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Parameter Evaluation of the Differential Diagnosis of Female Urinary Incontinence for the Construction of an Expert System

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Abstract. Female urinary incontinence is a difficult problem for a patient but also for a physician. In the differential diagnosis of female urinary incontinence the physician has to determine a diagnostic class for the patient. This task is complex because of the unreliable patient history and the overlapping class boundaries. In order to develop an expert system to help the physician, a retrospective investigation on the incontinent women was performed to detect the potential expert system parameters. Also a diagnosis table was constructed from the expected values of parameters and the diagnostic classes. The results from K-means cluster analysis indicate that it is possible to develop the expert system on basis of the defined parameters and classes.

1. Introduction

Urinary incontinence is a slightly known major health problem. Thomas et al. [1] found that among the population between 15 and 64 years of age, the prevalence of urinary incontinence in women ranges from 10% to 25%. For noninstitutionalized persons older than 60, the prevalence of this symptom ranges from 15% to 30% [2]. Seeking help can be difficult for an incontinent person because of embarrassing nature of the problem. However, when incontinence is correctly diagnosed and treated a considerable number of the patients are cured. For example, the outcome of different surgical stress incontinence treatments is that from 78% to 84% of patients are entirely cured and the state of patients from 4% to 5% are partly improved [3].

The differential diagnosis of female urinary incontinence is a difficult task, since the diagnosis made on the basis of patient history alone can be unreliable [4]. Also the incontinence classes are to some degree overlapping. Usually only the results of urodynamic testing provide the basis for accurate enough diagnosis. The reliability of final diagnosis is especially important when surgery is considered.

Our aim is to ease this problem by developing an expert system to help the physicians in the differential diagnosis of female urinary incontinence. Expert systems have previously been implemented in medicine for various areas, but little work [5,6] has been done at the problem of female urinary incontinence. The purpose of this study was to discover and evaluate the parameters, i.e., symptoms, tests and measurements, which are needed to develop the expert system. For this reason, we defined the potential parameters and the diagnostic classification and performed a retrospective investigation on the women who were treated because of urinary incontinence.

2. Materials and methods

The retrospective investigation was performed in the year 1996 at the clinic of the Department of Obstetrics and Gynaecology of Kuopio University Hospital, Finland. The patients with the diagnosis of urinary incontinence from the year 1989 to the year 1996 were included in the investigation. Cases older than those were excluded from the study because of the lack of parameters. All included patients who were diagnosed as mixed or urge incontinent had underwent urodynamical testing. The total number of patients included in the study was 477. The ages of the women ranged from 14 to 90 years, with a mean age of 52.0 years and a standard deviation of ±11.1 years.

The data was collected with an inquiry sheet containing the parameters. In addition to the parameters, also the age and the diagnosis of patients were recorded. Sometimes the patient may have a set of different diagnoses. For example, after treating the stress component of mixed incontinence with surgery it may be possible that the urge component has be cured with medication. For this reason, if there were many diagnoses, then the diagnosis which was clearly accurate and contained most of the parameter data was selected. In this study methods, definitions and units conform to the standards recommended by the International Continence Society [7].

Fifteen potential binary valued parameters were defined for the differential diagnosis of female urinary incontinence. The parameter values were selected to be binary because some of them are binary by nature and some, such as urgency score and post voiding residual, are traditionally converted into binary values. Also the development of the expert system will be easier when the parameters have a small set of values. The parameters and their possible values are shown in Table 1.

Table 1: The parameters for the differential diagnosis of female urinary incontinence.

Parameter	Explanation	Values
Findings		
P_1	Urine in vagina	**Yes**, **No**
P_2	Urgency score (US)	**Low** (0-6), **High** (7-20)
P_3	Post voiding residual (PVR)	**Nor**mal (0-100 ml), **High** (>100 ml)
P_4	Probability of motor urge incontinence	**High** (0.6-1), **Low** (0-0.5)
P_5	Cystometry	**Nor**mal, **Abn**ormal
	Profilometry	
P_6	- Pressure transmission ratio (PTR)	**Nor**mal (≥90%), **Abn**ormal (0-90%)
P_7	- Minimal urethral closure pressure	**Neg**ative (<0 mlH_2O),**Pos**itive≥0 mlH_2O)
P_8	- Stress sign	**Yes**, **No**
P_9	Mobility of urethrovesical (UV) junction	**Nor**mal, **Abn**ormal
P_{10}	Uroflowmetry	**Nor**mal (≥15 ml/s),**Abn**ormal (<15 ml/s)
P_{11}	Cystoscopy	**Nor**mal, **Abn**ormal
Symptoms		
P_{12}	Involuntary loss of urine during increased abdominal pressure	**Yes**, **No**
P_{13}	Continuous loss of urine	**Yes**, **No**
P_{14}	Difficulties with voiding	**Yes**, **No**
P_{15}	Urgency	**Yes**, **No**

The urgency score is calculated from a standard questionnaire [8,9] designed to separate stress incontinence from urge incontinence. The questionnaire contains 10 questions, such as 'Do you lose urine while coughing, sneezing or laughing ?' or 'Do you feel urgency before leaking ?'.

The urgency score equal or lower than score of 7 out of total score of 20 indicate stress incontinence with the probability of 0.62 [8]. Post voiding residual was measured before urodynamic testing with a catheter.

The probability of motor urge incontinence was calculated from the frequency and the range (maximum volume - minimum volume) of the 24 hour voiding frequency/volume chart [10]. Motor urge incontinence was defined probable when the value of this parameter is greater than 0.5, i.e., the middle value of probability range from 0 to 1.

The result of cystometry measurement with a microtip pressure transducer [11] is normal if there were no involuntary detrusor contractions during the measurement. Pressure transmission ratio and urethral closure pressure were measured with a microtip catheter [12]. Stress sign is positive when the leakage is observed clinically.

The last four parameters are symptoms associated frequently with different types of incontinence. Involuntary loss of urine during coughing, sneezing or laughing is a typical symptom of stress incontinence. Continuous loss of urine is observed if the patient suffers from a fistula, from overflow incontinence or from the difficult stress incontinence. Difficulties with voiding are related with overflow incontinence and urgency with urge and mixed incontinence.

After selecting the parameters, we determined which value each parameter should have with different types of female urinary incontinence. Also six diagnostic classes based on the diagnostic guidelines given by the International Continence Society [7] were defined. In addition to these classes also 'normal', i.e., continent was defined. The crosstabulation of classes and parameters is shown in Table 2. In sensory urge incontinence no detrusor contractions occur when cystometry is performed, while in motor urge incontinence involuntary contractions can be detected.

Table 2: The expected parameter values for the incontinence classes. Value abbreviations are from Table 1. *Parameter has 'Yes' value with the difficult stress incontinence and with the difficult mixed incontinence. **Cystometry has 'Normal' or 'Abnormal' value with mixed incontinence. X=Parameter is useless with this class.

Incontinence class	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
Stress	No	Lo	Nor	Lo	Nor	Abn	Neg	Yes	Abn	Nor	Nor	Yes	No*	No	No
Mixed	No	Hi	Nor	Hi	**	Abn	Neg	Yes	Abn	Nor	Nor	Yes	No*	No	Yes
Sensory urge	No	Hi	Nor	Hi	Nor	Nor	Pos	No	Nor	Nor	X	No	No	No	Yes
Motor urge	No	Hi	Nor	Hi	Abn	Nor	Pos	No	Nor	Nor	X	No	No	No	Yes
Overflow	No	X	Hi	X	Nor	Nor	Pos	Yes	Nor	Abn	X	Yes	Yes	Yes	No
Fistula	Yes	X	Nor	X	Nor	Nor	Pos	Yes	Nor	Nor	Abn	Yes	Yes	No	No
Normal	No	Lo	Nor	Lo	Nor	Nor	Pos	No	Nor	Nor	Nor	No	No	No	No

The data were analysed by using the K-means cluster analysis [13] which detects relatively homogenous groups of cases based on selected characteristics. In the K-means algorithm each case in turn is assigned to the nearest cluster centre and after all cases are added the location of cluster centre is updated. Algorithm iterates until the solution converges.

We analysed the parameter values to determine whether it is possible to detect case clusters corresponding to diagnostic classes. The other aim of the analysis was to discover the differences between the initial and the final cluster centres. The analysis was performed with the statistical software package SPSS for Windows 6.1.3.

3. Results

The cluster analysis was performed for the dataset containing all included cases. Fistula and overflow classes were small and therefore they were excluded from the analysis. Also two parameters, uroflowmetry and cystoscopy, were excluded from the analysis because of the lack of parameter values. The initial cluster centres shown in Table 3 were obtained by converting the values from Table 2 into the real numbers. The first parameter value is 1.00, the second parameter is 2.00 and parameter that can have both values in a particular class is 1.50. The final centres are presented in Table 4. The greatest changes can be noticed in the final centres of probability of motor urge incontinence (P_4), cystometry (P_5), pressure transmission ratio (P_6), closure pressure (P_7), mobility of urethrovesical junction (P_9) and involuntary loss of urine during increased abdominal pressure (P_{12}).

Table 3: The initial cluster centres.

Cluster	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{12}	P_{13}	P_{14}	P_{15}
1	2.00	1.00	1.00	2.00	1.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00	2.00
2	2.00	2.00	1.00	1.00	1.50	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00
3	2.00	2.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	1.00
4	2.00	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	1.00
5	2.00	1.00	1.00	2.00	1.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00

Table 4: The final cluster centres.

Cluster	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{12}	P_{13}	P_{14}	P_{15}
1	2.00	1.25	1.03	1.66	1.01	1.91	1.08	1.05	1.95	1.01	1.97	2.00	2.00
2	2.00	1.93	1.04	1.13	1.06	1.87	1.15	1.00	1.93	1.04	1.99	1.99	1.01
3	2.00	1.82	1.04	1.39	1.00	1.98	1.30	2.00	1.87	1.17	1.98	2.00	1.04
4	2.00	2.00	1.00	1.00	2.00	1.86	1.67	1.70	1.60	1.38	1.92	2.00	1.00
5	2.00	1.06	1.05	1.29	1.00	1.36	1.72	1.85	2.00	1.39	2.00	2.00	1.94

The frequencies of the resulting clusters with crosstabulation of the physician made diagnoses are shown in Table 5. As expected, stress urinary incontinence was the most common type of incontinence. The percentages of mixed incontinence, urge incontinence and normal were considerably smaller.

The statistically significant ($p \leq 0.01$ based on Fisher's test) findings and symptoms were urgency score (P_2), probability of motor urge incontinence (P_4), cystometry (P_5), pressure transmission ratio (P_6), closure pressure (P_7), stress sign (P_8), involuntary loss of urine during increased abdominal pressure (P_{12}) and urgency (P_{15}).

Table 5: The cluster frequencies (rows) crosstabulated with the physician made urinary incontinence diagnoses (columns).

Cluster	Stress	Mixed	Sensory urge	Motor urge	Normal	Frequency (N)	Frequency (%)
1	222	4	0	0	0	226	47.4
2	35	91	6	2	0	134	28.1
3	16	21	16	0	0	53	11.1
4	0	4	0	9	0	13	2.7
5	27	4	2	0	18	51	10.7
Total (N)	300	124	24	11	18	477	
Total (%)	62.9	26.0	5.0	2.3	3.8		100

4. Conclusions

As expected, the results from the cluster analysis confirmed that it is possible to perform differential diagnosis of female urinary incontinence on the basis of the defined parameters and classification. Because of the nature of the female incontinence there is some overlapping between classes. Therefore each cluster did not contain cases only from one diagnostic class. However, in all clusters except in clusters 3 and 5 the expected diagnosis was clearly the most frequent. The final cluster centres are mostly located at the initial centres. Results showed also that most of the parameters are useful and statistically significant.

In conclusion, this study shows that an expert system can be developed using the classification and the parameters of the diagnosis table. None of the parameters should be excluded from the expert system since also the worst parameters may sometimes be useful. Additional parameters, such as the thickness of bladder wall and closing velocity of pelvic floor muscles, measured with ultrasonic and EMG should be evaluated later.

During the recent years a growing number of expert systems have been developed with the neural networks. We have also decided to follow this biologically inspired path by investigating the possibility to implement the expert system by using genetic algorithms.

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