A Fuzzy Model to Predict Risk of Urinary Tract Infection

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Abstract. Urinary tract infections (UTIs) are among the most common bacterial infections and account for a significant part of the workload in clinical microbiology laboratories. Hence, urine is the specimen most frequently submitted for culture. Physicians distinguish UTIs from other diseases that have similar clinical presentations with use of a small number of tests to distinguish bacteriuria. The microbiological examination of urine consists of examining a methylene smear of the urine specimen, a screening test of significant bacteriuria and culture. In the smear one or more bacterial cells per oil- immersion field usually implies that there are 105 or more bacteria per milliliter in the specimen, the number of RBC and WBC is also a very important indicator. In literature, the normal ranges of these variables are differently defined. The analysis of this data could be very simplified using data management systems. Fuzzy logic, in a narrow sense, is a logical system, which is an extension of multivalued logic. The fuzzy logic works on a theory which relates to classes of objects with blurred boundaries in which membership is a matter of degree. This enables fuzzy systems applicable to broad range of parameters and expected output values in many aspects of science. The aim of this study was to create a fuzzy model, in the MATLAB environment, to aid physicians in interpreting the results of the microscopic urine analysis, considering the number of bacteria, RBC and WBC as well as turbidity of the sample.

Keywords: Fuzzy logic, MATLAB, UTI, Microscope Examination of Urine

1. Introduction

Urinary tract infections (UTIs) are among the most common bacterial infections and account for a significant part of the workload in clinical microbiology laboratories [1]. Escherichia coli is the leading causative agent in uncomplicated UTIs [2,3], whereas in complicated UTIs the bacterial spectrum is much broader, including Gram-negative and Gram-positive and often multiresistant microorganisms [4]. The diagnosis of UTIs and administration of antibiotic therapy is essential, since untreated UTIs may lead to severe pathophysiological complications.

The common tests used to distinguish bacterial infection from other disease with similar clinical manifestations include: physical examination of the specimen, microscopic examination of the urine sample, biochemical analysis and culture. The results of culture define the minimum number of bacteria per milliliter of urine that is associated with UTI.

General recommendations for reporting are (Fig.1):

1. 10^4 bacteria per milliliter: Probable absence of UTI [5]
2. 10^4-10^5 bacteria per milliliter: Patients with no symptoms probable absence of UTI, for patients with symptoms require another specimen [5]
3. 10^5-10^7 bacteria per milliliter: Urinary tract infection [5]

Culture is considered the gold standard in the microbiological analysis of urine specimen to detect urinary tract infection. However, considering the severe symptoms, some patients with urinary tract infections have waiting for the results of culture can be very inconvenient. The microscopic examination of urine specimen can be used as a screening test for the diagnosis of urinary tract infection. In microscopic examination, a drop of the urine specimen is examined under the microscope in search for bacteria, red blood cells (RBC) and white blood cells (WBC). In sterile specimen, this screening test can be used to exclude infection since none of the afore mentioned elements occur per oil-immersion field. However, in the case of infection, only well trained microbiologists can make sense of the number of occurring sporadic elements (bacteria, RBC, WBC) and correlate them to one of the three categories.

Per literature in the analyzed smear, one or more bacterial cells per oil-immersion field usually implies that there are

The original version of this chapter was revised: The spacing error in fifth author's name has been corrected.

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105 bacteria per milliliter or more in the specimen. The presence of one or more leukocytes per oil-immersion field is a further indicator of UTI. Non-infected urine samples will usually show few or no bacteria or leukocytes in the entire preparation [6]. Based on literature findings, as well as practical observations, one can conclude that there are many overlapping in the categorization of UTI based on the number of WBC, RBC and bacteria.
To model bacterial infections and make medical diagnosis and treatment suggestions for UTI, probabilistic networks and fuzzy logic based methodologies have been proposed by some researchers [7,8,9,10,11]

The input parameters regarding microscopic examination of urine could be very simplified using fuzzy logic tool in MATLAB [12].

Fuzzy logic, in a narrow sense, is a logical system, which is an extension of multivalued logic. The fuzzy logic works on a theory which relates to classes of objects with blurred boundaries in which membership is a matter of degree. Even in the narrower definition of fuzzy logic, it differs both in concept and substance from traditional multivalued logical systems. [13] This enables fuzzy systems applicable to broad range of parameters and expected output values in many aspects of science. Conclusions that are based on vague, imprecise, missing input information are simply provided by fuzzy logic [14,15]. There are various parameters that lead to urinary tract infections as previously stated in the introduction part. With the application of fuzzy logic, missing parameters and the output variable affected from such missing parameters are estimated within the fuzzy logic. Considering these facts was our main aim to create a fuzzy model using MATLAB to predict UTI based on the number of relevant elements found in the microscopic examination of urine specimen (bacteria, RBC, WBC) and one physical characteristic of the sample(turbidity).

2. Methods

A total of 100 bacterial isolates obtained from urine specimen from patients were collected from Institute for Biomedical Diagnostics and Research NALAZ in the period of July 2015 to December 2015. The criteria for inclusion into the study was that only one of three successive urine samples from the same patient was taken into consideration. Upon admission to the laboratory, urine samples were analyzed as follows: physical examination of the samples (turbidity), microscopic screening and culture observation. The microscopic examination of the urine specimen was carried out by placing a drop of well-mixed, uncentrifuged urine on a sterile glass slide. The drop was dried without spreading, heat-fixed, stained per the gram staining procedure and examined under an oil-immersion lens for the presence or absence of bacteria, WBC count and RBC count. Per literature findings and the experience of microbiologists, we categorized UTIs based on the number of WBC, RBC and bacteria, as well as turbidity (Table 1).

2.1 Fuzzification and Membership Functions

The function of the fuzzification stage is to convert the measured quantities from the process into fuzzy sets to be used by the inference stage. In simpler words, fuzzification is the process of changing a real scalar value into a fuzzy parameter. This is achieved with the different types of fuzzifiers (membership functions). To make fuzzification, the linguistic expressions shown in Table 1 are used. The proposed fuzzy logic factors consists of 4 input variables and one output variable for this model

Since different data can be found in literature in regards to the normal range of CFU, RBCs, WBCs and turbidity of urine, we decided to take the estimation of all the literature data through consulting with two microbiology specialists from two different hospitals in Mostar.

The entry that represents the CFU is composed of three fuzzy intervals and membership functions defining the few, moderate and many. The second entry, that represents the RBC, is composed of two fuzzy intervals and membership functions defining the normal and elevated number of RBC. The entry that represents the WBCs is composed of three fuzzy intervals and membership functions defining the normal, elevated and high number of WBCs. The last input entry is turbidity which is composed out of three intervals and membership functions defining: clear, cloudy and turbid.

As output variable, we defined five variables representing the expected risk rate of UTI. We represent each membership function defining the five rates "very low risk", corresponding to a value between 0 and 2„ low risk “, corresponding to a value between 1 and 3, „medium risk “corresponding to a value between 2 and 4, „high risk “corresponding to a value between 3 and 5, „very high risk “corresponding to a value between 4 and 6.