

A scoring system for predicting group A streptococcal throat infection

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SUMMARY

Background. Sore throat is very common in general practice and is usually caused by viral infection. Nevertheless, up to 95% of patients may be treated with antibiotics. Previous diagnostic systems have not transferred well from one area to another because of an inability to allow for changing prevalence of streptococcus.

Aim. To measure the occurrence rates of symptoms and signs in sore throat patients with and without streptococcal infection, and to develop a Bayesian scoring system which is easily adapted for prevalence to predict if patients have bacterial infection.

Method. Occurrence rates of symptoms and signs were measured for 206 patients with sore throat symptoms over a 3-year period. Bayesian probability scores (B-scores) for each data item were calculated from the occurrence rates in the patients with positive throat cultures for group A streptococci and the rates in patients with negative throat cultures. The B-score values were then used to predict the probability of positive culture for each patient.

Results. The streptococcal throat B-score system predicted positive culture with a sensitivity of 71% and a specificity of 71%. In comparison, the unaided general practitioners predicted infection with a sensitivity of 61% and a specificity of 65%. If the B-score prediction had been used to decide on treatment, more patients with streptococci present on culture would have been treated with antibiotic (71% instead of 68%) and appreciably fewer patients with negative streptococcal cultures would have been treated (29% instead of 59%).

Conclusion. Use of the B-score system could result in significant savings in unnecessary antibiotic prescription, and unnecessary throat swab cultures, while achieving better levels of treatment.

Keywords: streptococcal infection; sore throat; diagnostic systems.

Introduction

SORE throat is the commonest respiratory symptom that patients come to see their general practitioner (GP) about, resulting in around 300 consultations per GP each year.¹ Most sore throats are caused by viral infections, with between 5 and 40% resulting from group A beta-haemolytic streptococci.^{2,3} In spite of the higher incidence of viral infections than streptococcal infections, up to 95% of patients with sore throat may be treated with an antibiotic by GPs.⁴

Why may this overtreatment with antibiotics occur? There are four main factors which have resulted in the drive to treat streptococcus: (1) prevention of rheumatic fever; (2) prevention of other complications of streptococcus infection (e.g. otitis media, sinusitis, cervical adenitis, and retropharyngeal or peritonsillar

abscesses); (3) achievement of an earlier cure; and (4) prevention of transmission to household and classroom contacts.⁵ These factors, coupled with the difficulty in distinguishing between viral and bacterial infections on clinical grounds,⁶ can result in a policy of treating most patients with sore throat 'to be sure'.

Several studies⁶⁻⁹ have found that doctors varied a lot in their ability to diagnose streptococcal infection accurately on clinical grounds (sensitivity 39-87%, specificity 52-86%). Some of this variability may be accounted for by the differing incidences of streptococcal infection (5-40% of sore throat patients), and of asymptomatic streptococcal carriage (2-36% of asymptomatic population) in different populations.

The classical approach to diagnosis of streptococcal throat infection was developed at a time when rheumatic fever was common, and consisted of taking a throat swab culture from all sore throat patients, starting penicillin treatment for the majority, and either stopping antibiotics or continuing for a full 10-day course when the result of the throat culture became available 48 hours later. Herz¹⁰ has shown that this approach may result in more frequent attendance for future sore throat episodes, thus leading to over-medicalization of a common non-serious complaint.

Since 1984, rapid antigen-detection tests have been available which produce results in about 10 minutes. Measured results from routine general practice have been variable with sensitivity of 55-82% and specificity of 63-98%.⁷ The cost of each test was £4 sterling in 1988,⁷ and this rules out routine use in countries such as Ireland, which spends less than 30% of the amount spent *per capita* in the USA on health care.

Method

The present study was carried out in a semi-rural general practice on the west coast of Ireland between November 1988 and July 1991. It was planned to collect a minimum of 60 patients in the streptococcal infection group in order to achieve an accuracy of measurement of occurrence rate of symptoms of $\pm 10\%$ for common symptoms (e.g. for a 20% occurrence rate). This figure was calculated using the Epi-Info computer program.¹¹ The occurrence rates would be sufficiently accurate to achieve correct integer Bayesian probability scores (B-scores).

Patients presenting with a main symptom of sore throat, aged 4 years or more, who had not taken antibiotic in the previous 2 weeks, were enrolled in the study. A questionnaire was filled in by the doctor, covering: the presenting symptoms (throat very sore, sore to swallow, bad smell from breath, rhinitis, sore ears, cough, abdominal pain, vomiting, diarrhoea, fever, myalgia and headache); the duration of illness; and signs observed (face flushed, nose moist, glands very enlarged or tender, exudate on tonsils, mouth red or ulcerated, presence of otitis media, and rhonchi or crepitations). These symptoms and signs were chosen from previous studies^{3,6-8,10} as being either associated with streptococcal or non-streptococcal throat infections.

The doctor also noted his or her opinion on whether streptococcal infection was present or not, and noted if penicillin V or another antibiotic was prescribed.

Two throat swabs were taken by rubbing vigorously against each tonsil as recommended by Brien and Bass.¹² The swabs (in Stewart's transport medium) were sent for culture to Sligo General Hospital Microbiology Laboratory at roughly 1300

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hours each weekday. Swabs taken after 1300 hours each day were stored at room temperature and went to the laboratory the next day. Anaerobic culture was performed on blood agar with a bacitracin disk, and colonies causing haemolysis and sensitive to bacitracin were subcultured for sensitivity testing and tested for Lancefield group using the Wellcome Streptex kit.

Cultures showing any number of group A β -haemolytic Streptococci were considered as indicating infection with streptococcus. Negative cultures and cultures positive for any other organisms (e.g. group C or group G Streptococci) were judged as not infected with group A β -haemolytic Streptococcus. Management was left up to the individual doctor, and culture results were inserted in the patients' notes and recorded on the questionnaire when they came from the laboratory (roughly 3 days later).

The first 50 patients enrolled were assessed as a pilot study to test the use of the questionnaire. No changes were required, so the group was included in the full study.

No questionnaires had to be excluded for data collection problems (e.g. absence of culture results and uncertainty with patient identification). A small number of questionnaires had minor omissions (e.g. duration of symptoms not recorded), so that the denominator for these items was slightly lower.

Occurrence rates for each data item in the group with infection and the group without infection were calculated, and differences between the two groups were tested for significance using the chi-squared test with Yates' correction for small numbers. Fisher's exact test was used if the expected value was less than 5 in any group.

Bayesian probability scores (B-scores) were then calculated using the method of Dobbs & Fleming¹³ for season (Autumn: October to December, inclusive), age less than 11 years, duration less than 3 days, and for all the symptoms and signs where the difference in occurrence rate between the two groups was statistically significant.

Results

Altogether, 206 patients were recruited with sore throat. Out of these subjects, 72 (35%) had group A β -haemolytic Streptococci growing from their throat swabs. Group C streptococci grew from six patients and group G streptococci from two patients, and these were included in the non-streptococcus infected group, to bring the non-streptococcus patient total to 134.

There were 24 patients enrolled after 1300 hours whose swabs were kept overnight at room temperature before transport to the laboratory. Out of these subjects, seven were culture-positive for streptococcus. This proportion (29%) was not significantly different from the overall culture-positive proportion (35%), so the storage procedure was considered as adequate and these cases amalgamated with the main data-set.

Differences between the streptococcus and non-streptococcus groups were tested for significance using the chi-squared test. B-scores were calculated for each of the symptoms and signs where there were significant differences between the two groups (see 'Appendix 1'). These results are shown in Table 1.

Multiple logistic regression with stepwise elimination of data items showed independent positive correlation of age less than 11 years ($P < 0.005$), myalgia ($P < 0.025$), and tender or very enlarged glands with streptococcal infection ($P < 0.05$), and negative correlation of cough ($P < 0.0001$) and ear pain ($P < 0.005$).

The scores for each data item calculated in Table 1 were then used to calculate a total score for each patient in the database (see 'Appendix 2'). A score of -2 was added to each total for the population prevalence.

Selection of a cut-off B-score level for prescribing antibiotic requires consideration of the clinical result of missing a case which would benefit from treatment or of treating a case unnecessarily. The numbers diagnosed as having streptococcal infection in each group for several B-score cut-off levels, and for the doctor's prescribing behaviour and opinion are shown in Table 2. It is likely that the scoring system slightly over-estimates the likelihood of infection, as some of the data items are partly correlated with each other.

A B-score cut-off level of more than -3 (i.e. a predicted probability of infection of 36% or more) picks up as many of the positive-culture cases (51) as the doctor's prescribing (49), but reduces the number of non-streptococcal cases treated from 55 (41%) to 39 (29%). Clearly, using this cut-off as a guide to cases requiring treatment will save expense and over-medicalization, and decrease the risk of penicillin reactions, without losing any clinical benefits.

The sensitivity and specificity of the B-score system is compared with the sensitivity and specificity of the doctor's opinion and prescribing behaviour, in Table 3.

Discussion

The most successful scoring system previously developed for prediction of group A β -haemolytic Streptococcus throat infection is that described by Breese.¹¹ This worked well in the researchers' own practice, but was unreliable in other areas.¹⁰ A major defect was the inability of the system to allow for differences in prevalence of Streptococcus infection between populations, which can result in serious errors.¹⁴ Each score would have to be changed when the system was used in a situation with different disease prevalence. The B-score system easily adjusts for changes in prevalence by changing the single score for population prevalence.

The B-score system was as sensitive as the doctor's prescribing action and more specific ($P < 0.05$, chi-squared test with Yates' correction). In fact, if the decision to prescribe antibiotics had been based on the B-score, the number of patients with non-streptococcal sore throats who received antibiotic would have been reduced by 29%. If throat cultures were only sent for patients who scored -2 or -1 (9% of all patients), 58% of these would be able to stop their antibiotic on receiving the negative culture report 48 hours later. Alternatively, a rapid strep test could be carried out in the surgery on the subset with scores of -2 or -1, thus sparing those with negative tests from the risk of penicillin allergy.

When a scoring system is developed in one practice, it is important that it should be tested in other practices and other geographical areas. A validation study is under way in County Sligo and will be reported on at a later date.

A scoring system such as this can be useful as an educational tool, both for the doctor and for the patient. The patient can be told the actual probability of their infection being sensitive to antibiotics, and may then be happy to avoid taking medication. The doctor can rapidly learn which symptoms and signs are best for confirming or ruling out a diagnosis of streptococcal infection. After a period of several months use, it would only be necessary to calculate the B-score in borderline cases or where a patient needed convincing.

Appendix 1. Calculation of B-score factors.

Bayes' Theorem can be expressed in logarithmic form as :

$$2 * \log_2 (\text{odds on diagnosis}) = 2 * \log_2 (I\%/N\%) + 2 * \log_2 (\text{prior odds})$$

Table 1. Occurrence of symptoms and signs, and the associated B-score factors for diagnosis of Group A streptococcal infection.^a

Data item	Streptococci grown (n = 72)	Streptococci not grown (n = 134)	B-score	
			Present	Absent
Autumn (October–December)	28 (39%)*	31 (23%)	1	-1
Age <11 years	41 (57%)**	45 (34%)	2	-1
Duration <3 days	56 (78%)**	72 (54%)	1	-2
Very sore throat	59 (82%)**	84 (63%)	1	-2
Sore to swallow	64 (89%)**	92 (69%)	1	-3
Bad smell	29 (40%)**	27 (20%)	2	-1
Rhinitis	13 (18%)	40 (30%)		
Ears sore	5 (7%)*	28 (21%)	-3	0
Cough	5 (7%)**	50 (37%)	-5	1
Wheeze	0 (0%)	5 (4%)		
Sputum	0 (0%)	5 (4%)		
Abdominal pain	10 (14%)	18 (13%)		
Vomiting	5 (7%)	6 (4%)		
Diarrhoea	0 (0%)	1 (1%)		
Fever	58 (81%)**	80 (60%)	1	-2
Muscle aches	38 (53%)*	51 (38%)	1	-1
Headache	23 (32%)	47 (35%)		
Flushed	36 (50%)**	44 (33%)	1	-1
Nose moist	14 (19%)	40 (30%)		
Glands	48 (67%)**	58 (43%)	1	-2
Exudate	32 (44%)*	39 (29%)	1	-1
Mouth red/ulcerated	34 (47%)*	47 (35%)	1	-1
Otitis media	0 (0%)	3 (2%)		
Rhonchi	0 (0%)	4 (3%)		
Creptitations	0 (0%)	0 (0%)		
Population prevalence	(35%)		-2	

* $P < 0.05$. ** $P < 0.01$. ^a n = Total number of patients in group (n varies slightly for some data items because of the incompleteness of the data).

Table 2. Number of patients diagnosed to have streptococcal infection by doctor's opinion, prescribing behaviour and several B-score cut-off levels, in groups with and without streptococcal growth from throat swabs.

	Streptococci grown (n = 72)	Streptococci not grown (n = 134)
Doctor's opinion	44	47
Penicillin V given	49	55
Other antibiotic	3	14
B-score:		
> -1	43	28
> -2	47	34
> -3	51	39
> -4	54	46

Table 3. The sensitivity and specificity of the B-score system, doctor's opinion and doctor's prescribing for prediction of streptococcal culture result.

	Sensitivity	Specificity
B-score > -3	71%	71%
Doctor's opinion	61%	65%
Penicillin prescription	68%	59%

where I% is the percentage occurrence rate of the symptom in the infected population and N% is the percentage occurrence rate of the symptom in the non-infected group; log₂ stands for 'logarithm to base 2'

Therefore, Bayesian probability-scores (B-scores) can be calculated for the presence or absence of each symptom or sign from the following formulae:

$$\text{B-score for presence} = 2 * \log_2 (I\%/N\%)$$

$$\text{B-score for absence} = 2 * \log_2 [(100-I\%)/(100-N\%)]$$

(Logarithms to the base 10 may be converted to logarithms to the base 2 by dividing by the logarithm of 2 to the base 10, i.e. 0.3010.)

For medical conditions, the majority of these scores will be single figures which can be easily added or subtracted. Rounding all scores to the nearest whole number also makes mental arithmetic easier. This results in a maximum error just less than 0.5 of a B-score unit, which is equivalent to an error of ± 0.2 to 1 in the ratio I%/N% (e.g. if the occurrence rate of the symptom in the infected group was 50% and the rate in the non-infected group was 25%, the error would be equivalent to an error in the occurrence rates of around ± 2 percentage points, which is considerably less than the error in estimation of the occurrence rates from medical data).

Logarithms to base 2 can be easily calculated from logarithms to base 10 using the formula:

$$\text{Log}_2 (x) = \log_{10} (x) / \log_{10} (2)$$

Therefore, the final formulae for calculating B-scores are as follows:

$$\text{B-score for presence} = 2 * \log_{10} (I\%/N\%) / \log_{10} (2)$$

$$\text{B-score for absence} = 2 * \log_{10} [(100-I\%)/(100-N\%)] / \log_{10} (2)$$

Appendix 2. Calculation of total B-score for each patient.

To calculate a total B-score for each patient, work down the list of scores, adding the B-score for presence or absence of each data item. The score for population prevalence is finally added. The total score can be converted to a percentage probability of infection using the formula:

$$\text{Odds for infection} = \text{antilog}_{10} \{ [B\text{-score} * \log_{10} (2)] / 2 \}$$

$$\text{Percentage probability of infection} = \text{odds} * 100 / (\text{odds} + 1)$$

A rule of thumb which gives the odds for infection is:

A total B-score of 2 corresponds to odds for infection of 2:1 in favour.

The odds double for every increase of 2 in the B-score, so a B-score of 4 corresponds to 4:1, a B-score of 6 corresponds to 8:1, and so on.

Negative B-scores correspond to similar odds against infection, i.e. -2 is equivalent to 2:1 against infection.

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