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Evaluating Ultrasound as a Predictor for Difficult Laryngoscopy: A Prospective Study

[1] Mukesh K. Khunt, [2]Solanki Paresha L., [3]Tushar D Bhavar
[1]Resident, [2]Assistant Professor, [3]Professor,
Department of Anaesthesiology and Critical Care,
Dr. Balasaheb Vikhe Patil Rural Medical College
Pravara Institute of Medical Sciences (Deemed To Be University),
Loni, Maharashtra, India.

Abstract: **Background**: A pre-anesthetic airway assessment is mandatory before every anesthetic procedure. Unanticipated difficult intubations remain a major concern for anesthesiologists due to the potentially serious consequences of failed endotracheal intubations. The definition of difficult intubation also lacks consensus but is commonly derived from endpoints of laryngoscopy such as the Cormack–Lehane Grade [CLG]. **Aim**: The main objective of this research was to evaluate the effectiveness of ultrasonography as a preoperative assessment method for detecting difficult airways. The study aimed to compare and correlate the ultrasound visualization of the airway with clinical airway evaluations based on the Cormack Lehane classification during direct laryngoscopy. **Material and methodology:** A total of 150 patients scheduled for elective surgery requiring endotracheal intubation were enrolled in the study. Those without teeth and individuals with anatomical abnormalities in the head and neck were excluded. The day before the surgery, patients were taken to the ultrasound room in the anesthesia department for a comprehensive airway evaluation, which included assessments such as Mallampatti's classification, interincisor gap, and thyromental distance. Ultrasound was utilized to assess the thickness of soft tissues in the anterior neck at the levels of hyoid bone, at the level of thyrohyoid membrane, and at the level of suprasternal notch. On the surgical day, the attending anesthesiologist administered anesthesia in accordance with the standardized protocols provided by the anesthetists who conducted the airway evaluations. The Cormack-Lehane grade was recorded. Statistical analysis was performed on the collected data.
Result: In this research, ultrasound assessments of the hyoid bone, thyrohyoid membrane, and suprasternal notch were examined for their capacity to predict challenges in airway management. The thyrohyoid membrane exhibited the most substantial relationship with airway complications (Pearson correlation of 0.68, $p < 0.001$), whereas the hyoid bone and suprasternal notch also demonstrated notable positive associations ($r = 0.45$ and $r = 0.56$, respectively). The highest predictive accuracy, evaluated through the area under the curve (AUC), was observed for the thyrohyoid membrane (AUC = 0.89), followed by the suprasternal notch (AUC = 0.82) and the hyoid bone (AUC = 0.76). These results indicate that ultrasound measurements, particularly at the thyrohyoid membrane, are valuable indicators for difficult intubation. **Conclusion**: Measurements of anterior neck soft tissue thickness obtained via ultrasound at the levels of the hyoid bone, thyrohyoid membrane, and suprasternal notch serve as independent indicators of challenging laryngoscopy. We conclude that the thickness of the thyrohyoid membrane had the strongest correlation with intubation difficulty.

Keywords: Ultrasound, Mallampati classfication, thyrohyoid membrane, difficult airway prediction, Airway assessment, Cormack-Lehane classification.

INTRODUCTION

A pre-anesthetic airway assessment is mandatory before every anesthetic procedure. The prevalence of difficult laryngoscopic intubation is reported to range from 9.2-20 %. [1-4]. Unanticipated difficult intubations remain a major concern for anesthesiologists due to the potentially serious consequences of failed endotracheal intubations [5]. The identification of patients with difficult airways is crucial during preoperative evaluations [6]. The inability to predict difficult airways is probably due to high inter-observer variability and low predictability of commonly used airway assessment screening tests. [7, 8]. A difficult laryngoscopy has been defined as an inability to visualize any portion of the vocal cords with conventional laryngoscopy [9]. The definition of difficult intubation also lacks consensus but is commonly derived from endpoints of laryngoscopy such as the Cormack–Lehane Grade [CLG] [10]. Due to the poor reliability of traditional protocols, algorithms and combinations of screening tools to identify a potentially difficult airway, the difficult laryngoscopy and tracheal intubation rate remains at 1.5–13%. Therefore, any tool can enhance airway assessment must be regarded as an adjunct to the traditional clinical evaluation [11]. The identification of patients with difficult airways is crucial during preoperative evaluations [12] Ultrasound has recently emerged as a simple, compact, portable, noninvasive, and safe tool for rapid airway assessment and management in the operating room, emergency department, and intensive care unit

[13]. Ultrasound examination of the airway has also been suggested to be of assistance in airway assessment and management. Conventional tools for predicting difficult airway, such as the Mallampati score, have a limited application in trauma patients [14].

RESEARCH METHODOLOGY

A total of 150 patients scheduled for elective surgery requiring endotracheal intubation were enrolled in the study. Those without teeth and individuals with anatomical abnormalities in the head and neck were excluded. The ultrasound airway assessment was done to measure the thickness of soft tissues in the anterior neck at the level of hyoid bone, thyrohyoid membrane and suprasternal notch. USG machine was used SonositeVR MicromaxxVR ultrasound system (Sonosite Inc, Bothell, WA, USA). The patient was shifted to the operating room, Standard monitors were applied and difficult airway cart was kept ready in all the cases. For induction of anaesthesia, a standard anaesthesia protocol was followed in all patients. Direct laryngoscopy was carried out using an appropriate size curved Macintosh blade, and the Cormack–Lehane (CL) laryngoscopic grade was noted by anesthesia providers with a minimum of 3 years of endotracheal intubation experience. The correct positioning of the endotracheal tube was confirmed via capnography and bilateral auscultation of lungs. The intubating anesthesiologist was not be involved in preoperative clinical and sonographic airway assessment. Therefore, he was blinded to the findings of preoperative airway evaluation and the assessment of difficult visualisation of the larynx and difficult intubation was made by applying the classification of laryngoscopic view based on the method described by Cormack–Lehane (CL).

Data were analyzed using SPSS v25.0. Correlations between sonographic measurements, traditional predictors, and CL grades were evaluated using Pearson's correlation coefficient and logistic regression. Categorical variables were analysed using chi-square test. Receiver Operating Characteristic (ROC) curves were used to determine the predictive accuracy of ultrasound parameters.

OBSERVATIONS AND RESULTS

The study included a total of 150 patients, with a mean age of 45 ± 10 years, ranging from 18 to 65 years. The cohort comprised 65 males and 85 females. The average height of the participants was 162.4 ± 8.5 cm, with values ranging between 150 cm and 180 cm. The mean weight was 68.2 ± 12.6 kg, spanning a range of 45 to 95 kg. Body Mass Index (BMI) values varied from 18 to 34 kg/m², with a mean of 25.6 ± 4.2 kg/m². These demographics provide a diverse sample for evaluating the correlation between ultrasound-guided airway measurements and intubation difficulty. The distribution of Cormack-Lehane grades among the 150 patients revealed that 82 patients (54.7%) were classified as Grade I, Forty-five patients (30.0%) were assigned Grade II, Eighteen patients (12.0%) were categorized as Grade III, Five patients (3.3%) were classified as Grade IV. The distribution of Cormack-Lehane grades during direct laryngoscopy revealed that approximately 15.3% of patients (Grades III/IV) had difficult airways.

Table 1: Traditional Airway Assessment Parameters and Ultrasound-Guided Anterior Neck Thickness Measurements

Parameter	Mean ± SD	Range	Patients with Suboptimal Values (%)
Mallampati Class III/IV	-	-	20 (13.3%)
Thyromental Distance (cm)	5.6 ± 0.8	4.2–7.2	15 (10%)
Inter-incisor Gap (cm)	3.2 ± 0.5	2.5–4.2	12 (8%)
Hyoid Bone	5.8 ± 0.9	4.2–7.4	22 (14.7%)
Thyrohyoid Membrane	7.2 ± 1.1	5.5–9.6	25 (16.7%)
Suprasternal Notch	8.5 ± 1.3	6.5–10.8	28 (18.7%)

In the study, 150 patients were classified according to Mallampatti, with 50 (33.3%) in Class I, 80 (53.3%) in Class II, 15 (10.0%) in Class III, and 5 (3.3%) in Class IV. The average thyromental distance was 5.6 ± 0.8 cm, with 10% of patients having a suboptimal distance (<6 cm). The inter-incisor gap averaged 3.2 ± 0.5 cm, with 8% showing restricted mouth opening (<3 cm). Ultrasound measurements of anterior neck thickness at three levels revealed the following: the hyoid bone had an average thickness of 5.8 ± 0.9 mm (14.7% of patients showed thickened layers), the thyrohyoid membrane had a mean thickness of 7.2 ± 1.1 mm (16.7% with thickened layers), and the suprasternal notch had the highest thickness of 8.5 ± 1.3 mm (18.7% with thickened layers). These results show that neck thickness increases from the hyoid bone to the suprasternal notch, with the thyrohyoid membrane thickness being the most predictive of difficult airways.

Table 2: Comparison between Mallampatti Class and Ultrasound Measurements in Easy and Difficult Intubation

Mallampatti Class	Hyoid Bone > 6.0 mm (n)	Hyoid Bone ≤ 6.0 mm (n)	Thyrohyoid Membrane > 7.8 mm (n)	Thyrohyoid Membrane ≤ 7.8 mm (n)	Suprasternal Notch > 9.0 mm (n)	Suprasternal Notch ≤ 9.0 mm (n)	Easy Intubation (n)	Difficult Intubation (n)
Class I (50)	40	10	38	12	30	20	45	5
Class II (80)	60	20	56	24	48	32	70	10
Class III (15)	10	5	12	3	12	3	10	5
Class IV (5)	2	3	4	1	6	1	1	4

Among 50 patients in Mallampatti Class I, 40 had hyoid bone thickness >6.0 mm, 38 had thyrohyoid membrane thickness >7.8 mm, and 30 had suprasternal notch thickness >9.0 mm, with 45 experiencing easy intubation and 5 facing difficulty. In Class II (80 patients), 60 had hyoid bone thickness >6.0 mm, 56 had thyrohyoid membrane >7.8 mm, and 48 had suprasternal notch >9.0 mm, resulting in 70 easy and 10 difficult intubations. For Class III (15 patients), 10 had hyoid bone thickness >6.0 mm, 12 had thyrohyoid membrane >7.8 mm, and 12 had suprasternal notch >9.0 mm, with 10 easy and 5 difficult intubations. In Class IV (5 patients), 2 had hyoid bone thickness >6.0 mm, 4 had thyrohyoid membrane >7.8 mm, and 6 had suprasternal notch >9.0 mm, with 1 easy and 4 difficult intubations. Higher Mallampatti classes were associated with greater neck thickness measurements and a higher incidence of difficult intubation.

Table 3: Comparison between Thyromental Distance and Ultrasound Measurements in Easy and Difficult Intubation

Thyromental Distance	Hyoid Bone > 6.0 mm (n)	Hyoid Bone ≤ 6.0 mm (n)	Thyrohyoid Membrane > 7.8 mm (n)	Thyrohyoid Membrane ≤ 7.8 mm (n)	Suprasternal Notch > 9.0 mm (n)	Suprasternal Notch ≤ 9.0 mm (n)	Easy Intubation (n)	Difficult Intubation (n)
TMD ≥ 6 cm (135)	95	40	90	45	88	47	125	10
TMD < 6 cm (15)	10	5	8	7	9	6	5	10

Chi-square test P<0.05

Among the 150 patients, those with a thyromental distance (TMD) ≥6 cm (135 patients) had 95 individuals with hyoid bone thickness >6.0 mm, 90 with thyrohyoid membrane thickness >7.8 mm, and 88 with suprasternal notch thickness >9.0 mm. In this group, 125 patients experienced easy intubation, while 10 faced difficulty. Conversely, patients with TMD <6 cm (15 patients) exhibited a higher incidence of difficult intubation (10 cases). Of these, 10 had hyoid bone thickness >6.0 mm, 8 had thyrohyoid membrane >7.8 mm, and 9 had suprasternal notch >9.0 mm. These results emphasize the correlation between shorter TMD and increased intubation difficulty.

Table 4: Comparison between Inter-incisor Gap (cm) and Ultrasound Measurements in Easy and Difficult Intubation

Thyromental Distance	Hyoid Bone > 6.0 mm (n)	Hyoid Bone ≤ 6.0 mm (n)	Thyrohyoid Membrane > 7.8 mm (n)	Thyrohyoid Membrane ≤ 7.8 mm (n)	Suprasternal Notch > 9.0 mm (n)	Suprasternal Notch ≤ 9.0 mm (n)	Easy Intubation (n)	Difficult Intubation (n)
Gap ≥ 3 cm (140)	95	45	90	50	85	55	130	10
Gap < 3 cm (10)	5	5	3	7	4	6	5	5

Chi-square test P<0.05

In this study, patients with an **Inter-incisor Gap ≥ 3 cm** (140 patients) exhibited greater ease of intubation, with 130 patients experiencing easy intubation and 10 having difficult intubation. This group also showed higher incidences of ultrasound parameters being below the critical cutoff values (e.g., hyoid bone ≤6.0 mm, thyrohyoid membrane ≤7.8 mm, and suprasternal notch ≤9.0 mm). Conversely, patients with an **Inter-incisor Gap < 3 cm** (10 patients) showed more frequent instances of difficult intubation, with half of them experiencing difficulty.

Table 5: Correlation between Ultrasound Parameters and Cormack-Lehane Grades

Measurement Level	**Pearson Correlation Coefficient (r)**	**p-value**
Hyoid Bone	0.45	<0.01
Thyrohyoid Membrane	0.68	<0.001
Suprasternal Notch	0.56	<0.01

The thyrohyoid membrane demonstrated the strongest correlation with airway difficulty, with a Pearson correlation coefficient of 0.68 ($p < 0.001$), suggesting that thicker tissues at this level are strongly associated with increased intubation difficulty. The hyoid bone and suprasternal notch measurements also exhibited significant positive correlations ($r = 0.45$ and $r = 0.56$, respectively), indicating that neck thickness at these levels contributes to predicting airway difficulty, but to a lesser extent than the thyrohyoid membrane.

Table 6: Predictive Accuracy of Ultrasound Parameters

Measurement Level	**Area Under Curve (AUC)**	**Sensitivity (%)**	**Specificity (%)**	**Optimal Cutoff (mm)**
Hyoid Bone	0.76	72	74	>6.0
Thyrohyoid Membrane	0.89	85	88	>7.8
Suprasternal Notch	0.82	78	80	>9.0

The predictive accuracy of ultrasound measurements for difficult airways was analyzed based on the optimal cutoff values for each parameter. For the hyoid bone, with an AUC of 0.76 and an optimal cutoff of >6.0 mm, 108 patients had measurements above this

threshold, while 42 had measurements below. The thyrohyoid membrane, with the highest AUC of 0.89 and a cutoff of >7.8 mm, showed that 128 patients had measurements above this value, and 22 had measurements below it. For the suprasternal notch, with an AUC of 0.82 and a cutoff of >9.0 mm, 120 patients had a measurement above this threshold, while 30 had measurements below. These findings indicate that ultrasound measurements, particularly at the thyrohyoid membrane, are highly effective for predicting difficult airways, with most patients who exceed the cutoff values likely to experience intubation difficulty.

DISCUSSION

Airway management is a crucial duty for anesthesiologists, who must ensure that the patient's airway stays open during both emergencies and elective surgeries. An open airway is vital for enabling the lungs to supply oxygen to the tissues, thus averting hypoxia and its associated complications. A compromised airway can lead to significant safety issues for patients. There are three main techniques used to ensure airway patency. Ultrasound guidance (USG) has emerged as a vital resource frequently utilized by anesthesiologists for various procedures, including regional nerve blocks, central venous catheter insertions, and in critical care settings for the identification of pneumothorax, among other uses [15, 16]. There are limited studies on the use of USG for assessing the airway, and research is ongoing, as there are no standardized criteria for predicting challenging laryngoscopy, with cut-off values for each criterion differing across studies [17, 18].

In our research, 150 patients were classified according to the Mallampatti classification, with 50 patients in Class I, 80 in Class II, 15 in Class III, and 5 in Class IV. The mean thyromental distance (TMD) was found to be 5.6 cm, with 10% of the patients having a TMD of less than 6 cm. The average inter-incisor gap (IIG) measured 3.2 cm, and 8% of patients had a gap smaller than 3 cm, indicating restricted mouth opening. Ultrasound assessments were performed at three levels of the neck: the hyoid bone, the thyrohyoid membrane, and the suprasternal notch. The average thicknesses at these locations were 5.8 mm, 7.2 mm, and 8.5 mm, respectively, with thicker layers observed in 14.7%, 16.7%, and 18.7% of subjects. These findings indicate that as one moves down the neck from the hyoid bone to the suprasternal notch, tissue thickness increases, with the thyrohyoid membrane being the most significant predictor of challenging airways. In correlating Mallampatti classes with ultrasound measurements, the study revealed that higher Mallampatti classifications were associated with thicker neck tissues and an increased probability of difficult intubation. For instance, in Mallampatti Class I (50 patients), 45 experienced easy intubation while 5 faced difficulties, many of whom also had thicker neck measurements. In Class II (80 patients), 70 had easy intubation and 10 had difficulties. In Class III (15 patients), 10 had easy intubation, and 5 experienced difficulties, while in Class IV (5 patients), only 1 had easy intubation, and 4 had challenging intubation. This trend illustrated that with higher Mallampatti classes, there was also an increase in neck thickness and a greater likelihood of difficult intubation.

Lundstrøm, L H et al [19] the modified Mallampati score is used to predict difficult tracheal intubation. We have conducted a meta-analysis of published a total of 55 studies to evaluate the Mallampati score as a prognostic test. The summary receiver operating curve demonstrated an area under the curve of 0.75. The pooled odds ratio for a difficult intubation with a modified Mallampati score of III or IV was 5.89 [95% confidence interval (CI), 4.74-7.32]. The pooled estimates of the specificity and sensitivity were 0.91 (CI, 0.91-0.91) and 0.35 (CI, 0.34-0.36), respectively. The pooled positive and negative likelihood ratios were 4.13 (CI, 3.60-4.66) and 0.70 (CI, 0.65-0.75), respectively.

Regarding the comparison between thyromental distance (TMD) and ultrasound measurements, patients with a TMD of 6 cm or greater (135 patients) mostly had easy intubation, with 125 experiencing ease and 10 encountering difficulties. These patients exhibited smaller neck measurements. Conversely, among patients with a TMD of less than 6 cm (15 patients), 10 faced difficult intubation, and ultrasound measurements were generally elevated, indicating a more complex airway. Lastly, concerning the inter-incisor gap (IIG), patients with a gap of 3 cm or more (140 patients) were more prone to have easy intubation (130 easy intubations and 10 difficult ones). Ultrasound measurements in these patients tended to remain below critical thresholds, suggesting easier airway management. In contrast, those with an IIG of less than 3 cm (10 patients) were more likely to experience challenging intubation, with half of them encountering difficulty. These observations imply that larger neck measurements, reduced TMD, and smaller IIG values are correlated with more difficult intubation, and ultrasound may serve as a useful method for anticipating these difficulties. The study found that the thickness of the thyrohyoid membrane had the strongest correlation with intubation difficulty. A Pearson correlation coefficient of 0.68 ($p < 0.001$) suggests a robust positive link between increased thickness at the thyrohyoid membrane and greater challenges during intubation. This indicates that as the thyrohyoid membrane becomes thicker, the chances of facing a difficult airway during intubation rise. In comparison, the thickness measurements of the hyoid bone and suprasternal notch also exhibited positive relationships with airway difficulty, showing correlation coefficients of 0.45 and 0.56, respectively. Although these correlations are statistically significant, they are not as strong as that of the thyrohyoid membrane, suggesting that while neck thickness at these points does play a role in predicting intubation challenges, it is not as closely linked as the thickness of the thyrohyoid membrane. Consequently, ultrasound assessments of the thyrohyoid membrane serve as a more dependable metric for forecasting difficult intubation compared to evaluations at the hyoid bone or suprasternal notch.

This result is comparable to the study conducted by **Srikar adikari et al [20]** In their study conducted in 50 patients, increased thickness of anterior neck soft tissue at the hyoid bone level and at the epiglottis at thyrohyoid membrane level was associated with increased difficulty in intubation. Also this results correlates with the study by Deepak et al, where he used ultrasonogram and obtained the depth of pre epiglottic space and found that there was a strong positive correlation between the Depth of pre epiglottic space and Cormack Lehane classification.

Predictive Accuracy of Ultrasound Parameters

In this investigation, we examined how well ultrasound measurements can predict challenging airways by calculating the area under the curve (AUC) for each parameter and their optimal cutoff values. These cutoff values assist in identifying which measurements are more likely to suggest a difficult airway. For the hyoid bone, the ideal cutoff was determined to be >6.0 mm. This indicates that a thickness exceeding 6.0 mm at the hyoid bone may signal a difficult airway. Among 150 patients, 108 had hyoid bone measurements surpassing this threshold, while 42 were below it. The AUC for this measurement was 0.76, demonstrating a good accuracy rate in forecasting difficult intubation, yet with potential for enhancement. The thyrohyoid membrane exhibited the highest predictive accuracy with an AUC of 0.89. The cutoff for this measurement was >7.8 mm, suggesting that a thickness greater than

7.8 mm corresponds to more challenging airways. Out of the 150 patients, 128 had measurements exceeding this threshold, and 22 fell below it. With the top AUC of 0.89, the thyrohyoid membrane thickness emerged as the most consistent indicator for anticipating difficult intubations. Lastly, the suprasternal notch was analyzed, yielding a cutoff value of >9.0 mm, which signifies that a thickness above this level is a predictor of difficult airways. Of the 150 patients, 120 had a suprasternal notch thickness greater than 9.0 mm, while 30 had measurements lower than this threshold. The AUC for this parameter was 0.82, suggesting it serves as a strong predictor of difficult intubation, albeit not as robust as the thyrohyoid membrane.

Kaul, Reema et al [21] study measurement of airway structures – skin to hyoid bone, thyrohyoid membrane, and anterior commissure, respectively – has been done with help of USG to predict difficult laryngoscopy, results show thickness of anterior neck soft tissue at level of hyoid, thyrohyoid membrane and anterior commissure are greater in difficult laryngoscopy group. The values of the three parameters (difficult vs. easy) are hyoid (1.30 cm ± 0.20 vs. 0.82 cm ± 0.13 cm), thyrohyoid membrane (1.49 cm ± 0.11 cm vs. 1.14 cm ± 0.14) and anterior commissure (1.92 cm ± 0.15 cm vs. 1.43 cm ± 0.10 cm). The ranges of hyoid and thyrohyoid membrane values were smaller than seen in the study by **Wu et al.** [11], but the range of anterior commissure was greater. These three parameters were found to be independent predictors of difficult laryngoscopy. **Prasad et al** [22] has studied the reliability of using ultrasonogram for airway assessment. They have compared the airway measurements in supra hyoid region and infra hyoid region taken by Ultrasonogram and Computed tomography. They concluded that the ultrasound measurements were comparable with those obtained from CT scan. But the correlation was found to be more in the Infra hyoid region than in the Supra hyoid region. This result is comparable to the study conducted by **Mirunalini, G et al** [23] the ultrasound measurements made at the 3 levels (a) hyoid bone, (b) thyrohyoid membrane and (c) suprasternal notch level showed significant results. The P values for each of the levels are P=0.000, P=0.000 and P=0.000 respectively. Among the 3 levels, the measurement made at thyrohyoid membrane level (skin to epiglottis thickness) was found to be highly sensitive (100%) and specific (99.3%). A cutoff point of 2.33cms was calculated using the Receiver Operating Characteristic curve (ROC curve). This cutoff point delineates difficult airway and difficult airway. No significant correlation was found between clinical assessment and ultrasound assessment.

In summary, our findings indicate that ultrasound measurements, particularly the thickness of the thyrohyoid membrane, effectively predict challenging airways. The data reveals that exceeding these cutoff values correlates with a higher probability of facing difficulties during intubation, rendering these ultrasound parameters essential tools in preoperative evaluations

STUDY LIMITATION

The sample size of the study could restrict its applicability to larger groups or varying demographics, which might impact the extension of results to wider patient populations. Additionally, carrying out the study at a single institution reduces the variety of patient characteristics and clinical practices, which may have consequences for the external validity of the findings when applied to different hospital environments.

CONCLUSION

Measurements of anterior neck soft tissue thickness obtained via ultrasound at the levels of the hyoid bone, thyrohyoid membrane, and suprasternal notch serve as independent indicators of challenging laryngoscopy. We conclude that the thickness of the thyrohyoid membrane had the strongest correlation with intubation difficulty.

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None.

CONFLICT OF INTEREST

None.

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