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COMPARATIVE EVALUATION OF PERFUSION INDEX TO ENDOTRACHEAL INTUBATION USING MACINTOSH, MCCOY, AND VIDEO LARYNGOSCOPES IN PATIENTS UNDERGOING ELECTIVE SURGERY UNDER GENERAL ANESTHESIA

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Abstract:
Background: Laryngoscopy and endotracheal intubation provoke hemodynamic responses due to sympathetic stimulation, which may be detrimental especially in patients with cardiovascular comorbidities. The perfusion index (PI), a non-invasive marker of peripheral perfusion, has emerged as a potential indicator of stress response during intubation. This study aimed to compare the changes in PI and hemodynamic parameters following intubation using Macintosh, McCoy, and Tuoren video laryngoscopes (VLHM5A, Tuoren Medical Device India Pvt. Ltd.) and to assess their correlation.
Methods: A prospective, randomized study was conducted in 135 ASA I–II patients undergoing elective surgery under general anesthesia. Patients were assigned to three groups (n=45 each): Group A (Macintosh), Group B (McCoy), and Group C (video laryngoscope). Perfusion index (PI), heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at baseline, post-induction, and up to 10 minutes post-intubation. Correlation coefficients between PI and hemodynamic variables were analyzed.
Results: Groups B and C demonstrated significantly higher PI values compared to Group A post-intubation ($p<0.05$). Group A showed the highest rise in SBP, DBP, MAP, and HR. A significant negative correlation was observed between PI and HR in Group A at 6–10 minutes and with DBP and MAP in Groups B and C in early intervals ($p<0.05$). Minor complications were minimal.
Conclusion: The McCoy and Macintosh laryngoscopes were associated with minimal hemodynamic fluctuation and better maintenance of PI, indicating reduced stress response.

Keywords: Perfusion index; laryngoscopes; patients; endotracheal intubation; hemodynamic; laryngoscopy.

Introduction:
Airway management is central to anesthetic practice, with laryngoscopy and tracheal intubation serving as essential steps in securing the airway during general anesthesia. The classical Macintosh laryngoscope, introduced by Sir Robert Macintosh, the first Professor of Anesthesia at Oxford University [1,2], enables direct epiglottis elevation for vocal cord visualization but exerts considerable force on the tongue base, contributing to a pronounced stress response. This manifests as tachycardia, hypertension, and arrhythmias, which can be deleterious in patients with cardiovascular or cerebrovascular comorbidities.

To mitigate these responses, the McCoy laryngoscope, introduced in 1993, incorporated a hinged tip allowing indirect epiglottis elevation with reduced force, potentially blunting sympathetic activation [3,4]. More recently, video laryngoscopes, such as the GlideScope, have offered improved glottic visualization through hyperangulated blades and Complementary Metal-Oxide-Semiconductor (CMOS) video technology, enhancing success in difficult airways and offering better operating control while minimizing mechanical stress [5].

Perfusion index (PI), a non-invasive measure derived from pulse oximetry, quantifies peripheral perfusion and is sensitive to sympathetic tone. A low PI suggests vasoconstriction, while a high PI indicates vasodilation. Given its sensitivity to sympathetic nervous system activity, PI serves as an objective marker for detecting stress responses [6,7]. In this context, PI emerges as a valuable adjunct to traditional hemodynamic variables, offering enhanced sensitivity in evaluating physiological responses to laryngoscopy and intubation.

The existing literature on perfusion index (PI) in the context of laryngoscopy is limited, and no study has comprehensively compared PI responses to endotracheal intubation using Macintosh, McCoy, and Tuoren video laryngoscopes (VLHM5A, Tuoren Medical Device India Pvt. Ltd.) within a single framework. This study was therefore designed to evaluate and compare changes in PI and non-invasive hemodynamic parameters during intubation with these three devices in patients undergoing elective surgery under general anesthesia. The primary objective was to assess differences in PI across the groups. Secondary objectives included comparing heart rate, systolic, diastolic, and mean arterial pressures; evaluating correlations between PI and these variables; and documenting complications such as local injuries, bleeding, or laryngospasm. It was hypothesized that the McCoy and Tuoren video laryngoscopes would produce a reduced hemodynamic response and demonstrate more favorable perfusion index values in comparison to the traditional Macintosh laryngoscope.

Material & methods:
This randomized comparative study was conducted after approval from the Institutional Ethical Committee (IEC Ref No: IEC-DDUH/upn79/2022-05-05/8/v1), and the study was registered with Clinical Trials Registry-India (CTRI Reg. No: CTRI/2023/09/057575), (CTRI Ref No: REF/2023/08/072561) dated 13/09/2023, accessible at www.ctri.nic.in. The research was conducted from May 2022 to June 2023 in the Department of Anesthesiology, Deen Dayal Upadhyay Hospital, New Delhi. Patients provided written and informed consent to participate in the study and allowed the use of their data for research and educational purposes.

The study included 135 adult patients of either gender belonging to the American Society of Anesthesiologists (ASA) physical status I and II undergoing elective surgery under general anesthesia. Patients with anticipated difficult airways, significant systemic comorbidities, or undergoing head and neck surgery were excluded from the study.

Patients underwent pre-anesthetic evaluation one day before scheduled surgery. On the day of surgery, patients were randomly assigned to Group A (Macintosh), Group B (McCoy), and Group C (Video) laryngoscopes. Randomization was performed using block randomization with sealed opaque envelopes. The patients were blinded to group allocation.

After application of standard monitors, patients were preoxygenated with 100% O2 for 3 min, and general anesthesia was induced using intravenous (IV) fentanyl 2 microgram/kilogram (µg/kg), propofol 2 milligram/kilogram (mg/kg), and vecuronium bromide (0.1 mg/kg). Endotracheal intubation was performed by a single experienced anesthesiologist using the assigned laryngoscope in sniffing position, and an appropriate-sized endotracheal tube was passed through the vocal cords under vision. Patients requiring >20 seconds or external pressure for intubation were excluded.
PI was monitored using the MASIMO Radical SET pulse oximeter, with the probe placed on the middle fingertip of the hand contralateral to the BP cuff and covered with a towel to minimize heat loss and shield it from ambient light.

Ambient temperature was maintained between 25–26°C throughout the study. PI and hemodynamic parameters like heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), oxygen saturation (SpO2), Bispectral Index (BIS), and end tidal carbon dioxide ($ETCO_2$)were recorded at baseline (T0), pre-induction (T1), pre-laryngoscopy (T2), immediately post-intubation (T3), and at 2-minute intervals up to 10 minutes thereafter (T4, T5, T6, T7, T8) by an independent observer who was unaware of group allocation. Any complications such as mucosal injury, bleeding, or laryngospasm during intubation were noted.

Anesthesia was maintained using sevoflurane (1.5–3%) in 50% O_2/N_2O to achieve a BIS target of 40–60 and MAP within 20% of pre-induction values. Intermittent doses of vecuronium (0.02 mg/kg) ensured continued muscle relaxation. Lactated Ringer's solution was infused at 6–8 ml/kg/h. At the end of the procedure, neuromuscular blockade was reversed using IV neostigmine (0.04 mg/kg) and glycopyrrolate (0.008 mg/kg).

Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 21.0. Categorical variables were presented as numbers and percentages; continuous variables as mean ± SD or median. Normality was assessed using the Kolmogorov–Smirnov test. ANOVA or Kruskal–Wallis test was used for intergroup comparisons; Chi-square/Fisher's exact test for categorical data. Pearson or Spearman correlation assessed the relationship between PI and hemodynamic parameters. A p-value <0.05 was considered statistically significant.

Using perfusion index values reported by Choudhary et al [8], the sample size was calculated for 80% power and a 5% level of significance. With pooled standard deviations of 1.08 and 1.58 and corresponding mean differences of 0.7 and 1.0, the required sample size was 40 per group. Accounting for a 10% dropout rate, a total of 135 patients (45 per group) were included.

Results:
A total of 135 patients were randomized into three groups, with 45 patients in each group. All patients included in the study completed the follow-up. (Fig. 1)

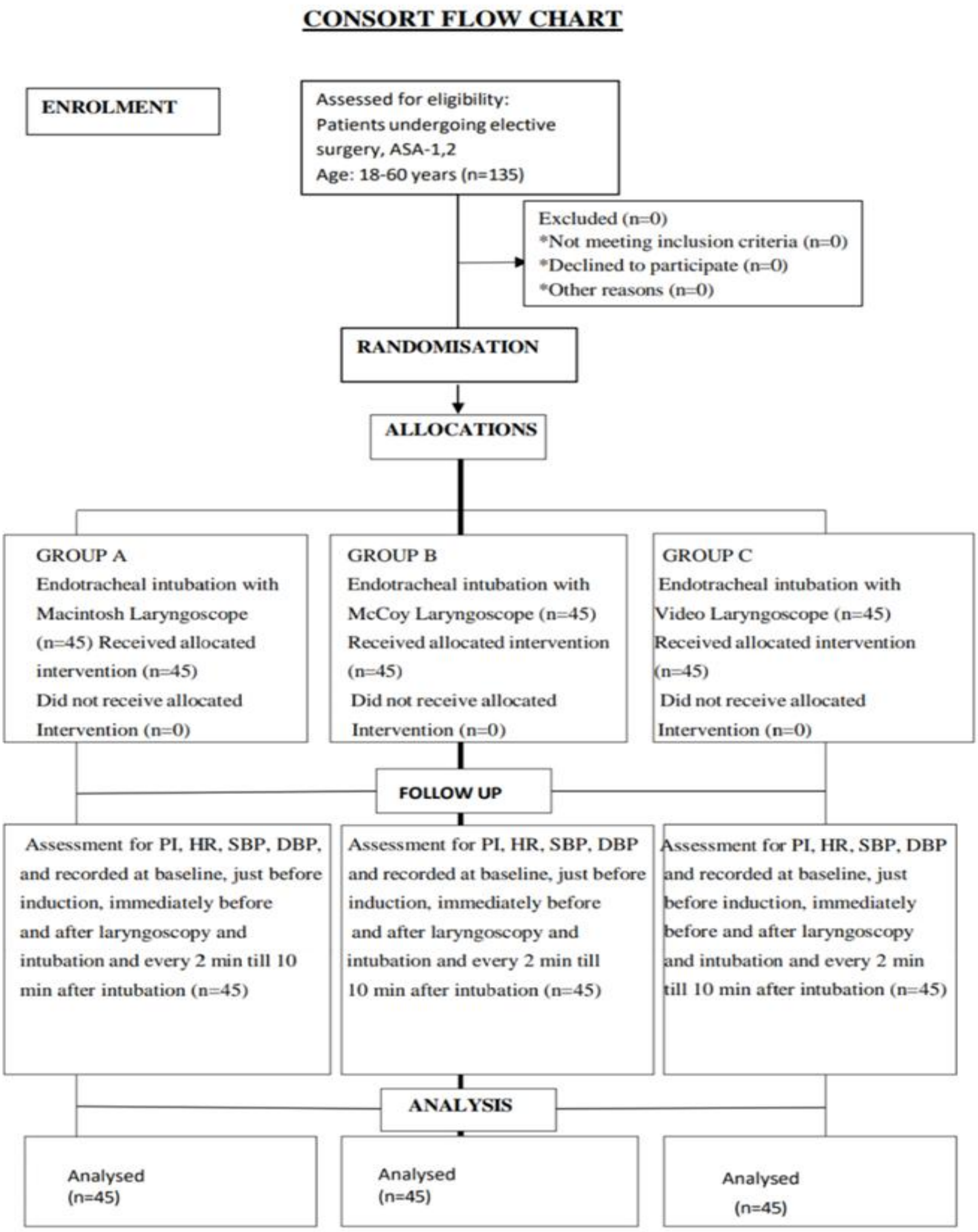

Figure 1: CONSORT flowchart (n-number of patients). Group A- Endotracheal intubation with Macintosh laryngoscope, Group B- Endotracheal intubation with McCoy laryngoscope, Group C- Endotracheal intubation with Video laryngoscope. CONSORT = Consolidated Standard of Reporting Trial

Demographic parameters such as age, height, weight, and gender were comparable across the groups ($p > 0.05$). Mean age (years) was 33.6 ± 11.83 (Group A), 31.62 ± 9.54 (Group B), and 33.11 ± 10.57 (Group C).

Perfusion Index

The mean PI was compared between the three groups at various time intervals. PI values were similar across groups at baseline (T0), pre-induction (T1), and pre-laryngoscopy (T2) ($p > 0.05$). A significant increase in PI was observed in groups B and C when compared to group A immediately post-intubation (T3) and up to 4 minutes post-intubation (T5) (T3: $p < 0.0001$; T4: $p < 0.0001$; T5: $p < 0.0001$). (Table 1) No significant difference was noted beyond 6 minutes (T6–T8).

Perfusion index	A(n=45)	B(n=45)	C(n=45)	P value
Baseline (T0)	3.02 ± 0.42	2.95 ± 0.51	2.94 ± 0.53	0.665 A vs B:0.495 A vs C:0.394 B vs C:0.864
Just before induction (T1)	3.19 ± 0.34	3.06 ± 0.48	3.07 ± 0.46	0.262 A vs B:0.138 A vs C:0.181 B vs C:0.884
Immediately before laryngoscopy (T2)	3.96 ± 0.22	3.98 ± 0.39	3.84 ± 0.46	0.168 A vs B:0.711 A vs C:0.155 B vs C:0.074
Immediately after laryngoscopy and intubation (T3)	1.51 ± 0.38	2.33 ± 0.28	2.16 ± 0.25	<.0001 A vs B:<.0001 A vs C:<.0001 B vs C:0.008
2 minutes after intubation (T4)	2.96 ± 0.36	3.36 ± 0.3	3.21 ± 0.24	<.0001 A vs B:<.0001 A vs C:0.0002 B vs C:0.016
4 minutes after intubation (T5)	3.93 ± 0.43	4.32 ± 0.33	4.16 ± 0.3	<.0001 A vs B:<.0001 A vs C:0.003 B vs C:0.035
6 minutes after intubation (T6)	5.22 ± 0.39	5.26 ± 0.33	5.3 ± 0.29	0.539 A vs B:0.622 A vs C:0.268 B vs C:0.537
8 minutes after intubation (T7)	6.44 ± 0.45	6.5 ± 0.39	6.47 ± 0.4	0.789 A vs B:0.492 A vs C:0.741 B vs C:0.721
10 minutes after intubation (T8)	7.72 ± 0.36	7.68 ± 0.37	7.63 ± 0.44	0.521 A vs B:0.667 A vs C:0.259 B vs C:0.484

Table 1: Comparison of mean perfusion index between Groups A, B, and C

Hemodynamic variables

Post-intubation HR was significantly higher in group A vs B and C at T3, T4, and T5 (T3: A vs B $p < 0.0001$, A vs C $p = 0.004$). HR differences diminished by T6–T8 ($p > 0.05$). SBP rose significantly in group A at T3–T7 compared to B and C (T3: A vs B & C $p < 0.0001$). (Fig. 2) No significant difference was seen at T8 ($p > 0.05$).

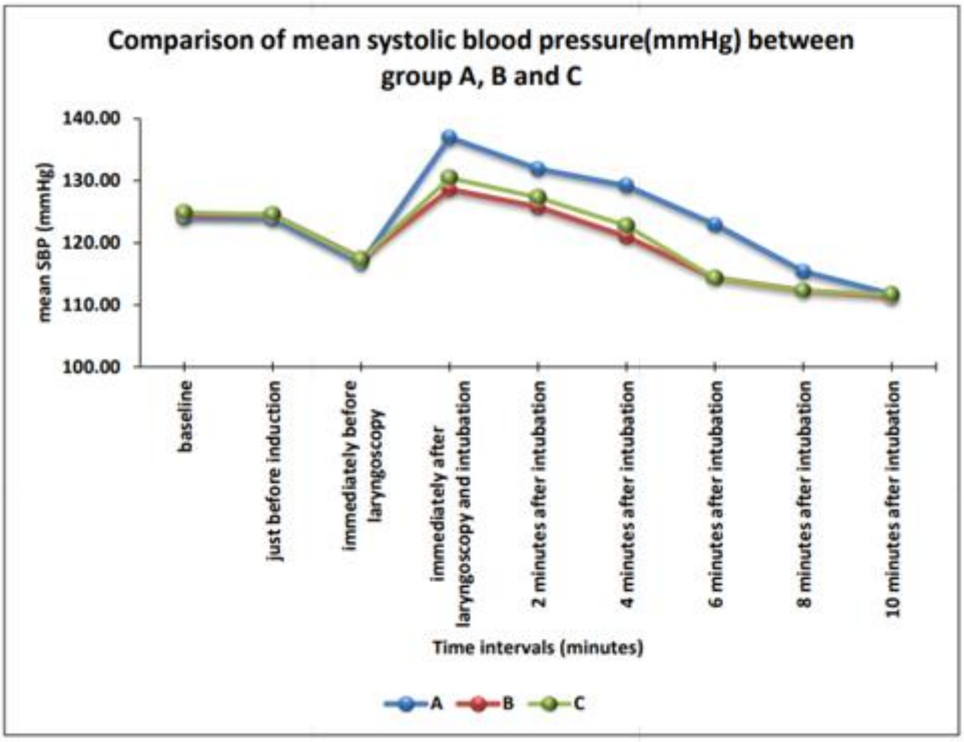

Figure 2: Comparison of mean heart rate (per minute) at various time intervals between Groups A, B, and C

Similar trends were observed with DBP and MAP. group A showed higher values than B and C from T3 to T7 (all $p < 0.0001$). No statistically significant differences in mean SpO_2, $ETCO_2$, or BIS were observed across any time point ($p > 0.05$). ECG remained normal (sinus rhythm) in all patients throughout.

Correlation

Correlation coefficients (r) were calculated for each group to determine the strength and direction of association between PI and hemodynamic parameters at predefined intervals

Correlations were graded as:

- No correlation (r: -0.08 to 0.08)
- Mild (r: 0.09 to 0.20)
- Moderate (r: 0.21 to 0.40)
- Strong (r: >0.40)

Positive correlations indicate synchronous variation of both variables, while negative correlations indicate an inverse relationship. Statistical significance was set at $p < 0.05$.

The correlation analysis between PI and hemodynamic parameters across all three groups revealed several important trends:

In group A, PI showed a significant, strong negative correlation with HR at 6, 8, and 10 min post-intubation (r = -0.45, -0.489, -0.435; $p < 0.05$). (Table 2) No statistically significant correlations were noted for SBP, DBP, or MAP at any interval. A non-significant moderate negative correlation with DBP was seen at 6 minutes (r = –0.238).

Heart rate (beats per minute)										
Perfusion index		Baseline (T0)	Just before induction (T1)	Immediately before laryngoscopy (T2)	Immediately after laryngoscopy and intubation (T3)	2 minutes after intubation (T4)	4 minutes after intubation (T5)	6 minutes after intubation (T6)	8 minutes after intubation (7)	10 minutes after intubation (T8)
Baseline (T0)	Correlation coefficient	0.029	0.160	0.135	0.083	0.052	0.107	-0.075	0.004	-0.078
	P value	0.852	0.293	0.377	0.590	0.733	0.485	0.623	0.981	0.609
Just before induction (T1)	Correlation coefficient	0.036	0.173	0.087	-0.055	-0.021	0.068	0.052	0.097	-0.002
	P value	0.817	0.257	0.570	0.720	0.893	0.659	0.736	0.527	0.992
Immediately before laryngoscopy (T2)	Correlation coefficient	0.040	0.094	0.053	0.141	0.285	0.270	0.153	0.039	0.029
	P value	0.792	0.538	0.731	0.357	0.058	0.073	0.316	0.800	0.852
Immediately after laryngoscopy and intubation (T3)	Correlation coefficient	0.053	-0.050	-0.135	0.076	-0.044	0.046	-0.243	-0.147	0.117
	P value	0.731	0.746	0.377	0.621	0.773	0.767	0.107	0.336	0.445
2 minutes after intubation (T4)	Correlation coefficient	-0.142	-0.140	-0.067	-0.003	-0.083	-0.105	-0.157	-0.254	-0.190
	P value	0.351	0.358	0.664	0.986	0.587	0.493	0.302	0.092	0.210
4 minutes after intubation (T5)	Correlation coefficient	-0.209	-0.166	0.193	-0.116	-0.115	-0.203	-0.282	-0.357	-0.477
	P value	0.168	0.275	0.205	0.448	0.453	0.181	0.061	0.016	0.001
6 minutes after intubation (T6)	Correlation coefficient	-0.152	-0.133	0.158	-0.117	-0.138	-0.244	-0.450	-0.329	-0.258
	P value	0.319	0.382	0.299	0.444	0.366	0.106	0.0019	0.027	0.087
8 minutes after intubation (T7)	Correlation coefficient	-0.153	-0.162	0.263	0.073	0.092	-0.062	-0.467	-0.489	-0.325
	P value	0.317	0.288	0.081	0.636	0.546	0.685	0.0012	0.0007	0.029
10 minutes after intubation (T8)	Correlation coefficient	-0.027	0.021	0.205	-0.171	-0.043	-0.191	-0.213	-0.327	-0.435
	P value	0.861	0.893	0.176	0.261	0.777	0.210	0.159	0.028	0.003

Table 2: Correlation of heart rate with perfusion index in Group A (Macintosh laryngoscope)

In group B, a significant moderate negative correlation between PI and HR was noted at 8 minutes post-intubation (r = -0.362; p < 0.05). A significant positive correlation with DBP was seen at 10 minutes (r = 0.346; p < 0.05). No other parameters showed significant correlation.

In group C, significant negative correlations between PI and HR were observed at baseline and pre-intubation intervals: T0 (r = –0.378), T1 (r = –0.385), and T2 (r = –0.327). PI showed a significant negative correlation with DBP immediately after intubation and at 2 minutes (DBP: r = –0.365 and –0.368; p < 0.05). PI also showed a significant negative correlation with MAP immediately after intubation and at 2 minutes. (MAP: r = –0.352 and –0.343; p < 0.05) (Table 3)

Perfusion index (%)		Mean arterial pressure (mmHg)								
		Baseline (T0)	Just before induction (T1)	Immediately before laryngoscopy (T2)	Immediately after laryngoscopy and intubation (T3)	2 minutes after intubation (T4)	4 minutes after intubation (T5)	6 minutes after intubation (T6)	8 minutes after intubation (7)	10 minutes after intubation (T8)
Baseline (T0)	Correlation coefficient	-0.394	-0.404	-0.272	-0.227	-0.150	-0.242	-0.207	-0.134	-0.123
	P value	0.007	0.006	0.071	0.134	0.326	0.109	0.172	0.380	0.420
Just before induction (T1)	Correlation coefficient	-0.442	-0.413	-0.259	-0.201	-0.125	-0.228	-0.178	-0.096	-0.126
	P value	0.002	0.005	0.086	0.186	0.415	0.131	0.243	0.530	0.408
Immediately before laryngoscopy (T2)	Correlation coefficient	-0.358	-0.353	-0.191	-0.208	-0.164	-0.289	-0.283	-0.237	-0.246
	P value	0.016	0.017	0.209	0.170	0.280	0.054	0.059	0.117	0.104
Immediately after laryngoscopy and intubation (T3)	Correlation coefficient	-0.286	-0.317	-0.311	-0.352	-0.318	-0.358	-0.320	-0.288	-0.327
	P value	0.057	0.034	0.037	0.018	0.033	0.016	0.032	0.055	0.028
2 minutes after intubation (T4)	Correlation coefficient	-0.199	-0.333	-0.351	-0.387	-0.343	-0.359	-0.291	-0.261	-0.295
	P value	0.190	0.025	0.018	0.009	0.021	0.015	0.052	0.083	0.049
4 minutes after intubation (T5)	Correlation coefficient	-0.094	-0.136	-0.119	-0.217	-0.154	-0.143	-0.098	-0.068	-0.121
	P value	0.540	0.374	0.438	0.152	0.313	0.347	0.523	0.659	0.429
6 minutes after intubation (T6)	Correlation coefficient	0.004	-0.130	-0.047	-0.071	0.007	0.051	-0.030	-0.023	-0.075
	P value	0.980	0.395	0.758	0.643	0.963	0.739	0.842	0.879	0.625
8 minutes after intubation (T7)	Correlation coefficient	-0.017	-0.217	-0.102	-0.101	-0.019	0.012	-0.006	-0.054	-0.056
	P value	0.913	0.153	0.504	0.509	0.900	0.939	0.968	0.726	0.713
10 minutes after intubation (T8)	Correlation coefficient	0.000	-0.196	-0.115	-0.120	-0.059	-0.042	-0.006	-0.041	-0.041
	P value	0.999	0.197	0.453	0.433	0.700	0.784	0.969	0.789	0.790

Table 3: Correlation of mean arterial pressure with perfusion index in Group C (Video laryngoscope)

These findings suggest that PI inversely correlates with hemodynamic changes following laryngoscopy and intubation, particularly with DBP and MAP in the McCoy and video laryngoscope groups. The Macintosh group showed delayed correlation primarily with HR, suggesting prolonged sympathetic activation.

Complications

Minor complications such as mucosal trauma were noted in 4 patients in group A, 2 in group B, and 1 in group C. No cases of laryngospasm or significant airway injury were reported.

Discussion:

Laryngoscopes are used to expose the larynx by elevation of the epiglottis. However, they provoke adverse cardiovascular stress responses and have a profound influence on the circulatory parameters and the intracranial pressure along with endotracheal intubation. Forces transmitted by the laryngoscope blades on the base of the tongue while lifting the epiglottis are assumed to be a major stimulus. Sympathoadrenal response arises from the stimulation of the supraglottic region by the laryngoscope blade. This peak response occurs approximately 30-45 seconds after laryngoscopy and lasts less than ten minutes.

Ever since understanding the stress response to laryngoscopy and intubation, the medical fraternity has been experimenting with various modifications being made to the existing models of laryngoscope blades in an attempt to reduce the sympathoadrenal response to laryngoscopy and intubation.

However, there is no single method that is simple and real-time to analyze the stress response to laryngoscopy and intubation. PI is a non-invasive numerical value of peripheral perfusion obtained from a pulse oximeter. It is an assessment of the pulsatile strength at a specific site, such as the fingers or toes and is calculated by expressing the pulsatile signal (during arterial inflow) as a percentage of the non-pulsatile signal, both of which are derived from the amount of infrared (940 nm) light absorbed [9]. This has incited an interest among researchers and is proposed to be a valuable objective parameter during anesthetic practice to find out non-invasive methods for predicting the hemodynamic responses to anesthetic drugs, techniques, and intraoperative stimuli. Low PI suggests peripheral vasoconstriction, and high PI suggests vasodilation. PI is sensitive to the temperature of the finger, exogenous vasoactive drugs, sympathetic nervous system tone (pain, anxiety, and so on), and stroke volume. In this study, we hypothesized that intubation using McCoy and video laryngoscopes would result in better PI trends and lesser hemodynamic responses compared to the conventional Macintosh laryngoscope.

Our findings confirmed this hypothesis. PI dropped in all groups post-intubation, but the Macintosh group exhibited the greatest decline, indicating higher stress. Our study demonstrated that tracheal intubation with the McCoy laryngoscope elicited the least decrease in PI compared to Macintosh and Tuoren video laryngoscopes, suggesting better attenuation of sympathetic stress response. This may be attributed to the McCoy blade's hinged tip, which allows for reduced mechanical stimulation during epiglottic elevation. PI significantly declined post-intubation in all groups, but the extent of reduction was lowest with McCoy, supporting its hemodynamic stability. These findings are consistent with findings of Atef et al.[9] , who reported significant decreases in PI with airway insertion, reinforcing PI's role in tracking autonomic activation, although their study did not compare laryngoscope types. Video laryngoscope showed intermediate results—possibly due to longer intubation time or learning curve—similar to findings by Aggarwal et al. [10] and Shah S Bhatia et al. [11].

In our study, tracheal intubation with the McCoy laryngoscope produced significantly lower hemodynamic changes compared to the Macintosh and Tuoren video laryngoscopes. These findings align with the established understanding that mechanical stimulation of the tongue base during laryngoscopy activates sympathetic pathways, resulting in a pressor response mediated by catecholamine release—primarily noradrenaline—which raises blood pressure and heart rate. Our results are supported by Aggarwal et al. [10] and Haidry et al. [12], both of whom found McCoy laryngoscope superior to Macintosh and video laryngoscopes in minimizing hemodynamic fluctuations. Choudhary et al. [8] further demonstrated McCoy's benefit when combined with fentanyl, yielding lower heart rate and blood pressure responses post-intubation.
Our study found no significant correlation in the Macintosh and McCoy groups in terms of PI-hemodynamic correlation. However, the video laryngoscope group exhibited a statistically significant inverse correlation between PI and DBP/MAP at early time points, suggesting that PI may more accurately reflect sympathetic activation in less invasive airway techniques. These observations align with those of Shah S. Bhatia et al. [11] and Coutrot et al. [13], who also documented inverse PI-hemodynamic trends during stress and vasopressor use. In contrast, Shah Prerana et al. [14] used delta (change) values for correlation analysis and reported stronger associations, suggesting that methodological differences in data handling may influence correlation strength.

Conclusion:
This study demonstrated that the Macintosh laryngoscope was associated with the greatest decrease in perfusion index (PI) and the most pronounced hemodynamic response following endotracheal

intubation, indicating a higher sympathetic stress response. In contrast, the McCoy laryngoscope produced the least variation in both PI and hemodynamic parameters, suggesting better attenuation of intubation-related stress. The video laryngoscope (Tuoren VLHM5A) exhibited intermediate effects. Although mild to moderate negative correlations between PI and hemodynamic parameters (HR, SBP, DBP, MAP) were observed at certain time points, these associations lacked consistency and statistical significance. Thus, while PI reflects autonomic trends, its standalone reliability in quantifying stress responses remains limited. The McCoy laryngoscope appears to be the most hemodynamically stable option, particularly beneficial in patients where minimizing cardiovascular stress is essential.

However, several limitations should be considered. The study was conducted at a single center with a relatively modest sample size, which may affect generalizability. High-risk patients (ASA III and above), including those with hypertension, coronary artery disease, or cerebrovascular conditions, were excluded, as were patients with anticipated difficult airways. Only non-invasive blood pressure monitoring was used, which precludes beat-to-beat analysis achievable with invasive techniques. Additionally, biochemical markers of stress such as serum cortisol were not measured. The study evaluated a single video laryngoscope model (Tuoren VLHM5A); including other available video laryngoscope designs may yield broader insights. Future multicentric studies with larger, more diverse populations and invasive monitoring may better elucidate the clinical utility of PI and its correlation with hemodynamic stress responses.

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