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SCIENTIFIC ARTICLE

Post analysis simulated correlation of the El-Ganzouri airway difficulty score with difficult airway

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KEYWORDS
Difficult airway;
Predictive score;
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Abstract
Background: Difficult airway (DA) occurs frequently (5–15%) in clinical practice. The El-Ganzouri Risk Index (EGRI) has a high sensitivity for predicting a difficult intubation (DI). However difficult mask ventilation (DMV) was never included in the EGRI. Since DMV was not included in the EGRI assessment, and obstructive sleep apnea (OSA) is also correlated with DMV, a study correlating the prediction of DA and OSA (identified by STOP-Bang questionnaire, SB) seemed important.
Methods: We accessed a database previously collected for a post analysis simulation of the airway difficulty predictivity of the EGRI, associated with normal and difficult airway, particularly DMV. As secondary aim, we measured the correlation between the SB prediction system and DA, compared to the EGRI.
Results: A total of 2747 patients were included in the study. The proportion of patients with DI was 14.7% (95% CI 13.4–16) and the proportion of patients with DMV was 3.42% (95% CI 2.7–4.1). The incidence of DMV combined with DI was (2.3%). The optimal cutoff value of EGRI was 3. EGRI registered also an higher ability to predict DMV (AUC = 0.76 (95% CI 0.71–0.81)). Adding the SB variables in the logistic model, the AUC increases with the inclusion of ''observed apnea'' variable (0.83 vs. 0.81, $p = 0.03$). The area under the ROC curve for the patients with DI and DMV was 0.77 (95% CI 0.72–0.83).
Conclusions: This study confirms that the incidence of DA is not negligible and suggests the use of the EGRI as simple bedside predictive score to improve patient safety.

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PALAVRAS-CHAVE
Via aérea difícil;
Escore preditivo;
Apneia do sono

Correlação simulada após análise dos escores de El-Ganzouri para via aérea difícil

Resumo
Justificativa: A via aérea difícil (VAD) ocorre com frequência (5-15%) na prática clínica. O Índice de Risco de El-Ganzouri (EGRI) tem uma alta sensibilidade para prever intubação difícil (ID). No entanto, a ventilação difícil via máscara (VDM) nunca foi incluída no EGRI. Como a VDM não foi incluída na avaliação EGRI e a apneia obstrutiva do sono (AOS) também está correlacionada com a VDM, um estudo correlacionando a previsão da VAD e AOS (identificada pelo questionário STOP-Bang, SB) pareceu importante.
Métodos: Nós acessamos um banco de dados previamente coletados para simular uma análise posterior da previsibilidade do EGRI para via aérea difícil, associado à via aérea normal e difícil, particularmente VDM. Como objetivo secundário, avaliamos a correlação entre o sistema de previsão do SB e da VAD, em comparação com o EGRI.
Resultados: No total, 2.747 pacientes foram incluídos no estudo. A proporção de pacientes com ID foi de 14,7% (IC de 95%; 13,4-16) e a proporção de pacientes com VDM foi de 3,42% (IC de 95% 2,7-4,1). A incidência da VDM combinada com a de ID foi de 2,3%. O valor de corte ideal de do EGRI foi 3. EGRI também registrou uma capacidade maior de prever VDM (ASC = 0,76 (IC de 95%; 0,71-0,81)). Ao somar as variáveis do SB no modelo logístico, a ASC aumenta com a inclusão da variável ''apneia observada'' (0,83 vs. 0,81, $p = 0,03$). A área sob a curva ROC para os pacientes com ID e VDM foi de 0,77 (IC de 95%; 0,72-0,83).
Conclusões: Este estudo confirma que a incidência de VAD não é desprezível e sugere o uso do EGRI como um escore de cabeceira preditivo simples para melhorar a segurança do paciente.

Introduction

Difficult airway (DA), in general as difficulty to secure an airway and ventilate for optimal patient's oxygenation, occurs frequently (5–15%) in clinical practice, however a challenging difficult that could results in morbidity or mortality is not so frequent yet it is fatal.[1,2] The ability to foresee a serious difficulty in an efficient manner would be ideal[3–6]: but unfortunately most of the tests utilized for prediction fails to reach high sensitivity and high positive predicted value: the poor tests performance prompted to question the value of available bedside screening tests as pointless exercise.[7] Indeed there has been a change in practice,[8] and, serendipitous or not, the NAP4 study recently showed poor assessment is a major factor contributing to airway disasters.[1] The multivariate risk index developed by El-Ganzouri and coworkers (EGRI)[9] involves the analysis of six parameters commonly performed during the preoperative evaluation and includes a history of DA. Each variable is assigned a score (from 0 to 1), a score $\geq$4 has a high sensitivity for predicting a difficult intubation (DI). However difficult mask ventilation was never included in the EGRI scoring. Since DMV was not included in the EGRI assessment, and obstructive sleep apnea (OSA),[10,11] is also correlated with DMV, a study correlating the prediction of DA and OSA, looking at the outcomes of DMV as well DI seemed important. The STOP-Bang (SB) questionnaire is a common screening test used for this aim, patients identified as high risk for OSA at the questionnaire being also at high risk for DA. Based on the hypothesis that El-Ganzouri test is valuable regardless of the airway technique, but based on the definition of difficult airway utilized, we accessed a database previously collected[10] for a post analysis simulation of the airway difficulty predictivity of the EGRI, associated with normal and difficult airway, particularly DMV. As secondary aim, we also measured the correlation between the SB prediction system and difficult airway, compared to the EGRI.

Methods

Data for this retrospective simulated sub-analysis was derived from a database collected prospectively from April 2010 to December 2011 at a general community hospital (''GB Morgagni-L. Pierantoni'' Hospital, Forlì, Italy) as part of a multisite prospective observational study. After obtaining approval by the Regional Research Ethics Committee of the ''GB Morgagni-L. Pierantoni'' Hospital, Forlì, Italy (Ref: 997/2010 I 5/209-439), all non-obstetric adult patients presenting for elective surgery requiring general anesthesia, were enrolled in this study.[11] Given the retrospective nature of the study, the requirement for written informed consent was waived by the ethics committee. All patients completed a SB questionnaire and EGRI as a part of their preoperative evaluation. Collected data included: demographic data, type of surgery, ASA class, postoperative course, complications within 48 h, difficult intubation (DI) and difficult mask ventilation (DMV). For the purpose of the present analysis, only the data from ''GB Morgagni-L. Pierantoni'' Hospital was utilized ($n = 2747$). In accordance with Italian Difficult Airway Management Guidelines,[12] the DI was defined as a maneuver performed with a correct head position and external laryngeal manipulation resulting in: (a) difficult laryngoscopy, defined as being characterized by the impossibility of obtaining a view of the vocal cords even after the best external laryngeal manipulation; (b) necessity of repeated attempts; (c) necessity of non standard devices and/or procedures; (d) withdrawal and procedure re-planning. Accordingly, a single repeated attempt or switch to a different blade qualifies as difficult intubation. Standard equipment is specified as the Macintosh laryngoscope and simple endotracheal tube; all other devices, such as videolaryngoscopes or procedures, such as the use of supraglottic airway devices as a conduit for tracheal intubation, are defined as nonstandard. DMV occurs whenever the required tidal volume cannot be administered to the patient unless any airway device or external help, standard procedure withdrawal or intubation. No grading of DMV was recorded. We adopted the cut-off of ≥5 to classify patients as at high or low risk of having OSA as recently suggested.[13]

Statistical analysis

Data are presented using descriptive statistics (mean ± SD, median (range) and percentage). Continuous variables were compared using the Wilcoxon–Mann–Whitney test. Chi-squared or Fisher's exact tests were used for categorical variables. To assess the discrimination ability of the EGRI, receiver operating characteristic (ROC) curves were constructed, and the areas under the ROC curves (AUC) were calculated. For each threshold, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive and negative likelihood ratios (LR+, LR−) and positive and negative post-test probabilities (PTP+, PTP−) were calculated. The optimal cutoff value of EGRI to predict difficult airway was identify using the Youden index method, which defines the cutoff in terms of the maximal sum of sensitivity and specificity.

Nine multivariate logistic regression models were performed including all the EGRI variables and adding one at time the variables of the SB questionnaire. We also explored the inclusion of body mass index (BMI) variable instead of the patient's weight in the logistic model that considered all the EGRI variables. Patients with BMI <30 kg/m^2 were assigned a value of 0 and patients with BMI ≥30 kg/m^2 were assigned a value of 1. The Hosmer–Lemeshov test and the area under the ROC, were used to compare the goodness of fit of the models. Differences were stated as statistically significant when $p < 0.05$. All the analysis was performed using SAS 9.3 (SAS 209 Institute, Cary, NC, USA).

Results

A total of 2747 patients were included in the study. The proportion of patients with DI was 14.7% (95% CI 13.4–16) and the proportion of patients with DMV was 3.42% (95% CI 2.7–4.1). Patients who concurrently reported DI and DMV were 63 (2.3%). The median EGRI and SB score were 1 (range 0–9) and 2 (range 0–8). The demographic and clinical characteristics of study participants were presented in Table 1. Patients with and without DI or DMV differed on BMI whereas male patients were more likely to have DMV. Higher level of EGRI and SB score were predictive of DI and DMV. The entire ability of EGRI to predict DI and DMV was evaluated using the ROC curves (Fig. 1). The area under the ROC curve for DI was 0.77 (95% CI 0.74–0.80). The optimal cutoff value of EGRI was 3, with sensitivity, specificity, PPV, and NPV values of 64.1%, 81.4%, 36.1%, and 92.4%, respectively (Table 2). The pre-test probability of DI in the study sample was 14.7%. After a negative test, the post-test probability of DI was reduced to 8% in correspondence to 3 cutoff value of EGRI. The cutoff value of 4 suggested by El-Ganzouri was associated with a sensitivity of 43.6% a specificity of 91.7% and post-test probability with a negative test of 10% (Table 2). In the multivariate logistic analysis including the EGRI variables, the Hosmer and Lemeshow test indicated a good model fit (Chi-Square = 11.03, $p = 0.14$). Replacing the patients weight with the BMI variable (<30 vs. ≥30 kg/m^2), the area under the ROC curve for DI did not change (0.78 vs. 0.79, $p = 0.23$) and the model fit remain reasonable (Chi-Square = 8.76, $p = 0.19$). Adding the SB variables (one at a time) to the EGRI variables in the logistic model, did not improve the AUC of the models (Table 3). EGRI registered also a higher ability to predict DMV (AUC = 0.76 (95% CI 0.71–0.81)). An EGRI ≥3 was the optimal cutoff for predict a DMV with a sensitivity of 66% and a specificity of 77% (Table 2). After a negative test, the probability of DMV was reduced from 3% to a post-test probability of 2% both for a cutoff value of 3 and 4. The cutoff value of 4 showed a lower sensibility and a higher specificity (43% and 88% respectively) compared to the cutoff of 3 (Table 2). The multivariate logistic model including the EGRI variables had a not significant Hosmer and Lemeshow test (Chi-Square = 4.64, $p = 0.59$) and

Table 1 Characteristics of the sample by difficult airway and difficult mask ventilation.

Characteristics	No DI (n = 2,343)	DI (n = 404)	p	No DMV (n = 2,653)	DMV (n = 94)	p
Age (yr)	56.4 ± 17	57.9 ± 12.7	0.4072	56.5 ± 16.6	57.7 ± 12.6	0.8318
Sex (Male)	1179 (50.3)	219 (54.2)	0.1488	1330 (50.1)	68 (72.3)	<0.0001
Height (cm)	168 ± 9.6	167.9 ± 9.9	0.7592	167.9 ± 9.6	169.8 ± 9.5	0.0469
Weight (kg)	74.1 ± 15.8	78.7 ± 18.5	<0.0001	74.3 ± 16.1	87.7 ± 17.9	<0.0001
BMI (kg/m^2)	26.3 ± 7.1	28.1 ± 9.6	<0.0001	26.4 ± 7.6	30.4 ± 6.1	<0.0001
El-Ganzouri index	1 (0–9)	3 (0–9)	<0.0001	1 (0–9)	3 (0–9)	<0.0001
STOP-Bang score	2 (0–8)	3 (0–8)	<0.0001	2 (0–8)	4 (0–8)	<0.0001

Data are mean ± std, median (min–max) or number (percentage).

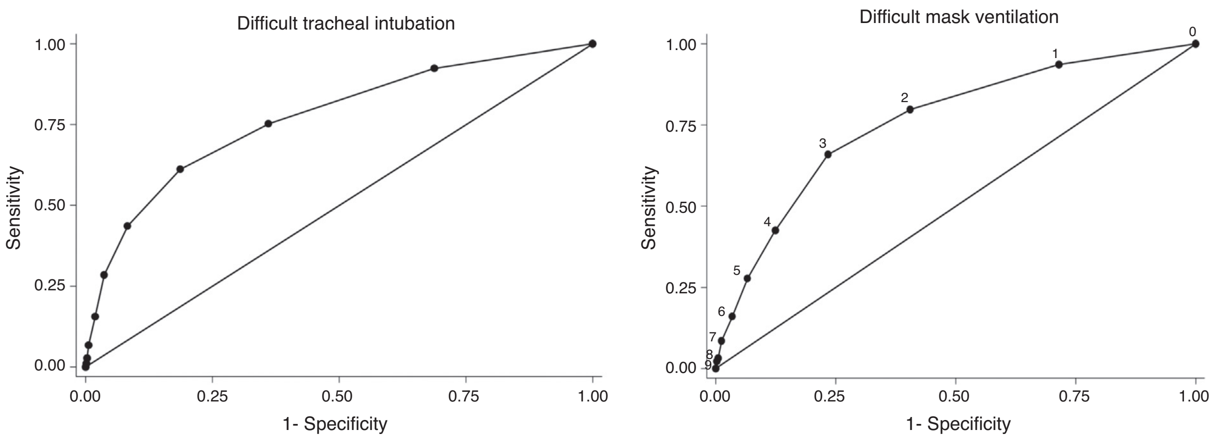

Figure 1 ROC curves for the EGRI to predict DI and DMV.

Table 2 Diagnostic indicator of the El-Ganzouri index in predicting a difficult intubation and difficult mask ventilation.

EGRI	Sensitivity (%)	Specificity (%)	LR+	LR−	VPP (%)	VPN (%)	PTP+ (%)	PTP− (%)
Difficult intubation								
0	100	0	1.00	–	14.71	–	–	–
1	92.33	31.24	1.34	0.25	18.80	95.94	19	4
2	75.25	63.89	2.08	0.39	26.43	93.74	26	6
3	61.14	81.35	3.28	0.48	36.11	92.39	36	8
4	43.56	91.72	5.26	0.62	47.57	90.41	48	10
5	28.47	96.33	7.76	0.74	57.21	88.65	57	11
6	15.59	98.16	8.50	0.86	59.43	87.09	59	13
7	6.68	99.40	11.18	0.94	65.85	86.07	66	14
8	2.72	99.74	10.63	0.98	64.71	85.60	64	14
9	0.99	99.87	7.73	0.99	57.14	85.40	57	15
10	0	100	–	1.00	–	–	–	–
Difficult mask ventilation								
0	100	0	1.00	–	3.42	–	–	–
1	93.62	28.53	1.31	0.22	4.44	99.21	4	1
2	79.79	59.48	1.97	0.34	6.52	98.81	7	1
3	65.96	76.55	2.81	0.44	9.06	98.45	9	2
4	42.55	87.56	3.42	0.66	10.81	97.73	11	2
5	27.66	93.40	4.19	0.77	12.94	97.33	13	3
6	15.96	96.57	4.65	0.87	14.15	97.01	14	3
7	8.51	98.76	6.84	0.93	19.51	96.82	20	3
8	3.19	99.47	6.05	0.97	17.65	96.67	18	3
9	2.13	99.81	11.29	0.98	28.57	96.64	28	3
10	0	100	–	1.00	–	–	–	–
Difficult intubation and mask ventilation								
0	100	0	1,00	–	2.29	–	–	–
1	96.83	28.35	1.35	0.11	3.07	99.74	3	0
2	79.37	59.02	1.94	0.35	4.35	99.19	4	1
3	68.25	76.12	2.86	0.42	6.29	99.03	6	1
4	42.86	87.22	3.35	0.66	7.3	98.49	7	2
5	30.16	93.22	4.45	0.75	9.45	98.27	9	2
6	17.46	96.46	4.93	0.86	10.38	98.03	10	2
7	11.11	98.73	8.77	0.90	17.07	97.93	17	2
8	3.17	99.44	5.68	0.97	11.76	97.77	12	2
9	1.59	99.78	7.10	0.99	14.29	97.74	15	2
10	0	100	–	1.00	–	–	–	–

Table 3 ROC contrast estimation between El-Ganzouri model and El-Ganzouri + SB models.

Models	Difficult intubation			Difficult mask ventilation		
	AUC	95% CI	Contrast with El-Ganzouri model *p*	AUC	95% CI	Contrast with El-Ganzouri model *p*
El Ganzouri model	0.79	0.77–0.82		0.81	0.76–0.85	
+snoring	0.79	0.77–0.82	0.85	0.82	0.78–0.86	0.08
+observed	0.80	0.77–0.82	0.24	0.83	0.79–0.87	0.03
+tired	0.79	0.76–0.81	0.31	0.81	0.76–0.85	0.98
+collo	0.79	0.77–0.82	0.69	0.82	0.78–0.86	0.14
+blood	0.79	0.76–0.82	0.61	0.81	0.76–0.85	0.71
+age	0.79	0.77–0.82	0.45	0.81	0.76–0.85	0.83
+sex	0.79	0.76–0.81	0.41	0.81	0.77–0.86	0.36
+bmi	0.79	0.76–0.81	0.53	0.81	0.76–0.85	0.34

a AUC of 0.81 (95% CI 0.76–0.85). Adding the SB variables (one at a time) in the logistic model, the AUC increases with the inclusion of observed variable (0.83 vs. 0.81, $p = 0.03$) (Table 3). The area under the ROC curve for the subset of patients with DI and DMV was 0.77 (95% CI 0.72–0.83). The diagnostic index confirmed the optimal cutoff of 3 with a sensitivity of 68% and a specificity of 76%. The probability of the combined difficult airway was reduced from 2% to 1% (negative post-test probability).

Discussion

In the current study the incidence of DMV was 3.42%, DI 14.7%, and the DI-DMV combination 2.3%. EGRI has proved a useful bedside screening test to predict DA, performing well for both DI as in the original description, but also for DMV. The combination of EGRI and SB does not improve the predictive value for DA, except for observed apnea item in the SB questionnaire. The DMV has become the subject in recent years of a more extensive investigation aware of the fact that the ability to ventilate and oxygenate the patient is the key to a good outcome in front of a DA. The incidence of DMV varies from 1.4% to 16%, depending on the definition and differences in the study population, the reported incidence in our study is in line with the literature and non-negligible.[14–16] Several risk factors have been identified and predictive scores proposed but not widespread in the daily clinical practice.[3–6] This study found an incidence of DI higher than usually reported, however a standard definition of the difficult airway cannot be identified in the available literature as also mentioned in the update of Difficult Airway Guidelines recently published by ASA.[17] We decided to use the definitions of Difficult Airway of the Italian Society of Anaesthesia,[12] as formally adopted by the centers involved in the study and reference standards of the Italian Ministry of Health. It is recognized in the literature that the incidence of difficult airway changes with the definition used,[14] accordingly the published estimates of the incidence of difficult intubation range from 0.1 to 13%. Recently, Corso and coworkers[10] using the same definition found similar rate of DI. The incidence of DI combined with DMV, despite its importance, has only recently been highlighted. Kheterpal and colleagues[6] in a recent multi center observational study reported an incidence of 0.04% of DMV combined with difficult laryngoscopy. In our study we observed a much higher incidence largely due to the different definitions used. The DA is therefore a problem as far from rare and a harbinger of potential risks to the patient. Searching for an easy to use screening test has the target of reducing the proportion of patients that due to an unpredicted DA are at risk of serious complications until death, predictable complications by adopting organizational strategies and appropriate management. Predicting the DA actually means to implement specific clinical pathways and appropriate airway management strategies. An ideal DA airway screening test should be simple to use, objective, inexpensive, reproducible, and particularly characterized by high negative predictive values. Having an objective test is important because it allows us to identify patients at risk of DA regardless of the operator. The subjectivity in the assessment of risk factors has recently been emphasized.[18] The updated ASA guidelines state that the airway assessment should be done in all patients, but merely lists a number of risk factors. Cattano[19] showed that the implementation of an comprehensive airway assessment does not improve the ability to predict the DA in an academic, tertiary-based hospital, anaesthesiology residency training programmed. As a result, the airway assessment in clinical practice is still a subjective evaluation perceived as a waste of time by anesthesiologists. In our study EGRI has proven to work both in the prediction of DI that DMV, in this way the operator with a single bedside screening test is able to assign a red flag to selected cases, turning on a specific clinical pathway for airway management. In view of the risk that an unforeseen difficulty entails, the high number of false positives is a small price to pay without extra costs and particularly with little risk to the patient. In our sample EGRI with a cutoff of 3 has proved to be clinically useful in identifying both the DI that the DMV. El-Ganzouri and colleagues[9] suggested a cutoff of 4. In our sample the best cutoff was 3, this variation being most likely a statistical artifact caused by the small number of cases with EGRI higher than 7. The patients identified at high risk for sleep apnea at the SB questionnaire are also at greater risk of DA 10, hence the rationale to investigate the hypothesis that adding its variables to EGRI could improve the predictive value. However our results show that only variable associated with DA is the reported observed apnea an indirect evidence of OSA. This is not surprising since it is known in the literature the association between OSA and DMV.[6] Our study also has limitations: first the sample size is underpowered to identify the situation of DI combined to DMV, second we did not grade the DMV potentially producing an overestimation of rate of DMV, finally the nature retrospective of our analysis could led to a selection and treatment bias. In conclusion the results of this study confirm that in a real world clinical setting, the incidence of DA is not negligible and suggest the use of the EGRI as simple bedside predictive score to improve patient safety. Further prospective study to validate this score would be useful.

Authorship

Ruggero M. Corso conceived of the study, and participated in its design and coordination and helped to draft the manuscript, Davide Cattano helped to draft the manuscript, Matteo Buccioli has prepared the database and assisted in the presentation of data, Elisa Carretta participated in the design of the study and performed the statistical analysis, Oriana Nanni has revised the statistical analysis, Salvatore Zampone helped to draft the manuscript, Stefano Maitan helped to collect data and draft the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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