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A multiple logistic model for prediction of urinary tract infections in an urban community: A public health perspective

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ABSTRACT

Purpose: Urinary tract infection (UTI) is one of the most common infectious diseases globally. A lot of clinical research has been done on UTI patients, but a questionnaire-based study on UTI is scarce.
Materials and Methods: A cross-sectional study was conducted on outpatients with a high suspicion of uncomplicated UTI in Hayes Memorial Mission Hospital at Prayagraj (Eastern part of Northern India) to find out the frequency of symptoms and predisposing factors and their relationship towards the prediction of UTI.
Results: Logistic regression analysis showed a significant association between UTI and some of the variables. Also, the factors responsible for the occurrence of UTI are "gender", "how many times you urinate from morning till night", "a sudden desire to urinate, which is difficult to hold", "weakness of urinary stream", "splitting or spraying of the urinary stream" and "fever". A statistical model (multiple logistic model) has been also established for the prediction of UTIs with an accuracy of 82.2%. It is also observed that the prevalence rate (odds ratio) of UTI in females is 2.38 times that of males.
Conclusion: The study created a screening questionnaire for patients suspected of having UTI. A multiple logistic model has been established for the prediction of UTI which can be instrumental for clinicians from a public health perspective in the management of Urinary Tract Infections in this era of escalating AMR.

1. Introduction

Urinary tract infection (UTI) is one of the most common infectious diseases seen in ambulatory patients, with a 50-60% prevalence rate in adult females.[1] It imposes a significant socioeconomic burden, leading to an increase in hospital visits, absenteeism, and a lower quality of life. Antibiotic resistance among uropathogens, particularly those causing community-acquired UTIs, has recently emerged as one of the most challenging public health concerns and significant attributes influencing UTI care and management.[2] Community-acquired UTI is the second most encountered microbial infection in the community setting.[3] Urinalysis and urine culture with antibiotic susceptibility are used to diagnose UTIs; however, in smaller cities where there is no suitable facility for sample

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analysis, patients must rely entirely on their clinician's discretion. UTIs can be asymptomatic, acute, chronic, complicated, or uncomplicated, with clinical symptoms varying depending on the region of the urinary tract affected, the causative microorganisms, the severity of the disease, and the patient's ability to develop an immune response.[4] UTI symptoms include fever, burning sensation while urinating, lower abdominal pain, vaginal discomfort, genital, and supra-pubic pain.[4] These symptoms vary depending on the person's age and the region of the infected urinary tract.[5] Sex, age, ethnicity, circumcision,[6,7] HIV,[8–10] diabetes, urinary catheterization, genitourinary tract anomalies,[11,12] sexual intercourse, pregnancy[13] and hospitalization status[14] are all factors that contribute to recurrent UTIs.[15] Men have a lifetime risk of only 13%; however, women have a 60% probability of having UTI.[16] Various parameters such as the type of UTI (complicated or uncomplicated), gender, age, and previous history of antibiotic medication of each UTI patient should be examined and considered to establish accurate global data on susceptibility.[17]

The increased accessibility of technological devices and user-friendly statistical software appears to have increased the usage of multivariable regression models in clinical research.[18] Binary outcomes are common in biomedical research, and multivariable logistic regression is the most utilised regression model among the various binary link functions.[19] A self-created questionnaire for the diagnosis of one of the most prevalent diseases, UTI, requires standardisation where validation is necessary to determine its accuracy with the help of microbiological culture. The study is quantitative in nature and focuses on the presence of UTI symptoms from the start. Its target population is a general population with basic traits who, when diagnosed with UTI, seek further speciality care if necessary. The objective of this study was to investigate the sensitivity and specificity of a newly designed questionnaire based on signs and symptoms through a personal interview. With this goal in mind, we address the following questions:

1. Elucidate the frequency of symptoms and varied predisposing factors leading to UTI in the general population and work out their co-relationship.
2. Establish statistical significance (association/co-relation) between UTI and all its independent variables (Symptoms/predisposing factors) for the better screening of UTI patients in the OPD.
3. To fit a suitable statistical model (multiple logistics) for the prediction of UTI.

2. Materials and Methods

2.1. Study area and population

This study was conducted in the Prayagraj district. Geographically, the data was gathered from the OPDs section of Hayes Memorial Mission hospital, located in the southern part of Prayagraj city. The study size was calculated using a Kish Leslie formula based on a prevalence of 22.8%, with the addition of design effect (1.5 times) and non-response rate (5%). A total of 427 samples were collected, with 333 of them proving to be UTI-positive based on clinical evidence generated by treating physicians using a questionnaire and then microbiologically verified.

2.2. Exclusion criteria

Patients under the age of five, those who were terminally ill, those with polymicrobial infections, those who had received antibiotics in the previous weeks, and any female on her menstrual cycle were all excluded from participating in the study.

2.3. Study design

In a year-long cross-sectional survey, outpatients with a high suspicion of uncomplicated UTI were recruited based on a questionnaire. A simple random sampling technique was applied to recruit patients from each outpatient's department. The samples of all patients who completed the questionnaire and were strongly suspected of having a UTI were microbiologically confirmed. The investigation was conducted in three stages. A well-designed data collection questionnaire[20] was created during the first stage to record all essential patient information. Patients under the age of 12 and those beyond the age of 5 were represented by their parents. All case information was documented during the second stage, including the patient's demographics, clinical and medication history, signs and symptoms, and urine culture investigation details. A questionnaire comprising open-ended questions such as age and closed-ended questions with nominal categorical values such as gender were implored. Medical professionals from primary and specialty care, general practitioners, emergency medicine, and microbiologists validated the entire questionnaire. The clinicians collected all the data mentioned in the questionnaire, and oral and written consent was taken from the participant. The study was reviewed and the experimental protocols were approved by an Institutional ethical committee for human research (AUR/REG/2709). All procedures performed in this study involving human participants were in accordance with 1964 Helsinki declaration and its later amendments or comparable standards. All the data were analyzed statistically in stage three.

Using a standard questionnaire both in English and Hindi, patients were asked about socio-demographic data such as age, marital status for females, past history of infection, age-related complications, structural and functional abnormality, symptoms such as frequency of micturition during day and night, frequency of

straining, urgency, leakage and hesitancy, incomplete emptying of the bladder, burning micturition, fever and all this information was kept confidential during the research. Each patient suspected of uncomplicated UTI who completed the questionnaire was microbiologically examined for confirmation. As a result, it is a symptom-based observational study relying on clinician discretion.

2.4. Statistical analysis

The data were also analyzed via a logistic regression model (Backward conditional). A p-value of < 0.25 by likelihood ratio (LR) was considered statistically significant at 95% confidence interval (CI) for univariable analysis and was put up for multivariable analysis ($p \leq 0.05$) with an unadjusted odds ratio (OR) were performed. SPSS software version 23 performed all statistical tests. Variables put up for regression analysis are described in Table 1.

3. Results

3.1. Descriptive statistics

The subjects in this study ranged from 6 to 94 years old. The prevalence rate of UTI positivity was high (77.9%) with 60.7% women, and 39.3% men in our study, as rigorous screening took place at the initial stage with the help of clinicians using a questionnaire. There were 239 females and 188 males among the 427 individuals. Patients aged 17 to 50 were the most vulnerable to UTI, followed by 50 to 80 years, 5 to 17 years, and more than 80 years.

3.2. Univariable and multivariable analysis

During univariable analysis, ten independent variables were statistically significant. The analysis revealed that "gender" play a significant role as females have 2.38 times odds of UTI as compared to males; "how many times you urinate from morning till night" frequency of 8-14 from morning to night has 2.62 times odds of UTI and frequency of more than 15 from morning to night has 0.06 times odds of UTI as compared to less than 7 frequency of urination from morning to night; "fever" has 1.74 times odds of UTI as compared to not having it; "a sudden desire to urinate which is difficult to hold"- rarely has 1.38 times odds of UTI and having it often has 3.29 times odds of UTI as compared to not having it; "urinary leakage because you cannot hold sudden desire to urinate"- rarely has 1.65 times odds of UTI and having it often has 1.83 times odds of UTI as compared to not having it; "a desire to urinate when you have small amount of urine in bladder"- rarely has 1.80 times odds of UTI and having it often has 2.06 times odds of UTI as compared to not having it; "weakness of urinary stream"- rarely has 1.28 times odds of UTI and having it often has 6.25 times odds of UTI as compared to not having it; "splitting or spraying of urinary stream"- rarely has 2.03 times odds of UTI and having it often has 2.61 times odds of UTI as compared to not having it; "feeling of incomplete emptying of bladder"- rarely has 1.00 times odds of UTI and having it often has 1.69 times odds of UTI as compared to not having it; "pain in bladder or Lower abdomen"- rarely has 0.76 times odds of UTI and having it often has 1.36 times odds of UTI as compared to not having it. The predictor variables (predisposing factors and symptoms) for UTI deemed statistically significant with a $p < 0.25$ in logistic regression univariable analysis are listed in Table 2. However, "age", "hypertension", "diabetes", "obstruction due to urethral stricture", "calculus", "neurogenic bladder", "genital prolapse", "vesicourethral reflux", "catheterization/surgery", "marital status", "pregnancy", "scrotal pain", "prostatic hypertrophy", "how many times you urinate from night till morning", "urinary leakage when you cough, sneeze or strain", "urinary leakage while you do not notice", "delay in starting of urinary stream", "leakage of urine after you finish urinating", "pain in urethra" and "burning micturition" variables were found to have no significant association with UTI.

Ten independent variables that showed statistical significance during logistic regression univariable analysis were further put up for multivariable analysis. The independent variables that showed significance statistically ($p \leq 0.05$) were "gender", "how many times you urinate from morning till night", "a sudden desire to urinate which is difficult to hold", "weakness of urinary stream", "splitting or spraying of urinary stream" and "fever" as shown in Table 3. The independent variables removed were "urinary leakage because you cannot hold sudden desire to urinate", "feeling of incomplete emptying of bladder", "a desire to urinate when you have small amount of urine in the bladder" and "pain in bladder or lower abdomen". Also, there was no multicollinearity found among those mentioned above statistically significant independent variables.

3.3. Model fit assessment

According to the Hosmer-Lemeshow test ($c2(8) = 2.156$; $p=0.976$), the gap between observed and expected counts for the UTI is smaller (Table 4), and 82.2% of subjects were correctly classified (Table 5), implying that it is good model to fit the data. Also, the area under ROC (receiver operating characteristic) curve is 0.789 (95% CI: 0.74, 0.84) (Table 6), which is an acceptable fit; hence it is a good model to fit the data (Figure 1).

The test result variable(s): Predicted probability has at least one tie between the positive actual state group and the negative actual state group where statistics may be biased; a- Under the nonparametric assumptions; b- Null hypothesis: true area = 0.5.

Table 1: List of dependent and independent variables

Dependent Variable (Yes/No)	Independent variable	
	Health conditions/ Predisposing factors that may make the person more vulnerable to UTI (Yes/No)	**Symptoms that may or may not occur during UTI (No/ Rarely/Often)**
Urinary Tract infection	Gender	How many times you urinate from morning till night
	Age	How many times you urinate from night till morning
	Hypertension	A sudden desire to urinate which is difficult to hold
	Diabetes	Urinary leakage because you cannot hold sudden desire to urinate
	Obstruction due to urethral stricture	Urinary leakage when you cough, sneeze or strain
	Calculus	Urinary leakage while you do not notice
	Neurogenic bladder	A desire to urinate when you have small amount of urine in bladder
	Genitals prolapse	Weakness of urinary stream
	Vesicourethral reflux	Splitting or spraying of urinary stream
	Catheterization/surgery	Delay in starting of urinary stream
	Marital status	Feeling of incomplete emptying of bladder
	Pregnancy	Leakage of urine after you finish urinating
	Scrotal pain	Pain in bladder or Lower abdomen
	Prostatic hypertrophy	Pain in urethra
		Fever (Yes/No)
		Burning Micturition (Yes/No)

Table 2: Univariable analysis between independent variables (predisposing factors and symptoms) and dependent variable (UTI)

Variables	Categories	Unadjusted OR	95% CI		p-value (Wald test)	p-value (LR test)
			Lower	Upper		
Gender	Male	0				
	Female	2.38	1.49	3.80	0.000	0.000
How many times you urinate from morning till night	<7	0				
	8-14	2.62	1.50	4.58	0.001	
	>15	0.06	0.02	0.18	0.000	0.000
A sudden desire to urinate which is difficult to hold	No	0				
	Rarely	1.38	0.71	2.69	0.346	
	Often	3.29	1.62	6.68	0.001	0.001
Urinary leakage because you cannot hold sudden desire to urinate	No	0				
	Rarely	1.65	0.77	3.52	0.199	
	Often	1.83	0.86	3.88	0.118	0.139
A desire to urinate when you have small amount of urine in bladder	No	0				
	Rarely	1.80	0.86	3.75	0.116	
	Often	2.06	1.14	3.69	0.016	0.023
Weakness of urinary stream	No	0				
	Rarely	1.28	0.59	2.55	0.603	0.005
	Often	6.25	1.48	26.43	0.013	
Splitting or spraying of urinary stream	No	0				
	Rarely	2.03	0.77	5.36	0.153	0.126
	Often	2.61	0.59	11.53	0.205	
Feeling of incomplete emptying of bladder	No	0				
	Rarely	1.00	0.50	2.01	0.992	0.142
	Often	1.69	0.98	2.94	0.061	
Pain in bladder or Lower abdomen	No	0				
	Rarely	0.76	0.41	1.43	0.394	0.235
	Often	1.36	0.80	2.31	0.252	
Fever	No	0				
	Yes	1.74	0.85	3.55	0.131	0.113

CI = Confidence interval; p = probability; $p < 0.25$ value is statistically significant under logistic regression univariable analysis

Table 3: Multivariable analysis between independent variables (predisposing factors and symptoms) and dependent variable (UTI)

Variables	Categories	Unadjusted OR	95% CI		p-value (LR test)
			Lower	Upper	
Gender	Male	0	1.576	4.683	0.000
	Female	2.716			
How many times you urinate from morning till night	<7	0			
	8-14	2.487	1.363	4.537	
	>15	0.036	0.010	0.129	0.000
A sudden desire to urinate which is difficult to hold	No	0			
	Rarely	0.945	0.418	2.136	
	Often	3.574	1.528	8.360	0.004
Weakness of urinary stream	No	0			
	Rarely	0.922	0.379	2.238	
	Often	5.695	1.175	27.600	0.029
Splitting or spraying of urinary stream	No	0			
	Rarely	4.530	1.247	16.449	
	Often	1.194	0.161	8.858	0.034
Fever	No	0			
	Yes	3.370	1.408	8.067	0.003

CI = Confidence interval; p = probability; $p \leq 0.05$ value is statistically significant under logistic regression multivariable analysis

Table 4: Contingency for hosmer-lemeshow test

S.No.	UTI = No		UTI = Yes		Total
	Observed	Expected	Observed	Expected	
1	22	22.000	4	4.000	26
2	21	22.063	29	27.937	50
3	10	9.949	24	24.051	34
4	14	14.404	45	44.596	59
5	10	8.364	31	32.636	41
6	7	6.864	48	48.136	55
7	3	4.266	40	38.734	43
8	5	3.490	40	41.510	45
9	2	2.098	48	47.902	50
10	0	.503	24	23.497	24

Table 5: Classification table of the preliminary final model

Observed count		Predicted UTI		Percentage Correct
		No	Yes	
UTI	No	21	73	22.3
	Yes	3	330	99.1
Overall percentage				82.2

The cut value is 0.500; the percentage correctly classified should be > 70% for a good model fit

Table 6: Area under the curve (AUC)

Area	Standard Error [a]	Asymptomatic significance [b]	Asymptomatic 95% CI	
			Lower	Upper
0.789	0.026	0.000	0.737	0.840

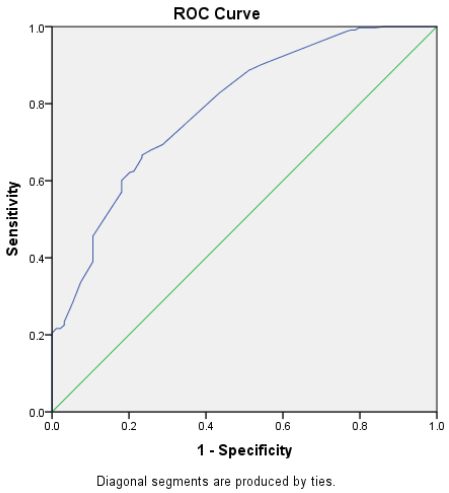

Figure 1: The ROC curve is the true positive rate (Sensitivity) is plotted in function of the false positive rate (100-Specificity) for different cut-off points

4. Discussion and Conclusion

The discovery of UTI-related parameters and their relationship to positive microbiological growth revealed a correlation between the onset of infection and microbiological culture reports. Our analysis demonstrated that the prevalence of UTI was 333/427 (77.9%). Our prevalence rate is higher than that of other researchers, which varies from 45.69%[21] to 37.30%[22] to 53.82%.[17] The fundamental selection for this study is the presence of UTI symptoms in primary care; nevertheless, even though the data was limited and focused to the group with acute urinary symptoms, it can be used to build a UTI screening in the broader population. The high prevalence of UTIs in our study could be attributed to the rigorous initial screening as well as the inclusion of a range of risk categories such as diabetes, pregnancy, benign hypertrophy of the prostate, and others who are susceptible to UTIs. Even though diabetes, calculus, prostate enlargement, pregnancy, and other variables are known to predispose individuals to UTI, we found no evidence of this in our study since the number of patients with these predispositions and UTI was low. Our study correlates to a study conducted in Mexico 97.3%[23] and Ethiopia 90.1%.[24] A multinomial logistic regression[25] analysis on UTI-related parameters was performed, with a 95% CI. During univariable analysis, ten independent variables were statistically significant, which were further put up for multivariable logistic regression analysis. During multivariable analysis, four independent variables ("urinary leakage because you cannot hold sudden desire to urinate", "feeling of incomplete emptying of bladder", "a desire to urinate when you have small amount of urine in bladder" and "pain in bladder or Lower abdomen") were removed. We can conclude that six independent variables ("gender", "how many times you urinate from morning till night", "a sudden desire to urinate which is difficult to hold", "weakness of urinary stream", "splitting or spraying of urinary stream" and "fever") were the final model. Gender has clinical implications for UTI since females are more susceptible to UTI than males, as demonstrated in this model. The proximity of the anus to the vagina and the shorter urethra may explain the greater prevalence of UTI in females.[4,26,27] The model has statistically demonstrated that the frequency of urination during the day increases from normal and that there is an urgent need to urinate, which becomes difficult to hold during UTI due to inflammation and irritation induced by bacteria in the bladder. However, depending on personal traits, bladder volume, and drinking habits, the frequency of regular urination might vary greatly from person to person. The frequency of micturition is commonly accompanied with dysuria due to UTI, but this was not the case in our study, thus we asked several other symptom-based questions about periodicity and others. A burning sensation or inflammation in the urethra may produce "weakness of the urinary stream" and "splitting or spraying of the urinary stream" during UTI; hence, to avoid pain, the external urethral sphincter voluntarily regulates urine flow from the bladder. In terms of model fit evaluation, the Hosmer-Lemeshow test, classification table, and area under the ROC curve show that our preliminary model has a good model fit. Each point on the ROC curve represents a sensitivity/specificity pair corresponding to a particular decision threshold. A test with perfect discrimination (no overlap in the two distributions) has a ROC curve that passes through the upper left corner (100% sensitivity and specificity). Therefore, the closer the ROC curve is to the upper left corner, the higher the test's overall accuracy[28]. Therefore, to increase the rate of true positivity, one needs to have an even bigger sample size.

Urinary tract infections are a common infectious disease irrespective of gender and are becoming a major public health concern. A self-generated questionnaire for the diagnosis of UTI ensures standardization where specific pattern guideline is created that can be used as a marker and can be retested on a bigger population. The study focused on the urinary system as a whole and found that the recurrence of UTI is not always proportional to the severity of UTI due to a variety of factors such as immunity, individual experience and sensation, related symptoms, and so on. The logistic regression analysis showed a significant association between UTI and some of the variables. A statistical model (multiple logistic model) has also been established for the prediction of UTI and obtained its accuracy of prediction as 82.2% which can be instrumental for further treatment and prevention of UTI in this era of escalating Antimicrobial resistance (AMR).

5. Author Contribution Statement

Neelam Jain, Jagdish Prasad, Gopal Nath, Amit Bhargava and Kanika Bhargava hypothesised and designed the research plan. Amit Bhargav and Kanika Bhargava performed data acquisition. Jagdish Prasad, Alexandru-Atila Morlocan, Palak Khinvasara and Kanika Bhargava performed and analysed SPSS outcomes. Statistical analysis and preparation of the initial draft of the manuscript were done by Kanika Bhargava and Jagdish Prasad. Final editing and reviewing were done by Jagdish Prasad, Neelam Jain, Kanika Bhargava, Alexandru-Atila Morlocan, Gopal Nath, Amit Bhargava, Palak Khinvasara, Ragini Yadav and G. K. Aseri. All the authors have reviewed the manuscript.

6. Data Availability Statement

All data generated or analysed during the study are included in this manuscript.

7. Source of Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

8. Conflict of Interest

The author(s) declare no competing interests

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