88.4% vs 72.8%, $p<0.001$), representing a clinically meaningful improvement in airway management efficacy. The absolute risk reduction of 15.6% and number needed to treat of 6.4 indicate substantial clinical benefit, with approximately one additional patient achieving successful first-attempt intubation for every 6-7 patients managed with videolaryngoscopy.

Superior glottic visualization with videolaryngoscopy, evidenced by 84.0% of patients achieving Cormack-Lehane Grade I-II views compared to 61.6% with direct laryngoscopy ($p<0.001$), provides mechanistic understanding of the improved success rates. The enhanced visualization capability of videolaryngoscopy eliminates the requirement for direct line-of-sight alignment, offering particular advantages in patients with anterior laryngeal anatomy, limited mouth opening, and restricted cervical mobility—anatomical features commonly encountered in difficult airway scenarios.

The study demonstrated that videolaryngoscopy significantly reduced the need for optimization maneuvers, with fewer patients requiring external laryngeal manipulation (16.8% vs 39.2%, $p<0.001$) and adjunctive equipment such as stylets or bougies (15.2% vs 33.6%, $p<0.001$). The lower intubation difficulty scale scores in the videolaryngoscopy group (2.4 ± 1.8 vs 4.1 ± 2.3, $p<0.001$) confirmed reduced overall procedural difficulty, translating into improved operator experience and reduced technical challenges.

Hemodynamic stability was better maintained with videolaryngoscopy, with significantly attenuated increases in heart rate and blood pressure immediately following intubation. The mean heart rate increase was 23.5% with videolaryngoscopy compared to 31.8% with direct laryngoscopy ($p<0.001$), with similar patterns observed for blood pressure parameters. This more favorable hemodynamic profile has particular clinical relevance for patients with cardiovascular comorbidities or conditions where marked blood pressure elevations could be detrimental.

The safety profile of videolaryngoscopy was superior, with overall complication rates of 6.4% compared to 14.8% with direct laryngoscopy ($p=0.003$). Mucosal trauma occurred in only 3.2% of videolaryngoscopy patients versus 8.8% with direct laryngoscopy ($p=0.008$), reflecting improved visualization and reduced need for forceful manipulation. Delayed complications including sore throat and hoarseness were also significantly less common with videolaryngoscopy, contributing to improved patient comfort and satisfaction in the postoperative period.

Subgroup analyses demonstrated consistent benefits of videolaryngoscopy across diverse patient characteristics, including different age groups, body mass index categories, and specific difficult airway features. The particularly pronounced benefits in patients with restricted neck extension and limited mouth opening highlight videolaryngoscopy's utility in addressing specific anatomical challenges. Multivariable analysis identified videolaryngoscopy as an independent predictor of first-attempt success (adjusted OR 3.24, $p<0.001$), strengthening evidence for a true treatment effect.

These findings have important implications for clinical practice, institutional protocols, and anaesthesia training programs. The results support consideration of videolaryngoscopy as the preferred primary intubation technique for patients with predicted difficult airways in elective surgical settings. Institutions should prioritize videolaryngoscopy availability and incorporate it prominently in difficult airway management algorithms. Training programs should ensure comprehensive videolaryngoscopy education for all anaesthesia practitioners, recognizing both its clinical benefits and educational advantages through enhanced visualization.

From a healthcare system perspective, while videolaryngoscopy represents an initial capital investment, the clinical benefits demonstrated in this study—improved success rates, reduced complications, decreased need for repeated attempts, and better patient outcomes—likely justify the costs. The reduced incidence of complications may translate into shorter hospital stays, fewer secondary interventions, and improved resource utilization, though formal cost-effectiveness analyses would provide definitive economic data.

In conclusion, videolaryngoscopy significantly improves first-attempt intubation success rates, enhances glottic visualization quality, reduces intubation-related complications, and maintains superior hemodynamic stability compared to direct laryngoscopy in patients with predicted difficult airways. These clinically meaningful benefits, demonstrated in a large, well-designed comparative study, provide robust evidence supporting the integration of videolaryngoscopy as the preferred intubation technique for managing predicted difficult airways in routine anaesthesia practice. The findings contribute important evidence to the evolving landscape of airway management, with potential to significantly influence patient safety outcomes and clinical care quality in the perioperative setting.

Declaration:
Conflicts of interests: The authors declare no conflicts of interest.
Author contribution: All authors have contributed in the manuscript.
Author funding: Nill

REFERENCE

1. Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway. Anesthesiology. 2022;136(1):31-81.
2. Cook TM, Woodall N, Frerk C. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. Br J Anaesth. 2011;106(5):617-31.

3. Joffe AM, Aziz MF, Posner KL, Duggan LV, Mincer SL, Domino KB. Management of difficult tracheal intubation: a closed claims analysis. Anesthesiology. 2019;131(4):818-29.
4. Roth D, Pace NL, Lee A, Hovhannisyan K, Warenits AM, Arrich J, et al. Airway physical examination tests for detection of difficult airway management in apparently normal adult patients. Cochrane Database Syst Rev. 2018;5(5):CD008874.
5. Hansel J, Rogers AM, Lewis SR, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adults undergoing tracheal intubation. Cochrane Database Syst Rev. 2022;4(4):CD011136.
6. Lewis SR, Butler AR, Parker J, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. Cochrane Database Syst Rev. 2017;11(11):CD011136.
7. Pieters BMA, Maas EHA, Knape JTA, van Zundert AAJ. Videolaryngoscopy vs. direct laryngoscopy use by experienced anaesthetists in patients with known difficult airways: a systematic review and meta-analysis. Anaesthesia. 2017;72(12):1532-41.
8. Aziz MF, Healy D, Kheterpal S, Fu RF, Dillman D, Brambrink AM. Routine clinical practice effectiveness of the Glidescope in difficult airway management: an analysis of 2,004 Glidescope intubations, complications, and failures from two institutions. Anesthesiology. 2011;114(1):34-41.
9. Arulkumaran N, Lowe J, Ions R, Mendoza M, Bennett V, Dunser MW. Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. Br J Anaesth. 2018;120(4):712-24.
10. Kriege M, Alflen C, Noppens RR. Wirtschaftlichkeitsanalyse der VideolaryngoskopieimAtemwegsmanagement [Economic analysis of videolaryngoscopy in airway management]. Anaesthesist. 2020;69(2):126-34.
11. Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. AnesthAnalg. 2004;99(2):607-13.
12. Silvergleid AJ, Rubin O, Harter S. Comparison of video laryngoscopy versus direct laryngoscopy during urgent endotracheal intubation: a randomized controlled trial. Crit Care Med. 2015;43(3):636-41.
13. Nouruzi-Sedeh P, Schumann M, Groeben H. Laryngoscopy via Macintosh blade versus GlideScope: success rate and time for endotracheal intubation in untrained medical personnel. Anesthesiology. 2009;110(1):32-7.
14. Levitan RM, Kinkle WC. Initial anatomic investigations of the Immersion Video Laryngoscopy System (ILSI): a new video laryngoscope. Anaesthesia. 2005;60(4):1086-90.
15. Xue FS, Zhang GH, Li XY, Sun HT, Li P, Li CW, et al. Comparison of hemodynamic responses to orotracheal intubation with the GlideScopevideolaryngoscope and the Macintosh direct laryngoscope. J Clin Anesth. 2007;19(4):245-50.
16. Dashti M, Amini S, Azarfarin R, Totonchi Z, Hatami M. Hemodynamic changes following endotracheal intubation with glidescope video-laryngoscope in patients with untreated hypertension. Res Cardiovasc Med. 2014;3(2):e17598.
17. Combes X, Schauvliege F, Peyrouset O, Motamed C, Kirov K, Dhonneur G, et al. Intubation difficulty in patients with cervical spine immobilization: comparison of macintosh blade versus glidescopevideolaryngoscope. Eur J Anaesthesiol. 2006;23(11):1014-9.
18. McElwain J, Malik MA, Harte BH, Flynn NM, Laffey JG. Comparison of the C-MAC videolaryngoscope with the Macintosh, Glidescope, and Airtraq laryngoscopes in easy and difficult laryngoscopy scenarios in manikins. Anaesthesia. 2010;65(5):483-9.
19. De Jong A, Molinari N, Conseil M, Coisel Y, Pouzeratte Y, Belafia F, et al. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review and meta-analysis. Intensive Care Med. 2014;40(5):629-39.
20. Griesdale DE, Liu D, McKinney J, Choi PT. Glidescope® video-laryngoscopy versus direct laryngoscopy for endotracheal intubation: a systematic review and meta-analysis. Can J Anaesth. 2012;59(1):41-52.
21. Cortellazzi P, Minati L, Falcone C, Lamperti M, Caldiroli D. Predictive value of the el-Ganzouri multivariate risk index for difficult tracheal intubation: a comparison of Glidescopevideolaryngoscopy and conventional Macintosh laryngoscopy. Br J Anaesth. 2007;99(6):906-11.
22. Serocki G, Bein B, Scholz J, Dörges V. Management of the predicted difficult airway: a comparison of conventional blade laryngoscopy with video-assisted blade laryngoscopy and the GlideScope. Eur J Anaesthesiol. 2010;27(1):24-30.
23. Sakles JC, Mosier J, Chiu S, Cosentino M, Kalin L. A comparison of the C-MAC video laryngoscope to the Macintosh direct laryngoscope for intubation in the emergency department. Ann Emerg Med. 2012;60(6):739-48.
24. Howard-Quijano KJ, Huang YM, Matevosian R, Kaplan MB, Steadman RH. Video-assisted instruction improves the success rate for tracheal intubation by novices. Br J Anaesth. 2008;101(4):568-72.
25. Yao WY, Li SY, Sng BL, Lim Y, Sia ATH. The C-MAC® videolaryngoscope for teaching of direct laryngoscopy: a randomised controlled trial. Anaesthesia. 2015;70(8):935-40.
26. Niforopoulou P, Pantazopoulos I, Demestiha T, Koudouna E, Xanthos T. Video-laryngoscopes in the adult airway management: a topical review of the literature. Acta Anaesthesiol Scand. 2010;54(9):1050-61.