Med. Decision Making
Vol. 1, No. 3, 1981

0272-989X/81/030239-0853.10

The Diagnosis of Strep Throat in Adults in the Emergency Room

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Adult patients who presented to an urban emergency room complaining of a sore throat had cultures and clinical information recorded. Models were constructed, using logistic regression analysis, of both a positive culture for Group A beta streptococcus and a positive guess by a resident. The model of a positive culture consisted of four variables—tonsillar exudates, swollen tender anterior cervical nodes, lack of a cough, and history of fever. Patients with all 4 variables had a 56% probability of a positive culture; 3 variables, 32%; 2 variables, 15%; 1 variable, 6.5%; and 0 variables, 2.5%. The model of a positive guess by a resident demonstrated an overreliance on physical exam and an underuse of history. The model of a positive culture allows stratification of patients to assist clinicians in the management strategies.

Adult patients with sore throats present a common management problem to outpatient physicians [1]. Clinical diagnosis is known to be imperfect, as Group A beta streptococcus and viral infections can mimic each other [1–7]. There are suggestions in the literature [1,5,6] that strep pharyngitis can be differentiated to some extent by the clinical presentation. If physicians had a simple set of parameters to predict the likelihood of a positive culture for Group A beta streptococcus, they could make more rational decisions as to treatment, culture, or no treatment. Previous attempts to establish diagnostic criteria have used as many as eight variables with unequal weighting [1,5,6]. Although these criteria may theoretically be excellent at differentiation, their application in practice is unlikely, as physicians will not remember such complex formulae and therefore will not use them. In order to gain physician acceptance, a simple model (less than five parameters and equal weighting) is necessary. Such a model would have a greater chance of physician acceptance and hence might improve patient care.

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Physicians currently make this decision (whether a sore throat is due to Group A beta strep or not); however, the basis of their decision making is not clear. It is possible that their decisions are already acceptable. However, if they are significantly overdiagnosing or underdiagnosing Group A beta strep then it would be helpful to understand which clinical cues are used inappropriately and which predictive cues are ignored.

The consideration of these problems assumes that there is a significant prevalence of positive cultures for Group A beta streptococcus in the population being treated. We studied adult patients with sore throats in an urban emergency room to determine (1) the prevalence of Group A beta strep in the population, (2) a simple model for positive culture results, and (3) a model for physicians' predictions of diagnosis. This information then allows us to offer to physicians a model which is practical and usable. Furthermore, we also understand better how current decisions are being made and can make suggestions toward improving patient management.

Methods

CLINICAL DATA. The subjects were two hundred eighty-six consecutive adults (age >15) presenting in the Medical College of Virginia (MCV) emergency room with complaints of sore throat between February 15, 1980 and April 15, 1980. Each patient had a throat culture obtained in a routine manner and sent to the MCV microbiology lab. All cultures positive for beta streptococcus were specifically typed with a rapid latex test (STREPTEX®) [8]. Clinical information was obtained on all patients (see Table 1), including a guess by the house officer as to whether or not the culture would be positive for Group A beta streptococcus. The patients were treated without any special provisions for followup.

Table 1. Clinical Information

Duration of symptoms
Age
Exposure history
Fever history
Difficulty swallowing
Coryza
Cough
Temperature $\geq 101°F$
Exudates on tonsils
Exudates on pharynx
Injection of pharynx
Tonsil swelling
Swollen tender anterior cervical nodes
Swollen tender posterior cervical nodes
Resident's guess

ANALYSIS OF DATA. The clinical data and culture results were computer-coded and -processed. Only patients with cultures growing normal flora or Group A beta streptococcus were analyzed. Complete clinical data were available for analysis on 234 patients with such cultures. All statistics were performed using SAS programs [9]. Sensitivities, specificities, and predictive values of results were calculated using PROC FREQ (SAS), as were chi-square analyses of significance of individual factors. Logistic regression analyses were performed using PROC LOGIST (SAS).

All clinical variables were analyzed in comparison with a positive or negative culture in a two-by-two chi-square analysis. Logistic analyses were performed for three separate models. First, a positive culture was modeled, using physical findings and historical features; next, a positive resident's guess was modeled, using the same factors; finally, culture growth was again modeled, using a positive resident's guess as a variable. These analyses were constructed so that only variables which made a significant ($p < 0.05$) contribution to the model were included. Variables were given a value of 1

Table 2. Individual Signs and Symptoms as Predictors of a Positive Culture

	Sensitivity	Specificity	Positive Predictive Value	Chi-square[a]	*P* Value
LACK OF COUGH	0.56	0.74	0.32	15.233	0.0001
SWOLLEN TENDER ANTERIOR CERVICAL NODES	0.80	0.55	0.27	16.954	0.0001
TONSILLAR EXUDATES	0.65	0.69	0.31	**17.917**	0.0001
TONSILLAR SWELLING	0.87	0.39	0.23	10.641	0.0011
FEVER HISTORY	0.78	0.45	0.23	7.869	0.0050
INJECTED PHARYNX	0.97	0.18	0.20	6.530	0.0106
TEMP ≥ 101°F	0.24	0.89	0.32	6.045	0.0139
PHARYNGEAL EXUDATES	0.32	0.83	0.28	**5.194**	0.0227
SWOLLEN TENDER POSTERIOR CERVICAL NODES	0.17	0.91	0.29	2.470	0.1160
LACK OF CORYZA	0.51	0.58	0.20	1.215	0.2704
RESIDENT'S GUESS	0.72	0.76	0.36	33.750	0.0001

[a]All chi-square analyses had one degree of freedom.

when present and 0 when absent. When P is the probability of the modeled outcome, and there are K predictive variables $y_1, y_2, \ldots$, and y_k, the logistic regression model is

$$P=\frac{e^x}{1+e^x},$$

where $x=\alpha+\Sigma\beta_i y_i$, with α and the various β_i being the calculated regression coefficients.

Results

Of the throat cultures, 17% grew Group A beta streptococcus. Control throat cultures on 25 patients and employees aged 16–35 with no upper respiratory symptoms were all negative for Group A beta streptococcus. Among the study subjects, 5% of throat cultures grew non-Group A beta streptococcus (predominantly Groups B, C, and G); these patients were excluded from further analysis in this study.

Table 2 shows the sensitivity, specificity, and predictive value, with chi-square and P values, for all clinical features as compared to a positive culture.

The model derived for a positive culture included only four variables: tonsillar exudates (*exudtons*), swollen tender anterior cervical nodes (*swolacn*), lack of a cough $-$(*cough*), and fever history (*fevhist*). The model was constructed as

$$P=\frac{e^x}{1+e^x}, \text{ and } x=a+b_1(y_1)+\cdots+b_n(y_n), \text{ or}$$
$$X=-2.69+1.04(exudtons)+1.00(swolacn)-0.95(cough)+0.89(fevhist).$$

The predictive power of this model is summarized in Table 3. Approximately 10% of the patients had all four predictors present; 20% had three, 25% had two, 30% had only one, and 15% had none of the four variables in the model.

The model for a positive resident's guess included six variables. Tonsillar exudates (*exudtons*) were the best predictor, followed by swollen tender anterior cervical nodes (*swolacn*), temperature greater than 101°F orally (*temp*), pharyngeal exudates (*exudphar*), lack of a cough $-$(*cough*), and

Table 3. Predictive Model for Positive Culture

Number of Variables Present	Probability of Positive Culture
4	55.7%
3	30.1–34.1%
2	14.1–16.6%
1	6.0–6.9%
0	2.5%

Table 4. Predictive Model for Resident's Guess

Variables			Probability of Positive Culture
Resident's Guess	Lack of Cough	Fever History	
+	+	+	55.7%
+	−	+	35.9%
+	+	−	31.6%
+	−	−	17.1%
−	+	+	14.9%
−	−	+	7.2%
−	+	−	6.0%
−	−	−	2.8%

swollen tender posterior cervical nodes (*swolpcn*), in that order of importance. The model used was

$$X = -4.18 + 4.49(exudtons) + 2.52(temp) + 2.51(swolacn) - 1.24(cough) + \\ + 1.99(exudphar) + 1.59(swolpcn).$$

Using $P = 0.50$ as a cutoff, the model correctly predicted residents' guesses with a specificity of 0.92 and a sensitivity of 0.90.

When a positive resident's guess was considered as a variable, the model of a positive culture included only three variables: positive guess (*guess*), lack of cough $-(cough)$, and fever history (*fevhist*). The model was

$$X = -2.74 + 1.97(guess) + 1.00(fevhist) - 0.81(cough).$$

The predictive power of this model is summarized in Table 4.

Discussion

The model developed for a positive culture satisfies our criteria of usability, as there are only four variables with approximately equal weighting. Logistic analysis was used for modeling because of several advantages of this type of analysis [10]. Logistic analysis makes use of maximum likelihood estimations to estimate values of α and β [11, 12]. After these coefficients are selected, the computer can be programmed to eliminate variables which do not add significant information to the discrimination of the two groups (here strep throat versus normal flora). This feature allows one to eliminate all but those variables which add significant information to the model. In other words, if a piece of data does not significantly increase our information base it is discarded from the predictive model. This allowed us to take 14 potential predictors and eliminate 10 of them as adding insignificant useful information to the model. Hence we are left with a model which contains only the four "most valuable variables" [13]. This advantage is not dif-

ferent from linear regression analysis. However, logistic analysis does have the advantage of more accurate handling of binary data [13,14]. Bayesian analyses have accurate handling of binary data; however, the capability of selecting the most significant variable is not available in Bayesian analyses. Therefore in such analyses one would not necessarily know which variables should be eliminated from the model.

Another disadvantage of most Bayesian analyses is the inclusion of redundant variables. In this example tonsillar swelling had a greater correlation with a positive culture than did fever history (Table 2). However, the inclusion of tonsillar swelling would have been redundant. If two variables are correlated very highly, then logistic analysis will include only one variable. The second variable would probably not add any significant information to the model. Most Bayesian analyses assume independence of variables; if this assumption were made, both variables would be included. This inclusion could lead to an overestimation of the predictive power of a model designed by Bayesian analysis (providing the independence assumption is used) [10].

This model helps us to stratify patients into differing groups by probability of disease. Knowing that a patient has a 56% chance of having Group A beta strep on culture may be very helpful in decision making. Likewise, patients with none of the four indicators present have only a 2.5% chance of a positive culture and this leads to specific implications for patient management. Tompkins has addressed the use of probability in managing sore throat patients [15]. The stratification produced by the model allows one to individualize therapy based upon the probability of disease.

Other models for improving predictions in adult sore throat patients have been proposed. Komoroff [1] outlined a complex decision table which included 12 management possibilities, 11 historical features, and 13 physical findings. Randolph, Redys, and Hibbard [5] suggested a numerical rating system which incorporated seven positive factors and six negative factors. These factors were assigned varying point values; the point values were then to be added to indicate that streptococcal disease was "unlikely, possible, or probable." Walsh, et al., [6] developed a discriminant score which had five findings, each of which had differing values; these scores were then added to yield a score which suggested the likelihood of a positive culture. These authors also proposed an algorithm with five branching points to determine high (28%), moderate (15%), or low (4%) risk of strep throat.

While these models may have good predictive power, they are unwieldy and difficult to remember. Our model has gained acceptance in discussions with house staff. It is easily remembered and provides simple guidelines for management of emergency room patients.

When the model for a positive resident's guess is examined in combination with the model of positive culture which included the guess as a variable, two observations are apparent. The physical examination is very

influential in residents' predictions, even (as with swollen tender posterior cervical nodes) when there is no evidence in the literature that the physical finding is correlated with the positive culture. History, however, is given much less consideration by residents in their guessing. Patient histories are valuable, and, at least in this clinical situation, there is documentation that symptoms such as fever history and lack of a cough are not given the same importance as abnormal physical findings.

It must be noted that the residents did a good job predicting a positive culture. Some experts would argue that a high sensitivity is more important in this clinical situation than a high specificity [15]. Assuming that to be true, improvement in residents' predictions could be made by considering the patient's history more strongly.

While one cannot always predict a positive culture for Group A beta streptococcus, the patients can be stratified into varying probability groups. This stratification does give the physician valuable information, as the management of a patient with a 50% probability of strep will be different from that of a patient with a 2.5% probability of strep infection.

These analyses have several general uses. Models of disease can be used to guide clinical management. Such models have previously been used widely. Models of physicians' predictions can help us elucidate part of the decision-making process. When physicians put too much or too little stress on particular variables, it is important to identify these varibles. These methods can be used to improve evaluation of physicians' decision making and to recommend improvements to the physicians. These applications add an educational function to the analysis of medical decision making.

Acknowledgments

We are indebted to Marsha George for assistance in the preparation of this manuscript, to the medical house staff of MCV for their help in collecting the clinical data, and to Dr. Hans Carter for statistical assistance.

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