ORIGINAL PAPER

Aspiration: the predictive value of some clinical and endoscopy signs. Evaluation of our case series

Aspirazione: significato predittivo di alcuni segni clinici non strumentali e strumentali endoscopici. Valutazione della nostra casistica

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Key words

Swallowing disorders • Dysphagia • Aspiration • Diagnosis • Endoscopy • Statistical analysis

Parole chiave

Disordini della deglutizione • Disfagia • Aspirazione • Diagnosi • Endoscopia • Analisi statistica

Summary

Signs and symptoms obtained by clinical examination and endoscopic observations in consecutive subjects presenting at our Phoniatry and Logopedics Service from 1998 to 2003 for swallowing disorders were reviewed and evaluated statistically. The predictive power of these parameters is discussed in terms of short-term complications of dysphagia (aspiration). Epidemiological considerations are made based on a statistical model.

Riassunto

Segni clinici desunti da valutazioni cliniche non strumentali e strumentali endoscopiche di clienti consecutivi con disturbi della deglutizione afferiti al nostro servizio di Foniatria e Logopedia dal 1998 al 2003 sono stati considerati e valutati numericamente. Considerazioni vengono fatte in senso predittivo, nei confronti di complicanze a breve termine di disfagia (aspirazione), ed epidemiologico, sulla scorta di un modello statistico, elaborato considerando i parametri suddetti.

Introduction

The demand for consultations for patients with swallowing disorders is destined to increase over the next few years [1 2]. The availability of centres for the study and treatment of swallowing disorders represents a useful resource for residential services managing patients with different burdens of care.

At our Health Agency, we have been actively engaged in the issue of swallowing disorders since 1997, and our case series provides a pool of data for statistical retrospective evaluation. Despite changes in the clinical approach and instrumentation, over time, a critical evaluation of this activity has offered the possibility to extract some parameters that may be useful in identifying subjects with dysphagia (predictive value).

Aim of the study was to apply statistical methods to select those parameters with the greatest predictive power for identifying the risk of complications from swallowing disorders (aspiration).

Materials, methods and results

Consecutive subjects seen at our Phoniatry and Logopedics Service for swallowing disorders were evaluated from mid 1998 to 2003. Subjects were submitted to the following diagnostic workup [3-7]:

1. Clinical history;
2. Clinical evaluation (informal BSE: bedside swallowing examination) that probes the functions listed in Table I, according to the scientific evidence in this field;
3. Endoscopy (FEES: fiberoptic endoscopic examination of swallow) carried out, as described elsewhere [8], and completed with dynamic tests with bolus [9-13]. In our practice, radiological studies (videofluoroscopic assessment and DSI) are limited to selected cases, those with unclear diagnostic questions, to confirm oesophageal disorders and after head and neck surgery or in degenerative neurological disorders.

The main parameters of the BSE and endoscopic evaluation were considered to determine their level of sensitivity and specificity in order to predict the risk of aspiration (predictive value).

Our case series is heterogeneous and includes acute, subacute, nursing home and rehabilitation in-patients and out-patients. A total of 520 subjects (V = 0), 323 male, 197 female (mean age 67.23 years) were taken

Table I. Clinical swallowing examination protocol.

1. Mental status
2. Language
3. Speech and articulation
4. Respiratory function/expiration
5. Voice and resonance
6. Positioning
7. Lip sensation, strength and seal
8. Mouth opening
9. Muscles of mastication
10. Dentition and periodontium
11. Salivary flow
12. Oral and pharyngeal sensation (gag reflex)
13. Tongue movement and strength
14. Velar elevation
15. Volitional swallow
16. Food and liquid swallows

into consideration. Based on the endoscopy results, the population was divided into two groups: 378 non-aspirating subjects (V0 = 0) and 142 aspirating subjects (V0 = 1).

The parameters chosen (independent variables) for the individual groups and pooled sample with their means and standard deviation (SD) are reported in Table II. Age was reported as decades and globally evaluated as significant or non-significant.

The pooled data were submitted to discriminant analysis and logistic regression which provide similar descriptive information but present peculiarities that help to better understand the impact of individual factors and the mechanisms behind the model used to predict subjects with aspiration.

Outcome of the discriminant analysis is shown in Table III.

The *test of equality of group means* provides an estimate of the probability of significance (*p value*) for the discrimination between the groups (Sig). Values of $p \leq 0.05$ are significant and of $p \geq 0.10$ not significant.

Since this analysis is univariate, we can also consider borderline values of significance for $0.05 < p < 0.10$. The influence of these factors is predictable and including them in the model is not likely to modify the significant values.

Evaluation of the predictive groups provided by this analysis confirms that 83.1% of the original data were correctly classified (classification error of 16.9%) which means that the number of subjects without aspiration becomes 319 and those with aspiration 113. Results and percentage data are reported in Table IV. From the Table, we can find the values of sensitivity and specificity of the statistical model.

Sensitivity = 100* 319/319 + 29 = 91.66%

Specificity = 100* 113/113 + 59 = 65.69%

Histograms of the discriminant functions for the two groups are shown separately in Figure 1.

In the group without aspiration, the distribution is skewed strongly to the right, supporting the prediction made by the model; whereas for the group with aspiration, the distribution is more dispersed, though presenting an appreciable skew to the left, even if a non-negligible number fall in the area of non-aspiration (classification error).

Table II. Mean and standard deviation (SD) for predictor variables in aspiration, non-aspiration and pooled groups.

	Non-aspiration		Aspiration		Pooled	
Factors	Mean	SD	Mean	SDcc	Mean	SD
X1 = Collaboration	0.862	0.345	0.641	0.481	0.802	0.399
X2 = Gurgling voice	0.071	0.258	0.106	0.308	0.081	0.273
X3 = Sensation	0.995	0.073	0.979	0.144	0.990	0.098
X4 = Dysarthria	0.217	0.413	0.254	0.437	0.227	0.419
X5 = Aphasia	0.087	0.283	0.070	0.257	0.083	0.276
X6 = Delayed trigger	0.061	0.239	0.380	0.487	0.148	0.356
X7 = Age/10	6.786	1.378	6.556	1.544	6.723	1.427
X8 = Sex (0 = M – 1 = F)	0.397	0.490	0.387	0.489	0.394	0.489
X9 = TBI	0.029	0.168	0.042	0.202	0.033	0.178
X10 = Stroke	0.772	0.420	0.697	0.461	0.752	0.432
X11a = Degenerative neurological diseases	0.093	0.290	0.106	0.308	0.096	0.295
X11b = Other diseases	0.114	0.318	0.169	0.376	0.129	0.335
X12 = Pre-swallow dump	0.474	0.500	0.542	0.500	0.492	0.500
X13 = Cough-penetration	0.127	0.333	0.718	0.451	0.288	0.453
X14a = Pooling	0.431	0.496	0.634	0.483	0.487	0.500
X14b = Post-swallow dump	0.040	0.195	0.106	0.308	0.058	0.233
X14c = Dry swallow	0.373	0.484	0.507	0.502	0.410	0.492

Table III. Test of equality of group means for predictor variables.

Tests of Equality of Group Means Factors	Wilks' Lambda	F	df1	df2	Sig.
X1 = Collaboration	0.9386	33.8637	1	518	0.0000
X2 = Gurgling voice	0.9969	1.6255	1	518	0.2029
X3 = Sensation	0.9948	2.7220	1	518	0.0996
X4 = Dysarthria	0.9985	0.7859	1	518	0.3757
X5 = Aphasia	0.9993	0.3865	1	518	0.5344
X6 = Delayed trigger	0.8394	99.0818	1	518	0.0000
X7 = Age/10	0.9948	2.7036	1	518	0.1007
X8 = Sex (0 = M – 1 = F)	0.9999	0.0389	1	518	0.8438
X9 = TBI	0.9989	0.5631	1	518	0.4533
X10 = Stroke	0.9940	3.1449	1	518	0.0767
X11a = Degenerative neurological diseases	0.9996	0.2013	1	518	0.6539
X11b = Other diseases	0.9946	2.8124	1	518	0.0941
X12 = Pre-swallow dump	0.9963	1.9495	1	518	0.1632
X13 = Cough-penetration	0.6618	264.6835	1	518	0.0000
X14a = Pooling	0.9674	17.4621	1	518	0.0000
X14b = Post-swallow dump	0.9841	8.3597	1	518	0.0040
X14c = Dry swallow	0.9853	7.7522	1	518	0.0056

Table IV. Discriminant function and classification obtained.

Discriminant function Centroid evaluation		Original	Groups	Assigned group Non-aspiration	Aspiration	Total
Non-aspiration	0.530125	Frequency	Aspiration	319 [TN]	59 [FN]	378
Aspiration	-1.41118		Non-aspiration	29 [FP]	113 [TP]	142
		%	Aspiration	84.39	15.61	100
			Non-aspiration	20.42	79.58	100

TP (True Positives), FP (False Positives), FN (False Negatives), TN (True Negatives)

A logistic regression was run on the same data including all the factors in the model and exploiting automatic selection of the most significant factors by the *backward* method. The recursion was interrupted at the next to last step to provide a model maintaining the sensation factor (X3). The risk of aspiration, in the series examined, includes the following factors in the final model (with the associated levels of significance) (Table V).
To correctly interpret the coefficients one must appreciate the negative and positive values since they express opposite effects. Particularly the Exp(B) column expresses an adjusted relationship of a likelihood relationship (Odds Ratio, OR) which is obtained by a simple size holding other variables.
Since the variables considered are dichotomic (with values of 0 or 1) the ratio expresses how many more times the subject has the probability to be in the condition where the dependent variable equals 1 (V0 = 1), namely the aspirating condition. In particular, when the OR is less than 1 (negative B coefficient), the factor characterizes non-aspirators (V0 = 0) viceversa when the OR is greater than 1 (positive B coefficient) the factor characterizes aspirators (V0 = 1). The factors with positive coefficients are X6 (delayed trigger) and X13 (cough-penetration).
As with discriminant analysis, the classification table produced by the regression model, considering the original and predicted distribution, is reported in Table VI. Again the positive predictive value can be expressed as the percentage of correctly classified cases, here 84.23%. The sensitivity and specificity can be calculated from the table using the formulas reported:

Specificity = 100* 95/95 + 35 = 73.07%
Sensitivity = 100* 343/343 + 47 = 87.94%

Distribution of the regression constant in the two groups is plotted in Figure 2. Note that the variables

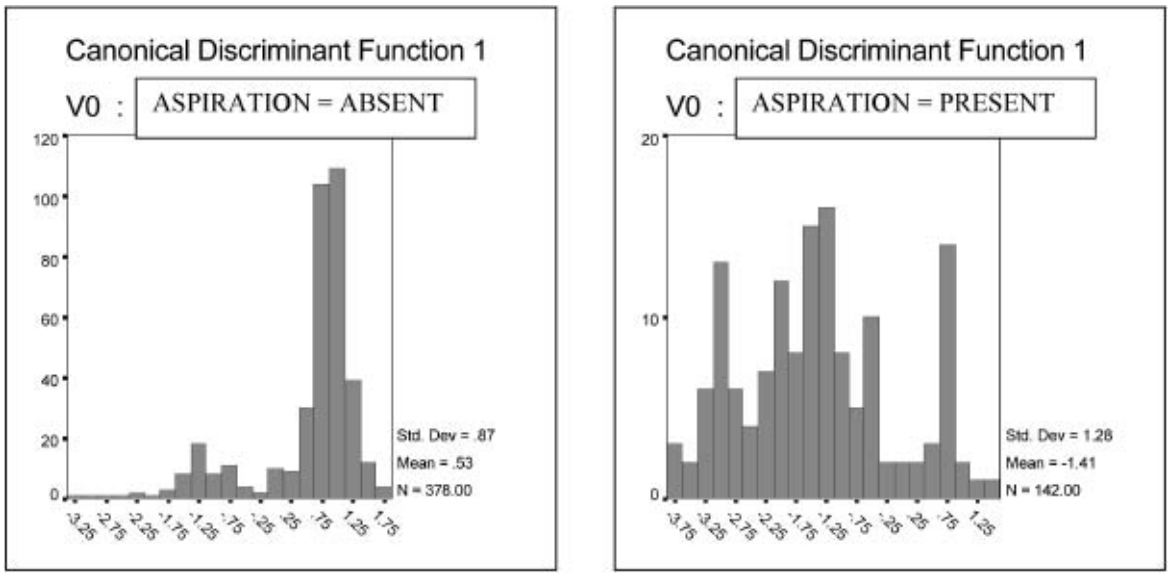

Fig. 1. Distribution (absolute frequency) of value of discriminant function for non-aspiration and aspiration groups.

x-Axis = values of discriminant function
y-Axis = number of subjects

Bars express score of non-aspiration and aspiration groups, respectively.

Table V. Logistic regression coefficient (B), standard error (SE), Wald statistic, degrees of freedom (DF), probability of significance, adjusted Odds ratio (OR) [Exp(B)] (impact on classification outcome).

Factors	B	SE	Wald	DF	Significance	Exp(B)
X1 = Collaborative	–0.79646	0.30303	6.90833	1	0.0086	0.45092
X3 = Sensation	–1.88258	1.11861	2.83239	1	0.0924	0.15220
X6 = Delayed trigger	2.04341	0.34655	34.76907	1	0.0000	7.71691
X7 = Age/10	–0.17599	0.08818	3.98328	1	0.0459	0.83863
X11a = Degenerative neurological diseases	–0.96930	0.45425	4.55333	1	0.0328	0.37935
X13 = Cough-penetration	2.77347	0.27306	103.16791	1	0.0000	16.01403
Constant	1.30529	1.25307	1.08507	1	0.2976	3.68874

Table VI. Classification obtained with logistic regression model.

Original Group	Predicted group Absent	Present	Total % correct
Absent (V0 = 0)	343 [TP]	35 [FP]	90.74
Present (V0 = 1)	47 [FN]	95 [TN]	66.90
Total			84.23

TP (True Positives), FP (False Positives), FN (False Negatives), TN (True Negatives)

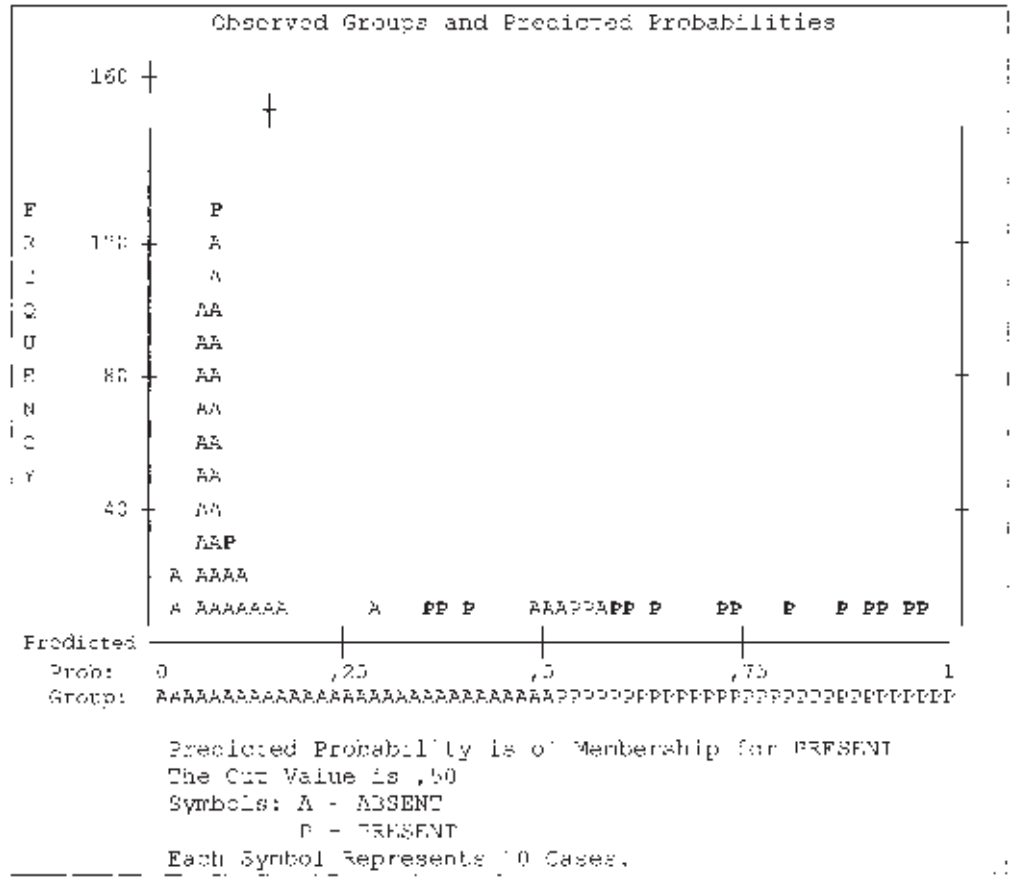

Fig. 2. Distribution of classification across the two groups obtained with logistic regression model (obtained by SPSS).

defined as significant by the logistic regression model differ, in part, from those obtained at discriminant analysis. This may be explained by the structure of the correlation between the predictor variables. When there is a strong correlation between variables, the introduction of one of these into the model can modify the selection of the other in the recursion since its weight is already accounted for by the information contained in the other variables of the group. A more in depth evaluation of the data can be run on the matrixes of correlation, as reported in Table VII.

Discussion

Some considerations can be drawn from the numerical analysis described above in terms of the percentage of correct classification of our sample (predictive value) expressed both as comparison of means (83.1%) and logistic regression (84.23%). The predictive value of our model may be considered adequate in the light of the heterogeneity of the sample and large number of variables included. The distribution of subjects with aspiration is more dispersed than those without aspiration who, in any case, can be better identified, despite the lack of instrumental studies. In the logistic regression, some endoscopic parameters that are highly significant at the comparison of means lose their predictive impact since they are overwhelmed by other factors that have a greater statistical weight, even though they are typical features (delayed trigger, pooling, etc.) used to discriminate between subjects with or without aspiration. In these terms, we can consider that although mean of pre-swallow dumping (X12) does not differ significantly in the regression matrix of Table VI, pre-swallow dumping is significantly correlated with the delayed trigger (X6), cough and penetration (X15) and thus expresses the risk of aspiration. Given the type of sample, we extracted a subgroup of specific disorders that place the subject in a high risk population for aspiration (TBI, stroke,

Table VII. Correlation matrixes.

		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11a	X11b	X12	X13	X14a	X14b	X14c
X1	r	1	−0,030	−0,049	0,004	0,044	−0,146	−0,061	−0,043	−0,207	0,039	−0,051	0,062	−0,041	−0,237	−0,076	−0,022	−0,086
	p		0,498	0,265	0,922	0,315	0,001	0,168	0,323	0,000	0,381	0,249	0,161	0,346	0,000	0,083	0,619	0,049
X2	r	−0,030	1	−0,115	0,058	0,014	0,155	0,035	0,006	0,025	−0,108	0,119	0,012	0,047	0,138	0,079	0,139	0,083
	p	0,498		0,008	0,183	0,759	0,000	0,428	0,884	0,571	0,014	0,007	0,778	0,286	0,002	0,073	0,002	0,058
X3	r	−0,049	−0,115	1	−0,041	0,030	−0,014	0,035	−0,001	0,018	0,080	0,032	−0,139	−0,021	−0,024	−0,062	0,024	−0,038
	p	0,265	0,008		0,354	0,501	0,743	0,431	0,979	0,680	0,067	0,465	0,002	0,630	0,581	0,159	0,579	0,385
X4	r	0,004	0,058	−0,041	1	−0,146	0,071	0,031	0,061	−0,048	−0,082	0,072	0,066	0,082	0,020	0,116	0,023	0,053
	p	0,922	0,183	0,354		0,001	0,104	0,482	0,166	0,275	0,061	0,099	0,134	0,062	0,651	0,008	0,593	0,228
X5	r	0,044	0,014	0,030	−0,146	1	−0,066	0,003	−0,014	−0,055	0,124	−0,074	−0,074	−0,002	−0,022	−0,055	−0,014	−0,080
	p	0,315	0,759	0,501	0,001		0,132	0,941	0,757	0,209	0,005	0,091	0,093	0,957	0,623	0,212	0,743	0,069
X6	r	−0,146	0,155	−0,014	0,071	−0,066	1	0,037	−0,026	−0,077	−0,124	0,121	0,131	0,142	0,296	0,157	0,129	0,115
	p	0,001	0,000	0,743	0,104	0,132		0,398	0,553	0,081	0,005	0,006	0,003	0,001	0,000	0,000	0,003	0,009
X7	r	−0,061	0,035	0,035	0,031	0,003	0,037	1	0,041	−0,226	0,103	0,077	−0,108	−0,032	0,042	−0,068	−0,020	−0,019
	p	0,168	0,428	0,431	0,482	0,941	0,398		0,348	0,000	0,019	0,079	0,014	0,461	0,334	0,119	0,654	0,666
X8	r	−0,043	0,006	−0,001	0,061	−0,014	−0,026	0,041	1	−0,060	−0,010	0,004	0,042	0,127	−0,036	−0,006	0,037	−0,008
	p	0,323	0,884	0,979	0,166	0,757	0,553	0,348		0,173	0,813	0,930	0,338	0,004	0,414	0,895	0,404	0,860
X9	r	−0,207	0,025	0,018	−0,048	−0,055	−0,077	−0,226	−0,060	1	−0,270	−0,060	−0,071	−0,030	0,026	0,037	0,140	0,067
	p	0,000	0,571	0,680	0,275	0,209	0,081	0,000	0,173		0,000	0,172	0,107	0,501	0,552	0,395	0,001	0,128
X10	r	0,039	−0,108	0,080	−0,082	0,124	−0,124	0,103	−0,010	−0,270	1	−0,553	−0,630	−0,138	−0,096	−0,171	−0,049	−0,110
	p	0,381	0,014	0,067	0,061	0,005	0,005	0,019	0,813	0,000		0,000	0,000	0,002	0,028	0,000	0,266	0,012
X11a	r	−0,051	0,119	0,032	0,072	−0,074	0,121	0,077	0,004	−0,060	−0,553	1	−0,125	0,122	0,138	0,139	0,003	0,060
	p	0,249	0,007	0,465	0,099	0,091	0,006	0,079	0,930	0,172	0,000		0,004	0,005	0,002	0,001	0,941	0,172
X11b	r	0,062	0,012	−0,139	0,066	−0,074	0,131	−0,108	0,042	−0,071	−0,630		1	0,104	−0,004	0,096	−0,046	0,065
	p	0,161	0,778	0,002	0,134	0,093	0,003	0,014	0,338	0,107	0,000	0,004		0,018	0,925	0,028	0,296	0,140
X12	r	−0,041	0,047	−0,021	0,082	−0,002	0,142	−0,032	0,127	−0,030	−0,138	0,122	0,104	1	0,146	0,119	−0,013	0,040
	p	0,346	0,286	0,630	0,062	0,957	0,001	0,461	0,004	0,501	0,002	0,005	0,018		0,001	0,007	0,773	0,360
X13	r	−0,237	0,138	−0,024	0,020	−0,022	0,296	0,042	−0,036	0,026	−0,096	0,138	−0,004	0,146	1	0,229	0,207	0,186
	p	0,000	0,002	0,581	0,651	0,623	0,000	0,334	0,414	0,552	0,028	0,002	0,925	0,001		0,000	0,000	0,000
X14a	r	−0,076	0,079	−0,062	0,116	−0,055	0,157	−0,068	−0,006	0,037	−0,171	0,139	0,096	0,119	0,229	1	0,056	0,488
	p	0,083	0,073	0,159	0,008	0,212	0,000	0,119	0,895	0,395	0,000	0,001	0,028	0,007	0,000		0,201	0,000
X14b	r	−0,022	0,139	0,024	0,023	−0,014	0,129	−0,020	0,037	0,140	−0,049	0,003	-0,046	−0,013	0,207	0,056	1	-0,005
	p	0,619	0,002	0,579	0,593	0,743	0,003	0,654	0,404	0,001	0,266	0,941	0,296	0,773	0,000	0,201		0,913
X14c	r	−0,086	0,083	−0,038	0,053	−0,080	0,115	−0,019	−0,008	0,067	−0,110	0,060	0,065	0,040	0,186	0,488	-0,005	1
	p	0,049	0,058	0,385	0,228	0,069	0,009	0,666	0,860	0,128	0,012	0,172	0,140	0,360	0,000	0,000	0,913	

degenerative neurological diseases) [7 14-21]: this high risk class was also identified as such by our model. Another finding worth mentioning, in keeping with the literature, is the importance of sensation [22-26], collaboration and age [22 27 28] in mediating the risk of aspiration.

This analytical approach may help identify the clinical and instrumental parameters that better identify patients at risk for aspiration and that require more aggressive management and follow-up.

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