

A Study on the Correlation between Peripheral Perfusion Index and Haemodynamic Fluctuations during the Induction Phase of Painless Gastroscopy in Adults

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Abstract

Objective: To investigate the dynamic changes in the peripheral perfusion index (PI) during the induction phase of anaesthesia for painless gastroscopy in adults, to analyse its correlation with haemodynamic fluctuations, and to evaluate the early warning value of PI for hypotension during the induction phase. **Methods:** A total of 219 patients scheduled for painless gastroscopy were selected and divided into three age groups: young adults (18 - 44 years), middle-aged adults (45 - 59 years), and young elderly (60 - 74 years), with 73 patients in each group. Intravenous anaesthesia was administered using a combination of propofol and sufentanil. PI, systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) were recorded pre-anaesthesia (T0), upon completion of propofol administration (T2), upon loss of the eyelash reflex (T3), and upon awakening (T6). These four time points were the primary analytical time points. The maximum changes during the induction phase (Δ PI, Δ SBP, Δ DBP) were calculated, and Pearson correlation analysis and ROC curve analysis were performed to assess their predictive value. **Results:** Following anaesthetic induction, PI increased significantly, peaking between T2 and T3, whilst SBP and DBP decreased significantly and showed a significant negative correlation with PI ($P < 0.05$); the changes in Δ PI, Δ SBP, and Δ DBP increased progressively with age, with the young elderly group showing the largest fluctuations and the young adult group the smallest ($P < 0.05$). The AUC for PI in predicting hypotension was 0.824, with an optimal threshold of 3.65%, a sensitivity of 78.3%, and a specificity of 81.5%; the threshold for the elderly subgroup was 3.2%. **Conclusion:** During the induction phase of pain-

less gastroscopy, PI provides a continuous, non-invasive, and early reflection of peripheral vascular tone and the state of sympathetic inhibition, and is significantly correlated with haemodynamic fluctuations; implementing stratified management using a warning threshold of $PI = 3.65\%$ (3.2% for the elderly) can improve the safety of outpatient anaesthesia.

Keywords

Painless Gastroscopy, Peripheral Perfusion Index, Haemodynamics, Anaesthetic Induction, Hypotension, Early Warning

1. Introduction

Gastroscopy is the most commonly used method for the diagnosis, screening, and minimally invasive treatment of upper gastrointestinal tract diseases. With the rapid development of patient-centered care, pain-free gastroscopy has become the clinical treatment of choice. Propofol combined with opioid analgesics is currently the most widely used anesthetic regimen for pain-free gastroscopy due to its rapid onset of action, swift recovery, and stable sedative effects [1]. However, propofol directly inhibits sympathetic tone and dilates peripheral blood vessels, which can easily lead to hemodynamic fluctuations such as a drop in blood pressure and a slowing of heart rate during the induction phase of anesthesia. The risk is particularly higher in elderly patients and those with comorbidities such as hypertension, diabetes, and cardiovascular disease; in severe cases, this may result in adverse events such as inadequate tissue perfusion, myocardial ischemia, and cerebral hypoperfusion [2].

Current routine monitoring parameters for outpatient anesthesia include heart rate, non-invasive blood pressure, and oxygen saturation. These parameters are relatively insensitive to circulatory changes and exhibit significant lag; abnormalities often only become apparent after a marked drop in blood pressure, making it difficult to provide early warning [3]. Therefore, identifying a non-invasive, continuous, sensitive, and readily available microcirculatory monitoring parameter holds significant clinical value for enhancing the safety of painless gastroscopy anesthesia.

The Peripheral Perfusion Index (PI), based on the photoplethysmographic signal derived from pulse oximetry, provides a real-time reflection of peripheral vascular vasodilation and vasoconstriction, as well as sympathetic tone [4]. Several studies suggest that changes in PI precede those in traditional indicators such as blood pressure and heart rate, and can be used to predict hypotension during the induction phase of anesthesia [5] [6]. However, in the context of painless gastroscopy—a procedure conducted outside the operating theatre, of short duration, performed in the lateral decubitus position, and utilizing a fast-track outpatient anesthesia protocol—there remains a lack of consensus regarding the patterns of PI changes, their quantitative relationship with hemodynamics, age-related differences, and optimal warning thresholds [7].

Through a prospective observational study, this research investigates the dy-

namic changes in PI during the induction phase of painless gastroscopy in adults, analyzes its correlation with fluctuations in blood pressure and heart rate, determines the optimal threshold for predicting hypotension [8], and compares these findings across age groups. The study aims to provide a basis for establishing a PI-guided safety management protocol for outpatient anesthesia.

2. Materials and Methods

2.1. General Characteristics

A total of 219 patients who underwent sedated gastroscopy at our hospital between April and May 2026 were selected; all were classified as ASA Class I - II and aged between 18 and 74 years. Patients were enrolled consecutively and were allocated to three age groups to achieve equal sample size: the young group (aged 18 - 44 years) comprising 73 patients; the middle-aged group (aged 45 - 59 years) comprising 73 patients; and the young elderly group (60 - 74 years) comprising 73 patients.

Inclusion criteria:

- 1) Age 18 - 74 years;
- 2) Scheduled for sedated gastroscopy;
- 3) ASA classification I - II;
- 4) Informed consent from the patient and their family.

Exclusion criteria:

- 1) Severe peripheral vascular disease, such as Raynaud's disease or occlusive arteriosclerosis;
- 2) Skin lesions on the fingers affecting perfusion index (PI) monitoring;
- 3) Severe hepatic or renal insufficiency, or coagulation disorders;
- 4) Allergy to anaesthetic agents such as propofol or sufentanil;
- 5) Impaired consciousness or inability to cooperate with the investigator.

This study was approved by the hospital's Ethics Committee, and all patients signed informed consent forms.

2.2. Anaesthetic Technique

Patients were fasted for 8 hours and had nothing to drink for 4 hours prior to surgery. Upon admission to the operating theatre, a peripheral vein was established and 500 mL of compound sodium chloride injection was administered. Oxygen was administered via a face mask at a flow rate of 6 L/min for at least 5 minutes.

Anaesthetic induction: Administer 0.1 - 0.2 µg/kg of sufentanil intravenously; 30 seconds later, slowly inject 1.5 - 2.5 mg/kg of propofol. Begin endoscopy once the MOAA/S score reaches ≤1.

Anaesthetic maintenance: Administer propofol 20 - 50 mg intermittently, as required, based on patient movement and swallowing reflexes, to maintain a stable level of sedation and vital signs.

2.3. Monitoring Parameters

Monitor and record data at the following time points:

T0: Pre-anaesthesia (5 minutes after entering the room in a supine position).

T1: Immediately after propofol injection.

T2: Upon completion of propofol injection.

T3: Loss of eyelash reflex.

T4: When the gastroscope passes the pyriform sinus.

T5: During the examination (recorded every 3 minutes, taking the average).

T6: Upon awakening (responsive to verbal stimuli, able to open eyes).

Primary analytical time points for this study were T0, T2, T3, and T6. T1, T4, and T5 were recorded for auxiliary observation but were not included in the main statistical analysis because T1 was transient and T4 - T5 belonged to the maintenance phase rather than the induction phase.

Parameters to be recorded: PI, SBP, DBP, HR, SpO₂.

Calculate the maximum change during the induction phase:

$\Delta PI = \text{Maximum PI value} - \text{Baseline PI value}$

$\Delta SBP = \text{Baseline SBP value} - \text{Minimum SBP value}$

$\Delta DBP = \text{Baseline DBP value} - \text{Minimum DBP value}$

Criteria for hypotension: SBP < 90 mmHg or a decrease of >30% from baseline.

Criteria for bradycardia: HR < 50 beats/min.

If any of the above conditions occur, administer vasoactive drugs in accordance with standard protocols.

2.4. Statistical Methods

SPSS 29.0 statistical software was used. Continuous variables are expressed as mean $\pm$ standard deviation; within-group comparisons were performed using repeated measures analysis of variance (ANOVA), whilst between-group comparisons were performed using one-way ANOVA with Bonferroni post-hoc correction for multiple comparisons. Categorical variables are expressed as percentages (%), and the chi-square test was used for analysis. Correlations were assessed using Pearson's correlation analysis. ROC curves were plotted to determine the optimal threshold for predicting hypotension using PI [9]. A p-value of <0.05 was considered statistically significant.

3. Results

3.1. Comparison of General Characteristics among the Three Groups (as Shown in Table 1)

There were no statistically significant differences ($P > 0.05$) in gender, BMI, ASA classification, time of examination, or total propofol dosage among the three groups; the groups were therefore comparable.

Table 1. Comparison of general data among three groups ($\bar{x} \pm s$, n (%)).

Indicators	Young adults (n = 73)	Middle-aged adults (n = 73)	Young elderly (n = 73)	P-value
Gender (Male/Female)	38/35	40/33	39/34	>0.05

Continued

Age (years)	32.6 ± 5.4	51.3 ± 4.2	66.8 ± 4.2	<0.05
BMI (kg/m ²)	23.5 ± 2.1	23.8 ± 2.3	23.6 ± 2.4	>0.05
ASA classification (I/II)	62/11	59/14	67/6	>0.05
Procedure duration (min)	3.8 ± 2.1	4.1 ± 2.3	4.3 ± 2.5	>0.05
Propofol dose (mg)	150.5 ± 22.4	146.3 ± 24.1	136.8 ± 23.6	>0.05

3.2. PI and Haemodynamic Changes (as Shown in Tables 2-5)

At T0, there were no statistically significant differences in PI, SBP, DBP, or HR among the three groups except for baseline SBP, which was significantly higher in the young elderly group (129.6 ± 12.1 mmHg) than in the young adult group (106.5 ± 10.2 mmHg) and the middle-aged group (108.3 ± 11.4 mmHg) ($P < 0.05$). Following induction of anaesthesia, PI rose rapidly, peaking between T2 and T3, before gradually declining and returning to near baseline levels during the recovery period [10]. SBP and DBP decreased significantly after induction, exhibiting a trend opposite to that of PI ($P < 0.05$). The changes in Δ PI, Δ SBP, and Δ DBP increased progressively with age: the young elderly group had the largest fluctuations, followed by the middle-aged group, and the young adult group had the smallest ($P < 0.05$). There were no significant intergroup differences in HR changes.

3.3. Correlation Analysis

The maximum PI during the induction phase was significantly negatively correlated with Δ SBP and Δ DBP ($r = -0.721$ and -0.684 , respectively; $P < 0.01$); Δ PI was significantly positively correlated with the incidence of hypotension ($r = 0.653$; $P < 0.01$); There was no significant correlation between PI and HR ($P > 0.05$).

3.4. Predictive Value of PI for Hypotension

As shown in **Figure 1**, the ROC curve showed: AUC for PI in predicting hypotension during the induction phase of anaesthesia = 0.824 (95% CI: 0.765 - 0.883); Optimal cut-off: 3.65%; Sensitivity: 78.3%; Specificity: 81.5% [11].

In the young-elderly group, the optimal threshold was 3.2%, with a sensitivity of 82.0% and a specificity of 79.5% [12].

3.5. Incidence of Hypotension

Young group: 12.3%.

Middle-aged group: 17.8%.

Young-elderly group: 34.2%.

The differences between groups were statistically significant ($P < 0.05$).

Note on time points: T1, T4, and T5 were recorded but excluded from the main analysis because T1 was transient and T4 - T5 belonged to the maintenance phase rather than the induction phase. Anaesthetic depth was stable after T3, and PI did not change substantially thereafter.

Table 2. Comparison of the perfusion index (PI) across age groups at different time points (% , $\bar{x} \pm s$).

Time point	Young adults (n = 73)	Middle-aged adults (n = 73)	Young elderly (n = 73)	P-value
T0	2.81 $\pm$ 0.72	2.76 $\pm$ 0.69	2.85 $\pm$ 0.75	>0.05
T2	4.15 $\pm$ 1.02	4.32 $\pm$ 1.06	4.89 $\pm$ 1.15* [#]	<0.05
T3	4.36 $\pm$ 1.08	4.51 $\pm$ 1.12	5.12 $\pm$ 1.21* [#]	<0.05
T6	2.92 $\pm$ 0.74	2.88 $\pm$ 0.71	2.96 $\pm$ 0.77	>0.05

Note: Legend: *Compared with the young group, $P < 0.05$; [#]Compared with the middle-aged group, $P < 0.05$. T0: Pre-anaesthesia; T2: End of propofol injection; T3: Disappearance of the eyelash reflex; T6: Upon awakening. Δ PI: Maximum change in perfusion index; Δ SBP: Maximum decrease in systolic blood pressure; Δ DBP: Maximum decrease in diastolic blood pressure. Same applies to all tables below.

Table 3. Comparison of SBP (systolic blood pressure) across age groups at different time points (mmHg, $\bar{x} \pm s$).

Time point	Young adults (n = 73)	Middle-aged adults (n = 73)	Young elderly (n = 73)	P-value
T0	106.5 $\pm$ 10.2	108.3 $\pm$ 11.4	129.6 $\pm$ 12.1	<0.05
T2	90.6 $\pm$ 8.9	96.2 $\pm$ 9.6	96.8 $\pm$ 10.2* [#]	<0.05
T3	89.2 $\pm$ 8.5	92.8 $\pm$ 9.1	92.5 $\pm$ 9.8* [#]	<0.05
T6	104.8 $\pm$ 10.1	106.2 $\pm$ 10.8	107.3 $\pm$ 11.5	>0.05

Table 4. Comparison of DBP (diastolic blood pressure) across age groups at different time points (mmHg, $\bar{x} \pm s$).

Time point	Young adults (n = 73)	Middle-aged adults (n = 73)	Young elderly (n = 73)	P-value
T0	68.2 $\pm$ 7.1	69.5 $\pm$ 7.6	70.1 $\pm$ 8.2	>0.05
T2	60.3 $\pm$ 6.2	57.8 $\pm$ 6.5	61.2 $\pm$ 7.0* [#]	<0.05
T3	58.5 $\pm$ 5.8	55.6 $\pm$ 6.1	58.3 $\pm$ 6.6* [#]	<0.05
T6	67.1 $\pm$ 6.9	68.2 $\pm$ 7.3	69.0 $\pm$ 7.8	>0.05

Table 5. Comparison of changes in induction-phase parameters and incidence of hypotension across age groups.

Indicators	Young adults (n = 73)	Middle-aged adults (n = 73)	Young elderly (n = 73)	P-value
Δ PI (%)	1.55 $\pm$ 0.42	1.75 $\pm$ 0.46	2.27 $\pm$ 0.53* [#]	<0.05
Δ SBP (mmHg)	20.3 $\pm$ 4.2	25.5 $\pm$ 5.1	37.1 $\pm$ 6.3* [#]	<0.05
Δ DBP (mmHg)	11.8 $\pm$ 2.6	14.2 $\pm$ 3.1	20.6 $\pm$ 3.8* [#]	<0.05
Incidence of hypotension [cases (%)]	9 (12.3)	13 (17.8)	25 (34.2)* [#]	<0.05

4. Discussion

4.1. Patterns of PI Changes during the Induction Phase of Painless Gastroscopy

PI reflects peripheral vasodilation and sympathetic tone [13]. Propofol inhibits the sympathetic nervous system and dilates peripheral blood vessels, thereby enhancing the pulsatile blood flow signal and causing a rapid rise in PI. This study shows that the rise in PI precedes the drop in blood pressure, suggesting that PI

may reflect changes in vascular tone at an earlier stage, which is consistent with the findings of domestic and international studies [14].

During highly stimulating phases of gastroscopy, such as passage through the pyriform sinus, there is a transient excitation of the sympathetic nervous system and mild vasoconstriction, causing a slight decrease in PI; during the recovery phase, as anaesthetic drugs are metabolised and vascular tone is restored, PI gradually returns to baseline levels. Changes in PI throughout the procedure are highly synchronised with anaesthetic depth, drug effects, and procedural stimuli [15].

4.2. PI Is Significantly Correlated with Hemodynamic Fluctuations

This study confirmed that the magnitude of PI elevation is significantly negatively correlated with the magnitude of blood pressure reduction, suggesting that PI can serve as an indicator for assessing vasodilatory reserve. Patients with high baseline PI have lower vascular tone and are more prone to hypotension following anaesthesia [16]. In elderly patients, with reduced vascular elasticity and diminished autonomic regulatory capacity, PI fluctuations are more pronounced and the risk of hypotension is higher, which is consistent with clinical practice [17].

There was no significant correlation between PI and heart rate, suggesting that PI primarily reflects peripheral vascular tone rather than cardiac time-dependent function, and can serve as an independent supplementary indicator to conventional circulatory monitoring [18].

4.3. PI Provides Good Early Warning Value for Hypotension

This study established that a PI of 3.65% can serve as the warning threshold for hypotension during painless gastroscopy in adults, with this threshold reduced to 3.2% for elderly patients [19]. Clinicians may use these values to implement stratified management:

- 1) $PI \geq 3.65\%$: Administer appropriate pre-procedural fluid expansion, slow the rate of propofol infusion, and reduce the induction dose;
- 2) Elderly patients with $PI \geq 3.2\%$: Exercise heightened vigilance and administer vasoactive agents prophylactically, if necessary;
- 3) Patients with lower PI values: Circulation is relatively stable; standard dosing may be administered.

PI monitoring requires no additional equipment, incurs no extra costs, and is simple to perform, making it suitable for implementation in endoscopy centres at all levels of hospital [20].

4.4. Clinical Significance of Age Stratification

This study found that, when grouped by age, elderly patients exhibited more sensitive PI fluctuations and more fragile circulation, suggesting that anaesthetic management should be individualized [21]. Adopting lower warning thresholds, slower administration rates, and simplified anaesthetic protocols for patients aged 60 years and over can significantly improve safety, aligning with the principles of

precision anaesthesia and patient-centred care [22].

4.5. Study Limitations

PI is susceptible to factors such as finger temperature, limb movement, and sensor placement [23]; this study was single-centre with a limited sample size; future multicentre studies could be conducted to include specific populations such as those with diabetes or hypertension, thereby further refining the application criteria for PI [24].

5. Conclusions

1) During the induction phase of painless gastroscopy anaesthesia, PI provides a continuous, non-invasive, and early reflection of peripheral vascular tone and the degree of sympathetic inhibition, with changes occurring earlier than traditional vital signs.

2) Changes in PI are significantly correlated with hemodynamic fluctuations; the greater the increase in PI, the higher the risk of hypotension.

3) A PI value of 3.65% may serve as a warning threshold for hypotension during the induction phase of painless gastroscopy in adults; for elderly patients, this threshold may be lowered to 3.2%.

4) Implementing age-stratified anaesthetic management based on PI monitoring enables early identification of circulatory risks, optimisation of anaesthetic medication, and improves safety and comfort in outpatient anaesthesia.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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