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A documented previous difficult tracheal intubation as a prognostic test for a subsequent difficult tracheal intubation in adults

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Summary

We investigated the diagnostic accuracy of a documented previous difficult tracheal intubation as a stand-alone test for predicting a subsequent difficult intubation. Our assessment included patients from the Danish Anaesthesia Database who were scheduled for tracheal intubation by direct laryngoscopy. We used a four-point scale to grade the tracheal intubation. A previous difficult intubation was defined according to the presence of a record documenting a difficult penultimate tracheal intubation-score for the 15 499 patients anaesthetised more than once. Our assessment demonstrates that a documented history of previous difficult or failed intubation using direct laryngoscopy are strong predictors of a subsequent difficult or failed intubation and may identify 30% of these patients. Although previous investigators have reported predictive values that exceed our findings markedly, a documented previous difficult or failed tracheal intubation appears in everyday anaesthetic practice to be a strong predictor of a subsequent difficult tracheal intubation.

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Difficult airway management including difficult tracheal intubation may be a major cause of severe perioperative morbidity and mortality related to anaesthesia [1–4]. Predicting difficult tracheal intubation enables the anaesthesiologist to take precautions to reduce the associated risks [5]. Several studies have focused on one or more patient factors which may identify those at risk of undergoing difficult tracheal intubation [6, 7]. Among these, a previous difficult tracheal intubation has been identified as a risk factor for a future difficult tracheal intubation [8, 9]. In these studies, however, the information of a previous difficult tracheal intubation was partly or totally reported by the patient, and therefore documented information may have only been partly retrieved for their assessments.

The Danish Anaesthesia Database contains information of 15 499 patients in whom anaesthesia and tracheal intubation was performed more than once. A recorded intubation score contains documented information about the association between a previous intubation score and a future difficult tracheal intubation. The primary aim of this study was to evaluate the diagnostic accuracy of a documented previous difficult tracheal intubation and a previous failed tracheal intubation by direct laryngoscopy as stand-alone tests for the prediction of a subsequent difficult tracheal intubation and a failed tracheal intubation by direct laryngoscopy, respectively. Furthermore, in a multivariate regression model we evaluated a documented previous failed intubation by direct laryngoscopy as a

risk factor of a subsequent failed tracheal intubation by direct laryngoscopy.

Material and method

The Danish National Board of Health, The Danish Data Protection Agency and The Danish Ethics Committees for Biomedical Research approved the registration of data in the Danish Anaesthesia Database. The steering committee of the Danish Anaesthesia Database approved this study and provided access to the data for the analysis presented here.

Fourteen Danish departments of anaesthesia in 2005, and 25 departments in 2006–07, prospectively and consecutively reported data to the Danish Anaesthesia Database version 2 (the database) concerning all patients undergoing anaesthesia for surgery. The database contains specific quantitative anaesthetic and surgical indicators describing the perioperative period. All types of surgery are represented in the database. The departments are connected via the Internet to a central server hosted by The Unit for Clinical Quality, in the Capital Region, Denmark. The information is recorded immediately after each anaesthetic and surgical procedure. The interface of the database is interactive and changes depending on the type of anaesthesia and surgery that is registered. All registered parameters are predefined and the interface to register the airway-evaluation, plan, and management was the same for all the registration sites as well as the rules of validation and the on-line user manual.

Each patient entered into the database is registered with a unique identifying number from the centralised civil register. This unique identifier contains information regarding the patient's gender and date of birth, enables registration of each patient during the statistical analysis and prevents duplicates of anaesthetic reports. Furthermore, the identifier made it possible to retrieve information of patients anaesthetised and registered more than once during the period of observation.

From the database we retrieved 374 308 records of patients undergoing anaesthesia from January 2005 to December 2007 (Fig. 1). We excluded records of patients exclusively undergoing regional anaesthesia or sedation. Records of patients undergoing general or combined anaesthesia without any attempts of tracheal intubation were also excluded. We identified a total number of 148 546 records of patients undergoing general or combined anaesthesia who were primarily scheduled to undergo tracheal intubation. We excluded patients who had already undergone tracheal intubation before arriving in the operating room, patients aged < 15 years and those primarily scheduled to undergo flexible or rigid fiberoptic tracheal intubation. There were no records of the reason for these patients to be allocated to undergo fiberoptic tracheal intubation; some may have been allocated to undergo this procedure due to educational purposes rather than anticipated difficult tracheal intubation.

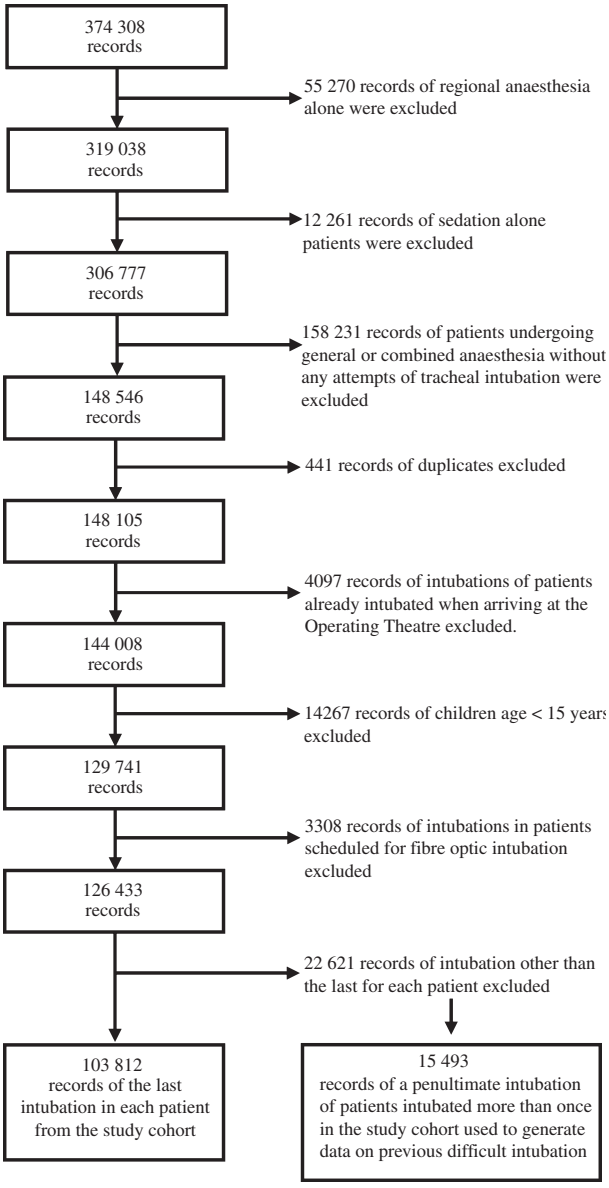

Figure 1 Selection of the study cohort. The final cohort includes 103 812 patients each represented by only one record of planned tracheal intubation by direct laryngoscopy. Of these patients, 88 313 underwent tracheal intubation only once, while 15 499 patients underwent tracheal intubation on more occasions, and therefore they had two or more records of tracheal intubation. For these last patients the penultimate record of a tracheal intubation was retrieved from the 22 621 records of tracheal intubation other than the last. Based on the penultimate record, information of a documented previous tracheal intubation was generated. Of these 15 499 patients information of a previous intubation score was missing for 6 patients.

Table 1 The Danish Anaesthesia Database tracheal intubation score.

All patients in whom the primary airway management was planned and attempted for tracheal intubation by direct laryngoscopy were scored as follows:	
Score = 1	Intubated by direct laryngoscopy by the first anaesthetist within a maximum of two attempts.
Score = 2	Intubated by direct laryngoscopy by the first anaesthetist but with more than two attempts or intubated by a supervising anaesthetist after one or more failed attempts at intubation.
Score = 3	Intubated by a method other than direct laryngoscopy.
Score = 4	Intubation abandoned after multiple attempts, no tracheal tube was inserted.
The predefined difficult tracheal intubation was defined as an intubation score > 1. Failed tracheal intubation by direct laryngoscopy was defined as an intubation score > 2.	

Tracheal intubation was performed or attempted in 103 812 eligible patients. However, records of 126 433 intubations exist as some patients underwent tracheal intubation by direct laryngoscopy for anaesthesia on more than one occasion. Of these patients, 88 313 underwent tracheal intubation only once (patients without documented information of a previous tracheal intubation), while 15 499 patients had been anaesthetised on more than one occasion, and therefore had two or more records of tracheal intubation by direct laryngoscopy. For these 15 499 patients both the last and the penultimate record of tracheal intubation were retrieved for the assessment.

We registered a tracheal intubation score (Table 1) for all patients in whom tracheal intubation by direct laryngoscopy was planned or primarily attempted. We defined difficult tracheal intubation as an intubation score > 1. Furthermore, for our assessments, we defined a 'failed tracheal intubation by direct laryngoscopy' as an intubation score > 2. This includes a change from direct laryngoscopy to a more advanced technique and any situation where tracheal intubation was abandoned. Both of these outcomes may be more significant clinical outcomes than the predefined definition of a difficult tracheal intubation. Based on the penultimate tracheal intubation of the patients who were anaesthetised more than once, the same intubation score and cut off values were used to identify a previous difficult tracheal intubation and a previous failed tracheal intubation by direct laryngoscopy.

A previous difficult tracheal intubation was categorised as 'yes' for patients who have a documented record of a previously difficult tracheal intubation (penultimate intubation score > 1). Otherwise the patients were categorised as 'no'. Consequently, the last group includes both patients who previously underwent a tracheal intubation without problems (penultimate intubation score of 1) and patients without documented information of a previous tracheal intubation. Likewise, based on a penultimate intubation score > 2, a previous failed tracheal intubation by direct laryngoscopy was categorised as 'yes' or 'no'.

In addition, we performed a multivariate regression analysis of a previous failed intubation by direct laryngoscopy as a risk factor for a subsequent failed intubation by direct laryngoscopy. The following other covariates were used: age; gender; body mass index (BMI) [10]; classification of American Society of Anesthesiologist physical status; modified Mallampati score [11]; use of a neuromuscular blocking agent [12]; priority of surgery and time of surgery.

Priority of surgery was defined as non-scheduled if there was no plan for anaesthesia and surgery the day before the actual procedure was performed. Otherwise surgery was categorised as scheduled. Time of surgery was categorised as daytime if surgery began between 08:00 and 16:00 or as shift if it began between 16:00 and 08:00. Body Mass Index was calculated as weight.height^{-2} (kg.m^{-2}) and was categorised as BMI $\geq$ 35 or BMI < 35. If the Mallampati class was registered in the database as unknown, the registration was categorised as a missing value. For the analyses, the four classes of the modified Mallampati score were categorised into three classes by combining class I with II. The use of a neuromuscular blocking agent was categorised as 'yes' or 'no' though it is impossible to determine from the database whether the neuromuscular blocking agent was used solely for tracheal intubation. At present it is not possible to acquire detailed information of airway management from the database records such as the type of laryngoscope blade or other types of equipment used for intubation.

There is no national or uniform recommendation for the evaluation and management of the airway in patients undergoing tracheal intubation in Denmark. Therefore, departments of anaesthesia reporting to the database may differ in their recommendations for the evaluation and handling of the airway.

Statistical analysis

We evaluated a previous difficult tracheal intubation as the sole predictor of a subsequent difficult tracheal intubation and a previous failed tracheal intubation by direct laryngoscopy as the sole predictor of a failed tracheal intubation by direct laryngoscopy. The accuracy of the predictors was described by: sensitivity; specificity; predictive value of a positive test; predictive value of a negative test; positive likelihood ratio; and negative likelihood ratio with 95% confidence intervals [13].

Table 2 The characteristics of the patients. Of all patients 84 had a missing intubation score. Because of missing values, the total number of patients within the cross tabulation of the covariates and difficult Intubation differs from the Total column. The (%) refers to the column percent within each covariate.

	Difficult tracheal Intubation		Total	
	Yes (%)	No (%)	(%)	Missing from total
All patients	5330	98398	103728	
Categorical covariates				
Previous difficult tracheal intubation				6 (0.0)
Yes	170 (3.2)	528 (0.5)	698 (0.7)	
No	5159 (96.8)	97865 (99.5)	103108 (99.3)	
Sex				0 (0.0)
Male	2707 (50.8)	41786 (42.5)	44525 (42.9)	
Female	2623 (49.2)	56612 (57.5)	59287 (57.1)	
Age				0 (0.0)
Age < 40 years	880 (16.5)	27855 (28.3)	28761 (27.7)	
40 ≤ Age < 60	1934 (36.3)	30995 (31.5)	32959 (31.7)	
60 ≤ Age < 80	2139 (40.1)	31083 (31.6)	33247 (32.0)	
80 ≤ Age	377 (7.1)	8465 (8.6)	8845 (8.5)	
Priority of surgery				21 (0.0)
Scheduled	4072 (76.4)	68962 (70.1)	73096 (70.4)	
Non-scheduled	1258 (23.6)	29432 (29.9)	30695 (29.6)	
Time of surgery				81 (0.1)
Daytime	4654 (87.3)	81478 (82.8)	86153 (83.0)	
Shift	676 (12.7)	16898 (17.2)	17578 (16.9)	
ASA classification				1729 (1.7)
ASA 1	1690 (32.1)	39128 (40.4)	40841 (39.3)	
ASA 2	2459 (46.7)	39430 (40.7)	41903 (40.4)	
ASA 3	953 (18.1)	15926 (16.5)	16883 (16.3)	
ASA 4	147 (2.8)	2116 (2.2)	2263 (2.2)	
ASA 5	15 (0.3)	178 (0.2)	193 (0.2)	
Mallampati score				11697 (11.3)
I	1855 (39.8)	54991 (62.9)	56862 (54.8)	
II	1765 (37.9)	26540 (30.4)	28313 (27.3)	
III	812 (17.4)	5181 (5.9)	5993 (5.8)	
IV	230 (4.9)	717 (0.8)	947 (0.9)	
Body mass index				1705 (1.6)
< 35	4858 (92.6)	91212 (94.2)	96104 (92.6)	
≥ 35	388 (7.4)	5614 (5.8)	6003 (5.8)	
Use of neuromuscular blocking agents				84 (0.1)
No	1899 (35.6)	26292 (26.7)	28191 (27.2)	
Yes	3431 (64.4)	72106 (73.3)	75537 (72.8)	
Continuous covariates		**Means (range)**		
Age; years	56.6 [15–100]	52.7 [15–106]	52.9 [15–106]	0 (0.0)
Weight; kg	78.2 [30–183]	75.5 [30–225]	75.6 [30–225]	854 (0.8)
Height; cm	171.7 [125–211]	171.1 [125–218]	171.1 [125–218]	1633 (1.6)

We performed univariate regression analyses to evaluate the possible associations between a failed tracheal intubation by direct laryngoscopy and the predefined covariates. A subsequent multivariate logistic regression analysis was performed including all significant covariates from the univariate analyses. Backward stepwise regression was performed to identify a final model.

The prevalence and pattern of missing data among all covariates were described. We used multiple imputations as a statistical method for handling missing data. [14–16]. SPSS version 15.0 and AMOS version 7.0 (SPSS Inc., Chicago, IL, USA) and NORM v 2.03 (J. L. Schafer, Department of Statistics and The Methodology Center, The Pennsylvania State University) were used for the analyses.

This study has been presented according to the recommendation of the STROBE-statement of the reporting of an observational cohort study [17].

Results

The overall proportion of patients who underwent a difficult tracheal intubation was 5.1% (5.0–5.3, 95% confidence interval (CI)). The proportion of a difficult

Table 3 The accuracy of previous difficult tracheal intubation as a dichotomous stand-alone test for the prediction of a subsequent difficult tracheal intubation.

	Outcome: difficult tracheal intubation	
	Yes	No
Test: previous difficult tracheal intubation		
Yes	170	528
No	5163	97865
Total	5329	98393

		95% confidence intervals
Sensitivity	0.03	(0.03–0.04)
Specificity	0.99	(0.99–1.00)
Predictive value of positive test	0.24	(0.21–0.28)
Predictive value of negative test	0.95	(0.95–0.95)
Positive likelihood ratio	5.94	(5.01–7.05)
Negative likelihood ratio	0.97	(0.97–0.98)

Table 4 The accuracy of a previous failed tracheal intubation by direct laryngoscopy as a dichotomous stand-alone test for the prediction of a subsequent failed tracheal intubation by direct laryngoscopy.

	Outcome: failed tracheal intubation by direct laryngoscopy	
	Yes	No
Test: previous failed tracheal intubation by direct laryngoscopy		
Yes	75	174
No	1908	101565
Total	1983	101739

		95% confidence intervals
Sensitivity	0.04	(0.03–0.05)
Specificity	1.00	(1.00–1.00)
Predictive value of positive test	0.30	(0.24–0.36)
Predictive value of negative test	0.98	(0.98–0.98)
Positive likelihood ratio	22.09	(16.92–28.86)
Negative likelihood ratio	0.96	(0.96–0.97)

tracheal intubation in 2005, 2006 and 2007 were 5.8%, 4.9% and 5.1%, respectively. The proportion of a failed tracheal intubation by direct laryngoscopy was 1.9% (1.82–1.98% CI). The characteristics of the patients are displayed in Table 2. The results are presented in Tables 3 and 4.

A proportion of 24% (21–28%) of the patients, who previously underwent tracheal intubation with difficulties, subsequently experienced a difficult tracheal intubation. Among the patients who previously underwent a tracheal intubation without difficulties, 95% (95–95%) subsequently went through tracheal intubation without problems.

The proportion of patients registered with a previous failed tracheal intubation by direct laryngoscopy and who subsequently underwent a failed tracheal intubation by direct laryngoscopy was 30% (24–36%). Among the patients who had no record of a previously failed tracheal intubation by direct laryngoscopy 98% (98–98%) did not subsequently experience a failed tracheal intubation by direct laryngoscopy.

A univariate regression analysis demonstrated a previous failed tracheal intubation by direct laryngoscopy to be a risk factor for subsequent failed tracheal intubation by direct laryngoscopy, with an odds ratio (OR) of 22.9 (17.4 – 30.2, 95% CI, $p < 0.0001$). In the univariate analyses the covariates: gender; time of surgery; American Society of Anesthesiologists classification; Mallampati score; use of neuromuscular blocking agents; and age were all statistically significantly associated with difficult intubation ($p < 0.0001$). In a subsequent multivariate regression model (Table 5) adjusted for all other significant covariates, a previous failed tracheal intubation by direct laryngoscopy remained a statistically significant risk factor of a subsequent failed tracheal intubation by direct

Table 5 Multivariate model for a failed tracheal intubation by direct laryngoscopy.

Covariates	Odds ratio	95% confidence interval	p value
Previous failed tracheal intubation by direct laryngoscopy			
No	Reference		
Yes	16.59	11.86–23.20	< 0.0001
Mallampati score			
Mallampati = I or II	Reference		
Mallampati = III	2.85	2.49–3.28	< 0.0001
Mallampati = IV	7.70	6.21–9.56	< 0.0001
Age; year			
Age < 40	Reference		
40 ≤ Age < 60	1.43	1.25–1.63	< 0.0001
60 ≤ Age < 80	1.60	1.40–1.84	< 0.0001
80 ≤ Age	1.15	0.92–1.44	0.24
Gender			
Female	Reference		
Male	1.27	1.15–1.40	< 0.0001
Use of neuromuscular blocking agent			
Yes	Reference		
No	3.19	2.89–3.53	< 0.0001

laryngoscopy with an OR of 16.6 (11.9–23.2, 95% CI, $p < 0.0001$).

Performing multiple imputations for handling missing values did not exhibit noticeable differences between our original estimates and the pooled imputed estimates.

Discussion

We found the frequency of difficult tracheal intubation to be 5.1%; similar to the estimate in a previous meta-analysis [7]. Use of a previous difficult tracheal intubation as a dichotomous test enables us to predict 24% of the patients who will subsequently undergo a difficult tracheal intubation. Further, a previous failed tracheal intubation by direct laryngoscopy was able to predict 30% of the patients with a subsequent failure. In our multivariate analysis a previous failed tracheal intubation by direct laryngoscopy was associated with a subsequent failure with an odds ratio of 16.6.

As stand-alone tests, a previous difficult tracheal intubation or a previous failed tracheal intubation by direct laryngoscopy are inadequate predictors of subsequent difficult or failed tracheal intubations by direct laryngoscopy respectively. However, our results indicate that the anaesthesiologist must take serious precautions if a patient who previously underwent a difficult or even a failed tracheal intubation by direct laryngoscopy is scheduled to undergo another tracheal intubation. For these patients, meticulous airway evaluation followed by careful planning of airway handling is mandatory.

As a consequence of our findings, the Danish Anaesthesia Database has implemented software, which will provide a pre-operative warning if the patient has a record of a previous difficult intubation. Furthermore, based on the Intubation Difficulty Scale [18] a detailed description of the circumstances and the method used for the tracheal intubation is now recorded in the database if a patient is registered with a difficult tracheal intubation. The clinical implications of these new capacities may help to identify those patients who had a previous difficult tracheal intubation and help the anaesthesiologist to make the necessary precautions before the patient undergoes tracheal intubation again.

A failed tracheal intubation by direct laryngoscopy may seem like a more clinically significant outcome than the predefined definition of a difficult tracheal intubation in the database. A previous study shows that multiple attempts at tracheal intubation may be associated with morbidity [19]. In a clinical context, it therefore seems reasonable that the Danish Anaesthesia Database intubation score includes the number of attempts to graduate difficulties.

Our estimates differ from previous reported results. A positive predictive value between 69% [9] and 78% [8] and an OR of 9.5 reported by El-Ganzouri et al. [9] are significantly greater than our findings. There may be several reasons for these differences. Arne et al. [8] demonstrated that only 44% of the patients with Cormack and Lehane [20] score of III or IV in fact underwent difficult tracheal intubations. El-Ganzouri et al. used the Cormack and Lehane score for graduating tracheal intubation difficulties, which may explain their higher estimates compared with our findings when using the Danish Anaesthesia Database intubation score. Arne et al. [8] used an intubation score, but only a few patients were registered with previous knowledge of difficult intubation and hence the statistical confidence interval of their findings is wide. In addition to patient factors successful airway management is determined by the anaesthetists technical skills, non-technical skills, as well as the facilities available, and the local environment [21, 22]. These determining factors may vary over time. As an example many more anaesthetists performing or attempting tracheal intubation participated in this study of everyday practice on Danish anaesthesia departments, which possibly adds to the variation and lack of agreement between the evaluations of a previous and a present difficult intubation. Finally, only the most severe episodes of a previous difficult tracheal intubation may be reported to the patients and consequently only these severe episodes may be included in the previously reported assessments. This may explain their higher positive predictive values of a previous difficult tracheal intubation as a risk factor and predictor for a subsequent difficult tracheal intubation.

The present study is based upon a large cohort of prospectively and consecutively collected data representing everyday experience from clinical anaesthesia practice in Denmark. The Danish Anaesthesia Database requires all recorded indicators to be subjected to relevant rules of validation. This minimises subsequent problems of missing and invalid data. This confers a high external validity to our results. The large number of patients enabled us to detect or reject even weak associations with great power and to strengthen the precision of the estimates to very narrow confidence intervals.

Limitations of the study

Confounding by indication is well-known to introduce bias in the results in any non-randomised study involving interventions [23]. The airway management of anticipated difficult tracheal intubation is likely to differ from that of an unanticipated difficult tracheal intubation. Our results could be biased by numerous variables that are not recorded in the Danish Anaesthesia Database. These unknown confounding variables may be important for the airway handling depending on the previous difficult

tracheal intubation. As an example a more experienced physician may be allocated for the task thereby resulting in a successful tracheal intubation. As another possible confounding factor, a patient may be scheduled for a fiberoptic intubation because of a record of a previous difficult tracheal intubation, thereby leaving this particular patient ineligible for the analysis performed in this study. The number of risk factors that may be considered for difficult intubation used in our multivariate analysis was limited. In future analysis, the inclusion of other additional risk factors for a failed tracheal intubation by direct laryngoscopy (such as the thyromental distance, ability of mouth opening, range of neck movement, or jaw protrusion ability) may change the impact of a previous failed tracheal intubation by direct laryngoscopy as a risk factor for subsequent failure. It is a limitation of the present study that there was no record of the educational level or years of experience of the individuals performing or attempting the intubations. Those with least experience may have the most episodes of difficult intubations. This information might have changed the results of our multivariate analysis. We cannot ensure that controlled and uniform conditions were met and applied in all the patient encounters due to a heterogeneous population of patients and reporters and a lack of a national recommendation for airway management. This may reduce the internal validity of this study.

Our assessment indicates that neither a documented previous difficult tracheal intubation nor a previous failed tracheal intubation by direct laryngoscopy are sufficient as sole predictors for a subsequent difficult tracheal intubation or failed tracheal intubation by direct laryngoscopy. However our results strongly suggest that the patients who previously underwent a tracheal intubation with difficulties or underwent a tracheal intubation which failed will be at risk of undergoing identical problems during a future tracheal intubation. For these patients, a careful airway evaluation including other significant predictors of a difficult tracheal intubation may be of vital importance to ensure adequate and safe handling of the airway.

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