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Neck circumference to thyromental distance ratio: a new predictor of difficult intubation in obese patients

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Editor's key points

- Obesity is often considered a risk factor for difficult intubation.
- In this study, a neck circumference: thyromental distance (NC/TM) ratio >5.0 predicted difficult intubation in obese Asian patients.
- The NC/TM ratio >5.0 performed better than BMI measurement, Mallampati, or other multivariate cores.
- Further data are required to confirm these findings.

Background. This study was performed to assess whether intubation is more difficult in obese patients and to assess the ability of a new index: the ratio of the neck circumference to thyromental distance (NC/TM), to predict difficult intubation in obese patients.

Methods. The incidence of difficult tracheal intubation in 123 obese (BMI≥27.5 kg m^{-2}) and 125 non-obese patients was compared. Difficult intubation was determined using the intubation difficulty scale (IDS≥5). The NC/TM ratio was calculated and its ability to predict difficult intubation in obese patients was compared with that of established predictors including high BMI, the Mallampati score, the Wilson score, NC, width of mouth opening, sternomental distance, TM, and a previous history of difficult intubation.

Results. Difficult intubation was more frequent in obese patients than in non-obese patients (13.8% *vs* 4.8%; $P=0.016$). Multivariate analysis revealed that the Mallampati score, the Wilson score, and NC/TM independently predicted difficult intubation in obese patients. Among these three indices, NC/TM showed the highest sensitivity and a negative predictive value, and largest area under the curve on an ROC curve.

Conclusions. Difficult intubation was more common in obese patients and the NC/TM was a better method for predicting difficult intubation than other established indices.

Keywords: airway management; laryngoscopy; obesity; risk assessment; tracheal intubation

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Difficult tracheal intubation is a major concern for anaesthetists and contributes to perioperative morbidity and mortality.[1] Opinions are divided as to whether or not tracheal intubation is more difficult in obese patients and available data are inconclusive.[2–11]

Many attempts have been made to develop reliable predictors for difficult intubation or difficult laryngoscopy. Suggested predictors for difficult intubation include a history of obstructive sleep apnoea syndrome (OSAS),[8 12] high Mallampati score,[8] increased age, male, short neck, and the Wilson score.[13] The Mallampati score[6] or increasing neck circumference (NC)[5 8] is reported to be associated with difficult intubation especially in obese patients. However, none of these has high diagnostic accuracy particularly in the obese.

We assumed that obese patients have a large amount of neck soft tissue that can be represented by the ratio of the NC to thyromental distance (TM). Our hypothesis was that the rate of difficult intubation would be higher in obese patients compared with non-obese patients and that the NC/TM ratio might be useful when compared with the previously reported difficult intubation indices in obese patients.

Therefore, the first aim of this study was to compare the incidence of difficult tracheal intubation between obese and non-obese patients using the intubation difficulty scale (IDS), which is a comprehensive scale for predicting difficult intubation.[14] The second aim was to develop a predictor for difficult intubation that is simple and easy to perform with high specificity and sensitivity compared with established indices.

Methods

This prospective observational study was approved by the Institutional Review Board of our institution and all patients provided informed consent. Two hundred and sixty patients, ASA class I or II, who were undergoing surgery under general anaesthesia with tracheal intubation during an 8 month period were enrolled. According to the Asian obesity criteria reported by the WHO expert consultation,[15] patients with a BMI of ≥27.5 kg m^{-2} were assigned to the obese group (Group O) and those with a BMI of <27.5 kg m^{-2} were assigned to the non-obese group (Group NO). Patients undergoing general anaesthesia without tracheal intubation, or those with an upper airway pathology (i.e. maxillofacial

fractures, tumours, etc.), cervical spine fracture, and younger than 18 yr, were excluded.

Difficulty of intubation was assessed using the IDS,[14] which was recorded by the senior anaesthetist. The IDS is graded as follows: N1, number of additional intubation attempt; N2, number of additional operators; N3, number of alternative intubation techniques used; N4, laryngoscopic view as defined by Cormack and Lehane (grade 1, N4=0; grade 2, N4=1; grade 3, N4=2; grade 4, N4=3); N5, lifting force applied during laryngoscopy (N5=0 if inconsiderable and N5=1 if considerable); N6, needed to apply external laryngeal pressure for optimized glottic exposure (N6=0 if no external pressure or only the Sellick manoeuvre was applied and N6=1 if external laryngeal pressure was used); and N7, position of the vocal cords at intubation (N7=0 if abducted or not visible and N7=1 if adducted). The IDS score is the sum of N1 through N7. A score of 0 indicated intubation under ideal conditions. The two groups of patients were classified further according to the IDS score. Those with an IDS score of $\geq$5 and $<$5 were defined as the difficult and easy groups, respectively.

A previous history of difficult intubation, BMI, neck circumference (cm) at the level of cricoid cartilage, and the width of mouth opening (cm), which was measured as the inter-incisor gap with the mouth fully opened, were obtained to evaluate the difficult intubation indices. The TM (cm) is the distance from thyroid notch to the mentum and the sternomental distance (SM, cm) is the distance from the upper border of the sternal manubrium to the mentum. Both distances were measured with the neck extended. The ratios of the NC to TM (NC/TM), to the SM (NC/SM), and to the BMI (NC/BMI) were calculated from these measurements.

Other relevant variables such as the modified Mallampati classification without phonation (Class I: soft palate, fauces, uvula, and pillars visible; Class II: soft palate, fauces, and uvula visible; Class III: soft palate and the base of uvula visible; Class IV: soft palate not visible),[16] the presence or absence of impaired temporomandibular joint mobility (inability to move the lower teeth in front of the upper teeth or retrognathia), limited neck movement (inability to extend and flex the neck to a range around 90°), and the presence or absence of abnormally protruding upper teeth were also recorded. Then, the Wilson's risk sum score[13] was calculated.

In the operating theatre, the patients were positioned with pillows under the head with the neck extended. Each patient was monitored routinely with an electrocardiogram, pulse oximetry, and non-invasive arterial pressure. Patients breathed 100% oxygen through a facemask for more than 3 min. Anaesthesia was then induced with sodium thiopental (5 mg kg^{-2}) and rocuronium (0.7 mg kg^{-2}). Cricoid pressure was applied as described by Sellick[17] when the intubator requested this for a better view at laryngoscopy. A size 3 Macintosh laryngoscope blade was used for the first laryngoscopy in each case. All tracheal intubations were performed by two anaesthetists with more than 2 yr of experience and they were blinded to the assignment of the patient.

If Sp_{O_2} decreased to $<$90% during the intubation period, the event was recorded as a hypoxic episode. The laryngoscopic view was graded according to Cormack and Lehane's scale: grade 1, the vocal cords were completely visible; grade 2, only the arytenoids were visible; grade 3, only the epiglottis was visible; and grade 4, the epiglottis was not visible.[18 19]

Statistics

On the basis of the previous studies that reported a 2.6–13% incidence of difficult intubation in lean[20] and obese [21] patients, respectively, it was postulated that obesity might increase the incidence of difficult tracheal intubation from 2.6% to 13%. A power calculation showed that 119 patients per group would be required to demonstrate this difference with 80% power (α=0.05 and β=0.2). Therefore, 130 patients per group were included to compensate for dropouts.

Data were analysed using SPSS software (version 12.0, SPSS Inc., USA). The measured variables are expressed as mean (SD). The differences between the obese and non-obese groups were analysed using a Fisher's exact test, Student's *t*-test, or the Mann–Whitney test. Differences between the difficult and easy groups in the obese patients were analysed using a binary univariate logistic regression model to determine the significant risk factors for difficult intubation. In the second step, all the significant variables from a previous step were entered in a binary multivariate logistic regression (forward-Wald) model to determine the independent risk factors for difficult intubation. The diagnostic performance of the significant risk factors was also assessed using the receiver-operating characteristic (ROC) curves. After identifying the adequate cut-off points by selecting the maximum specificity while sensitivity $\geq$80%, the continuous variables were transformed into binary variables to compare the accuracy of the tests. A value of $P<0.05$ was considered significant.

Results

Data from 123 obese and 125 non-obese patients were analysed; data from seven patients in Group O and five in Group NO were excluded as data were incomplete. No intubation failure occurred in this series. The incidence of difficult intubation determined by the IDS ($\geq$5) was more frequent in the obese patients (13.8% in Group O *vs* 4.8% in Group NO, $P<0.05$; Table 1). However, the incidence of the Cormack grade 3 or 4 was similar between groups (8.1% in Group O *vs* 7.2% in Group NO, $P=0.816$; Table 1). Although hypoxaemia occurred more frequently in obese than non-obese patients despite preoxygenation of the lungs, there was no statistical difference in the incidence of hypoxaemia during intubation (5.7% in Group O *vs* 1.6% in Group NO; $P=0.101$).

Obese patients with an IDS score of $<$5 were compared with those with an IDS score of $\geq$5 (Table 2). TM, SM, NC/TM, NC/SM, the Mallampati score, a history of difficult intubation, the Wilson score, and the Cormack grade were

related to an IDS of ≥5. Among these variables, the Mallampati score, the Wilson score, and NC/TM were independently associated with a difficult intubation revealed by Multivariate analysis (Table 3). These three variables accounted for 67.1% (R^2 of Nagelkerke) of the variability in difficult intubation. There was no significant difference in the gender ratio, age, BMI, mouth opening, NC, and NC/BMI between obese patients with IDS≥5 and those with IDS<5.

Figure 1 shows the ROC curves for TM, SM, NC/TM, NC/SM, the Mallampati score, and the Wilson score. The cut-off points for difficult intubation were the Mallampati score of III or IV, the Wilson score ≥2, and NC/TM≥5.0. Table 4 provides information on the accuracy of risk factors. NC/TM showed higher sensitivity and a negative predictive value, and large area under the curve (AUC) on the ROC curve than the Mallampati score or Wilson score.

Table 1 Patient characteristics. The values are expressed as the mean (SD or range). BMI, body mass index. Difficult laryngoscopy means the Cormack grade 3 or 4. *P<0.05

	Obese group (n=123)	Non-obese group (n=125)
Age	48.6 (18–86)	49.5 (18–88)
Sex (M/F)	46/77	61/64
Weight	75.9 (10.1)	61.9 (11.3)*
Height	158.8 (11.0)	161.1 (10.9)
Body mass index	30.1 (2.3)	23.7 (2.3)*
Incidence of difficult laryngoscopy	10 (8.1%)	9 (7.2%)
Incidence of difficult intubation	17 (13.8%)	6 (4.8%)*
Incidence of hypoxic episodes	7 (5.7%)	2 (1.6%)
Mouth opening (cm)	5.0 (1.1)	5.0 (1.1)
Neck circumference (cm)	39.2 (4.4)	34.8 (4.0)*
Thyromental distance (cm)	8.9 (1.7)	9.2 (2.2)
Sternomental distance (cm)	16.8 (3.0)	17.0 (2.9)
Mallampati score III–IV (n)	21	10*
Hx. of difficult intubation (n)	17	39
Wilson score ≥2 (n)	10	9*
Cormack grade ≥3 (n)	7	2

Discussion

The effect of obesity on difficulty of intubation and the utility of available predictive indices are unclear. In this study, we found that intubation was more difficult in obese patients compared with non-obese patients, and the ratio of the NC/TM is a better method than the previously reported Mallampati score or simple NC to predict difficult intubation for these patients.

Previous studies have suggested that the value of screening tests for difficult intubation is limited when a single test is used.[22 23] Therefore, combinations of individual tests or risk factors may add some incremental diagnostic value in comparison with the value of each test alone. Several studies have combined risk factors, such as the El-Ganzouri or Wilson scores,[13 24 25] which are a multivariate risk index systems. However, as these scores contain multiple risk factors, they are more time-consuming to perform. Thus, combining two of the most valuable risk factors may increase the diagnostic value while not increasing the burden of test significantly. Among the predictors of difficult intubation, NC and TM

Table 2 Binary univariate logistic regression comparing obese patients with an IDS score <5 and obese patients with an IDS score ≥5. Values are expressed as mean (SD or range). IDS, intubation difficulty scale; CI, confidence interval; NC/BMI ratio, the ratio of neck circumference to body mass index; NC/TM ratio, the ratio of neck circumference to thyromental distance; NC/SM ratio, the ratio of neck circumference to sternomental distance. *P<0.05

Variable	IDS<5 (n=106)	IDS≥5 (n=17)	Odds ratio (95% CI)
Continuous			
Age	47.9 (14.7)	52.8 (14.1)	1.023 (0.988–1.059)
Body mass index	30.1 (0.4)	29.8 (1.6)	0.925 (0.716–1.195)
Mouth opening (cm)	5.0 (1.1)	4.8 (1.0)	0.789 (0.485–1.284)
Neck circumference (cm)	38.9 (4.4)	41.1 (4.4)	1.121 (0.995–1.262)
Thyromental distance (cm)	9.1 (1.6)	7.2 (1.1)	0.343* (0.208–0.564)
Sternomental distance (cm)	17.2 (2.9)	14.7 (2.5)	0.701* (0.557–0.883)
NC/BMI ratio	1.3 (0.2)	1.4 (0.2)	27.828 (0.984–786.916)
NC/TM ratio	4.4 (0.9)	5.9 (1.0)	3.409* (1.979–5.871)
NC/SM ratio	2.3 (0.4)	2.9 (0.5)	7.837* (2.682–22.902)
Categorized			
M/F	38/68	8/9	1.591 (0.567–4.463)
Mallampati score III–IV (n)	11 (10.4%)	10 (58.8%)	0.081* (0.026–0.256)
Hx. of difficult intubation (n)	2 (1.9%)	5 (29.4%)	0.046* (0.008–0.264)
Wilson score ≥2 (n)	9 (8.5%)	8 (47.1%)	0.104* (0.032–0.337)
Cormack grade ≥3 (n)	2 (1.9%)	8 (47.1%)	0.022* (0.004–0.118)

Table 3 Binary multivairate logistic regression (forward-Wald) analysis performed in each patient group to determine the independent risk factors for difficult intubation in each population. NC/TM ratio, the ratio of neck circumference to thyromental distance; CI, confidence interval

Variable	β	SD	*P*-value	Odds ratio	95% CI	
					Lower	Upper
NC/TM ratio	1.782	0.432	<0.001	5.942	2.549	13.850
Mallampati score III–IV	3.219	0.970	0.001	25.015	3.738	167.417
Wilson score	3.414	1.092	0.002	30.382	3.572	258.436
Constant	−8.48	2.821	<0.001			

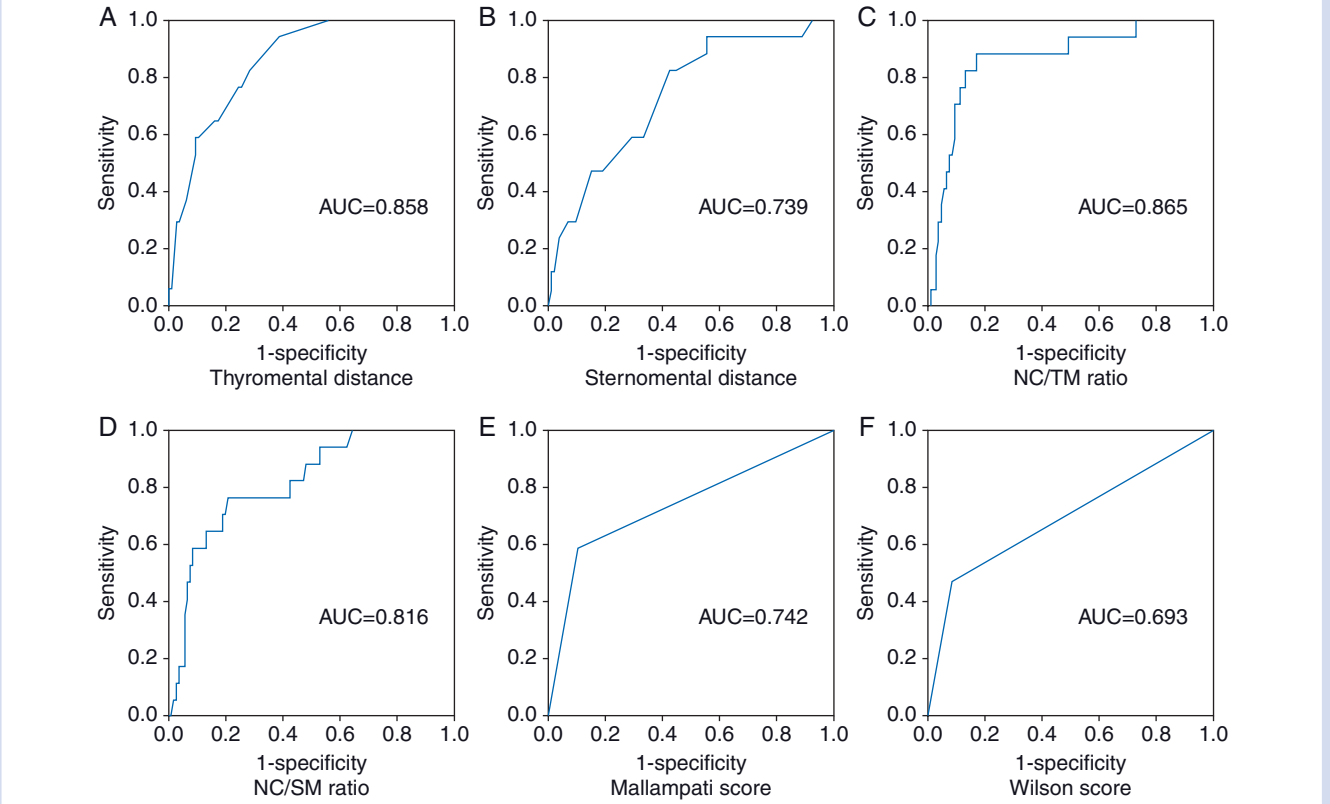

Fig 1 ROC curve analysis of six different bedside screening tests for difficult intubation. Each receiver characteristic curve is expressed as a solid line. AUC, area under the curve; NC/TM ratio, the ratio of the neck circumference to thyromental distance; NC/SM ratio, the ratio of the neck circumference to sternomental distance.

were selected based on a characteristic of obese patients' thick and short neck. The 'intubation difficulty index', with a numerator of NC and a denominator of TM (NC/TM), was developed by the authors and evaluated as a new index on the assumption that obese patients with both a large neck circumference and a short neck might be more difficult to intubate than patients with a large neck circumference or a short neck alone. From our results, NC/TM proved to be a better indicator than either the NC or TM alone (Fig. 1 and Table 3). For other variables using NC, the NC/BMI and NC/SM were also evaluated. However, multivariate analysis showed that the NC/BMI and NC/SM did not show a positive relationship with difficult intubation.

As an alternative, the index of the differences between the NC and TM, that is, NC–TM, and the differences between the NC and SM, that is, NC–SM were also evaluated. The value of this index increases as the NC gets longer and the TM or SM gets shorter. Therefore, these variables can also represent the characteristics of a short and thick neck simultaneously. Univariate analysis showed that the NC–TM and NC–SM are significant, but multivariate analysis failed to reveal any independent association with difficult intubation. In addition, the AUC on the ROC curve was smaller than the NC/TM or NC/SM (0.760 in NC–TM, 0.792 in NC–SM).

Previous studies reported that the NC is an independent risk factor for difficult intubation in obese patients.[5 8]

Table 4 Tests for difficult intubation. Values expressed as percentages. TM, thyromental distance; SM, sternomental distance; NC/TM, the ratio of neck circumference to thyromental distance; NC/SM, the ratio of neck circumference to sternomental distance; PPV, positive predictive value; NPV, negative predictive value

Test	Sensitivity	Specificity	PPV	NPV
TM≤7.3 cm	58.8	90.6	50.0	93.2
SM≤14.9 cm	47.1	81.1	28.6	90.5
NC/TM≥5.0	88.2	83.0	45.5	97.8
NC/SM≥2.4	82.4	56.6	23.3	95.2
Mallampati score III or IV	58.8	89.6	47.6	93.1
History of difficult intubation	35.7	98.2	71.4	92.2
Wilson score ≥2	47.1	91.5	47.1	91.5

However, the NC alone may not clearly indicate the amount of soft tissue at various topographic regions within the neck. Horner and colleagues[26] demonstrated that more fat was present in areas surrounding the collapsible segments of the pharynx in obese patients with OSAS using magnetic resonance imaging (MRI) measurements. Ezri and colleagues[27] demonstrated that difficult laryngoscopy could be predicted in obese patients by quantifying the neck soft tissue at the level of the vocal cords and suprasternal notch using ultrasonography. They reported that the amount of pretracheal soft tissue, quantified by ultrasound, was the only measure that fully distinguished an easy laryngoscopy from a difficult one. These results might explain why some obese patients are easy to intubate, whereas others not. NC/TM might represent the distribution of fat in the neck better than NC alone. However, NC/TM should be evaluated further to determine whether there is a correlation between the ratio and the amount of soft tissue quantified by ultrasound or MRI.

Multivariate analysis identified the Mallampati score, Wilson score, and NC/TM to be independently associated with difficult intubation in obese patients. The Wilson score was found to be significant in this study and others.[5 13] However, Juvin and collegues[6] demonstrated that none of the classic risk factors (the Wilson score, mouth opening, history of OSA) was satisfactory in obese patients except for the Mallampati score. The Mallampati score was consistently reported to be a significant predictor in obese patients including the present study.[5 6 8] However, the Mallampati score and Wilson score showed a poor-to-moderate sensitivity and a positive predictive value in this study. Moreover, the clinical predictive value of the Mallampati score may be reduced in obese patients as the jaw mobility is often limited by a mass effect. This is the same for the Wilson score because the Wilson score also evaluates jaw movement. On the other hand, NC/TM is relatively free from this effect. Among these three independent factors, NC/TM showed a moderate-to-fair sensitivity, specificity, and a negative predictive value (Table 3), and a relatively large AUC on the ROC curve (Fig. 1), which revealed that the NC/TM is highly predictive.

We used IDS scores to define difficult intubation. Many studies used different criteria, which may be one reason for the different results. Previous studies used the Cormack–Lehane grade,[28] IDS score,[5 6 20 29] or a product of the Cormack grade and the number of attempts.[8] The IDS score reflects all courses of intubation, whereas the Cormack grade only considers the moments of the laryngoscopic view. A poor laryngoscopic view did not always equate with difficult tracheal intubation according to this study. Previous studies[5 6] which used IDS also showed that intubation was more difficult in obese patients, and the incidence of a higher Cormack–Lehane grade was similar in obese and non-obese patients, as observed in the present results.

This study had several limitations. First, it was not blinded completely. The IDS score could have been increased intentionally if the anaesthetist knew the purpose of this study. Accordingly, the anaesthetists who perform the intubation were unaware of the purpose of this study to evaluate the ratio of NC/TM. Nevertheless, as the anaesthetist could recognize the patients' characteristics in the operating theatre, it was impossible to maintain complete blindness to this study. Secondly, the patient's initial position may have influenced the incidence of difficult intubation. Recent study revealed that the appropriate initial position for intubation in obese patients is the ramped position rather than the sniff position.[30] As we adopted the sniff position initially for all subjects, the incidence of difficult intubation may have been increased for obese patients. Therefore, strictly speaking, the study design would have been better if the sniff position for the non-obese patients and the ramped position for obese patients had been adopted initially. Furthermore, a Macintosh No. 3 laryngoscopic blade was used for the first laryngoscopy in each case; it may be inappropriate for some patients as a first choice. The size of the blade should have been chosen by the operator case by case.

Thirdly, there was no actual failed intubation in this study group, although several hypoxaemic episodes occurred. The incidence of failed intubation or hypoxaemic episodes may be more important than the incidence of difficult intubation defined by the IDS score in the clinical situation, and therefore, larger scale studies are required. Furthermore, all tracheal intubations were performed by anaesthetists with >2 yr experience. However, shorter experience in anaesthesia may increase the incidence of difficult intubation in obese patients. Finally, risk factors including NC/TM were also analysed in the non-obese group, but the number of cases with difficult intubation was too small to evaluate statistically. Accordingly, further studies will be needed to evaluate the NC/TM in a non-obese group with a larger number of subjects.

In conclusion, difficult intubations defined by IDS scores were more common in the obese patients group. Difficult intubation in obese patients was independently associated with a Mallampati score of III or IV, Wilson score ≥2, and NC/TM≥5.0. A NC/TM≥5.0 yielded a moderate-to-fair sensitivity, specificity, and a negative predictive value. Thus, we

consider a preoperative value of NC/TM≥5.0 to be a good predictor of difficult intubation in obese patients.

Conflict of interest

None declared.

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