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Continence Index: A new screening questionnaire to predict the probability of future incontinence in older women in the community

Ananias C. Diokno, MD^{1,2}, Theophilus Ogunyemi, Ph.D.³, Mohammad-Reza Siadat, Ph.D.⁴, Suzan Arslanturk, Ph.D.⁴, and Kim A. Killinger, MSN¹

¹Department of Urology, Beaumont Health, Royal Oak, MI

²Oakland University William Beaumont School of Medicine

³Department of Mathematics and Statistics, Oakland University, Rochester, MI, 48309

⁴Department of Computer Science and Engineering, Oakland University, Rochester, MI, 48309

Abstract

Purpose—Urinary incontinence (UI) is a chronic, costly condition that impairs quality of life. To identify older women most at risk, the Medical Epidemiologic and Social aspects of Aging (MESA) dataset was mined to create a set of questions that can reliably predict future UI.

Methods—MESA data were collected during four household interviews at approximately one year intervals. Factors associated with becoming incontinent at the second interview (HH2) were identified using logistic regression (construction dataset). Based on p-values and odds ratios, eight potential predictive factors with their 256 combinations and corresponding prediction probabilities formed the Continence Index. Its predictive and discriminatory capability was tested against the same cohort's outcome in the fourth survey (HH4-validation dataset). Sensitivity analysis, area under receiver operating characteristic (ROC) curve, predicted probabilities, and confidence intervals were used to statistically validate the Continence Index.

Results—Body Mass Index, sneezing, post partum UI, urinary frequency, mild UI, belief of developing UI in the future, and difficulty stopping urinary stream and remembering names emerged as the strongest predictors of UI. The confidence intervals for prediction probabilities strongly agreed between construction and validation datasets. Calculated sensitivity, specificity, false positive and false negative values revealed that the areas under the ROC's (0.802 and 0.799) for the construction and validation datasets, respectively, indicated good discriminatory capabilities of the Index as a predictor.

Conclusions—The Continence Index will help identify older women most at risk for UI in order to apply targeted prevention strategies in women that are most likely to benefit.

Corresponding Author: Kim Killinger MSN, Beaumont, Royal Oak, MI, 3535 W. 13 Mile Road Suite 438, Royal Oak, MI 48307, Phone: 248.551.9295, Fax: 248.551.2615, KKillinger@beaumont.edu.

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Introduction

The MESA project, funded by the National Institute on Aging (NIA) in 1983, established the prevalence, incidence and remission rates of urinary incontinence and other lower urinary tract symptoms (LUTS) in adults 55 years and older residing in Washtenaw County, Michigan [1]. The project also identified the correlates, psychological impact, clinical and urodynamic characteristics, current management and outcomes of UI among the respondents [2-7].

The MESA team also studied the use and effectiveness of pelvic floor muscle exercise program as a treatment modality for UI [8, 9]. Armed with promising initial results, the team then embarked on a UI prevention study using a group education approach of teaching behavioral modification program (BMP) as an active intervention tool to prevent UI among continent elderly women in the community [9, 10]. Results showed that the group lesson was easily adopted by the participants and was effective in preventing UI, as well as reducing urinary frequency, when compared to the control group that did not receive the lesson [11].

One lesson learned from the UI prevention study was the lack of tools to reliably predict those continent women that are most likely to be incontinent in the future. Being able to identify those that are ideal candidates for incontinence prevention programs is more beneficial in terms of cost than using precious health care resources to treat those who are unlikely to become incontinent.

With this gap in our armamentarium, the team decided to mine its voluminous MESA dataset to extract potential factors that may serve as predictors of UI among community dwelling older women. The goal was to identify significant risk factors and create a questionnaire with a high probability of predicting future incontinence. There were four datasets recorded in the MESA survey. The first dataset came from the first (baseline) household interview (HH1), followed by three follow-up interviews, named second, third, and fourth household surveys (HH2, HH3, HH4). The HH2 survey was carried out approximately one year after HH1, and the third and fourth surveys were conducted at yearly intervals thereafter. Subjects in the MESA study were categorized as incontinent if they reported urine loss on six or more days-per-year during screening. In a preliminary analysis, Ogunyemi et al [12] identified 15 significant factors (p-value <0.05) that were associated with becoming incontinent at one year. The purpose of the current study was to construct a Continence Index using previously identified risk factors with predictive potential, and determine the predictive and discriminatory capabilities of the Index to identify older women most at risk for developing UI.

Materials and Methods

After Institutional Review Board approval, the fifteen factors previously identified as risk factors for incontinence [12] were studied further. Although the current study was an extension of the preliminary analysis, the initial pool of 15 candidate variables was enlarged to a pool of 47 factors to avoid missing an important factor with potential predictive

capability. All the factors under consideration were dichotomized with level 0 meaning “negative” for potential for incontinence, and level 1 means “positive” for potential for incontinence. Both statistical and clinical expertise were employed in the dichotomization process, similar to the approach of Colditz et al [13].

For the current study, the HH1 and HH2 datasets were used to construct the predictive index (construction, or training, dataset). Its predictive and discriminatory capability for UI was tested against the outcome in the same cohort in the fourth survey (HH4), called validation dataset. The third survey dataset (HH3) was not used because the critical incontinence status variable was missing. Only women that were classified as continent during the HH1 survey were used to construct the proposed index. The incontinence status variable of the HH2 survey was regressed on the baseline factors via logistic regression (Figure 1). Initially, there were 417 continent subjects that were common to HH1 and HH2, but because of missing data, only 272 were used at this stage by logistic regression [14].

Satisfying at least one of two criteria (p -value < 0.05 or odds ratio > 1), eight factors out of 47 factors were initially identified as promising (Table I). Five of them were from the preliminary work [12]. All 256 combinations of the eight selected factors and their corresponding predicted probabilities for incontinence were calculated and used to derive the predictive Continence Index. The discriminatory ability of the Index was tested by investigating the transition from continence to incontinence in women that participated in both the HH1 and HH4 surveys (validation dataset). When the UI status variable was regressed on the selected baseline predictive factors, the results showed weakness in some of the eight factors. In order to improve the process, a few cases whose factors' combinations seemed strongly inconsistent with their UI classification (outliers) were removed. For example, subjects that had zero or one of the eight risk factors at baseline, but were classified as incontinent in the HH2 dataset, were considered outliers. Also removed were subjects with at least four risk factors (including strong factors on weighted analysis) that would presumably develop UI, but remained continent. Consequently, 7 out of 272 cases (2.5%) were removed from the construction data, and 21 out of 261 cases (8%) were removed from the validation data.

Next, estimates of incontinence prediction probabilities for 255 of the 256 combinations of the eight factors, and their corresponding 95% confidence intervals, were computed by constructing a contrast for each of the 255 combinations. In the computation, the combination (00000000-no risk factors) was treated as the base and 0.5 probability was assigned to it in logistic regression [14]. Probabilities of other combinations were treated relative to how significantly different they were from 0.5 or, equivalently, how significantly different the results were from flipping a coin or claiming ignorance on a change from continence to incontinence in Bayesian language.

To statistically validate the Continence Index, logistic regression was run on the reduced validation dataset with the same set of eight selected baseline predictive factors. The 95% confidence intervals for the 255 combinations from the training dataset were compared to those of the validation dataset. The level of overlap between the confidence intervals from

the training and validation datasets (denoted by R) were calculated to determine the percentage of combinations with specified minimum confidence interval overlap.

To determine the optimal probability threshold by which a subject would be declared incontinent in the future, sensitivity and specificity as well as the probabilities of false positive and false negative values were computed based on the results from logistic regression run on both the training and validation datasets. These probabilities were calculated at each threshold probability (cut-off point) for incontinence that varied from 0% to 100% in increments of 2%. A range of sensitivity levels that were higher than the corresponding false positive values, and a range of specificity levels that were higher than the corresponding false negative values, were determined from the sensitivity analysis. Analyses were conducted by applying logistic regression [14].

Results

Women that responded to the first household survey were mean age 70.5 ± 7.9 years (median 69 years), 92.1% white, 7.5% black, and 0.4% other race. The Continence Index is comprised of eight factors (Table 1). Though the data are not shown here, all the 255 p-values for testing combinations' probabilities indicated highly significant differences from 0.5 or, equivalently, none of the 255 corresponding 95% confidence intervals for probabilities of incontinence contained 0.5. When the discriminatory capability of the Index was tested with outliers eliminated, all eight factors were significant ($p\text{-value} < 0.05$) and/or their odds ratios were greater than 1, and they gave the highest confidence interval overlaps. Similarly, there was an improved discriminatory capability with regard to the area under the receiver operating characteristic (ROC) curve. The improved value of the area 0.802 indicates good discriminatory capability in contrast to only a fair discriminatory capability of 0.740 when strongly inconsistent cases (outliers) were included in the construction data (Table 2). Even better improvement in discriminatory capability was observed in the validation data. These improved values of the areas under the ROCs lend support to the use of reduced training and validation datasets with strongly inconsistent cases removed.

Predictive probabilities for the 255 combinations of the eight factors were examined. Confidence interval computations for the construction data indicated that the lowest probability (lower limit of confidence interval) of developing future incontinence was 51% with one risk factor present, and 96% with all eight factors present.

Simple linear regression was used to compare the predicted probabilities of developing incontinence for identical combinations from training and validated data. The predicted probability for incontinence from the validation data was regressed on the predicted probability of incontinence from the training dataset to investigate the strength of agreement between the two sets of probabilities (Figure 2). All indicated very strong agreement between the two sets of predicted probabilities.

The calculated sensitivity and specificity, as well as false positive and false negative values, revealed that the areas under ROC curves (Figure 3) were 0.802 and 0.799 for the HH1HH2 and the HH1HH4 data, respectively, indicating good discriminatory capabilities for the

proposed Index as a predictor. Based on sensitivity and specificity analysis, the optimal probability threshold was 84% with the sensitivity of 78.6% and specificity of 65.1%. This resulted in a false positive of 62.4% and a false negative of 8.1%. The data indicated good discriminatory capabilities for our proposed Continence Index, especially in the area of specificity and false negative value as the specificity value was always substantially greater than the false negative values. However, analysis of the sensitivity versus false positive value showed the superiority of the sensitivity value over the latter, which started diminishing at a threshold probability of 80%.

Discussion

The first factor in the Continence Index is body mass index (BMI). A BMI ≥ 30 (obese) has been associated with UI in both men and women, and BMI 25–29.9 (overweight) has been associated with UI in women but not men [15]. Although BMI cutoffs may vary in other races, in the current study of mostly caucasian women, BMI of 24.4 or higher at baseline was a significant risk factor for developing UI even though 24.4 is still within the normal range (18.5–24.9). One explanation may be that women with higher BMI were already incontinent at baseline and excluded from this study of transition from continence to incontinence. Or, perhaps women with high normal BMI at baseline were incontinent at the second interview because even a modest weight gain put them in the overweight category and at higher risk for UI. Nonetheless, our finding suggests that women with a borderline weight issue may be at risk for developing UI.

The second risk factor, sneezing often or sometimes in contrast to rarely or never, is not surprising. Adequate pelvic floor support is needed to control urinary flow. Chronic cough associated with chronic obstructive pulmonary disease has also been associated with UI [16]. Constant bombardment of the pelvic floor with high abdominal pressures during coughing or sneezing can weaken pelvic floor support and predispose to UI, especially stress urinary incontinence.

The third risk factor is history of urine loss after delivery. Vaginal delivery when compared to cesarean delivery has been shown to increase risk for UI [17], presumably by weakening pelvic floor support. Urinary incontinence has been reported to be 3.3 times higher in primiparous women during pregnancy and 2.5 times more prevalent at one year post delivery when compared to nulliparous controls [18]. It is also presumed that the risk here is probable damage to the pelvic floor that over time leads to further weakening and UI [17]. As a well known consequence of parturition, numerous efforts have been advanced to prevent such future occurrences with good success [19]. A weak pelvic floor leading to incontinence is also likely the culprit behind the sixth factor in the Continence Index: the inability to voluntarily shut-off the flow of urine at the middle of the stream.

The fourth factor, having trouble getting to the bathroom on time, suggests that the respondent may have had significant urinary urgency symptoms. This is a good screening question because this is another issue that expert opinion feels is highly predisposing or a prodrome to future urge urinary incontinence.

Some respondents reported minimal urine loss that did not meet the definition of UI in the MESA study and were therefore categorized as continent at baseline. However, this minimal level of self reported wetting or soiling at baseline emerged as the fifth factor in the Continence Index. The reason for conflicting reports within the same survey is unclear, but might reflect inconsistencies in survey design. Or, perhaps this finding may simply suggest that patients with very minimal urine loss still did not consider themselves incontinent. Intuitively, mild incontinence that did meet the study definition would be an obvious risk factor for future UI. These subjects might be at higher risk for progression, so clinicians should identify even minimal urine loss that may worsen over time.

The seventh factor suggests that problems with memory, specifically in regards to remembering names, might contribute to the transition from continence to incontinence. Cognitive impairment has been associated with UI in several studies of UI in nursing homes [20]. Perhaps reported difficulty remembering names in this community dwelling sample indicated mild memory loss that may progress over time. Future studies may benefit from correlating cognitive variables such as this with validated tools.

The eighth factor is a tendency to believe that one will have urine loss condition in the future. Those that became incontinent had a heightened awareness of the possibility of developing UI. This belief may be due to past history of episodic incontinence or having family members or friends with UI. It is also possible that some respondents may erroneously believe that incontinence is a normal part of aging. The relationship between health beliefs and outcomes is an important concept that bears further investigation.

Our statistical validity testing of this Continence Index using the HH1 and HH4 datasets showed strong agreement between the confidence intervals. Another way to validate the Continence Index was to compare the probabilities of developing incontinence for identical combinations of risk factors from both data sets. The results of this analysis showed very strong agreement between the probabilities of developing incontinence for identical combinations of risk factors from both data sets as demonstrated in Figure 2. For sensitivity and specificity analysis, the combination of variables with 84% probability of predicting future incontinence had a sensitivity and specificity of 78.6% and 65.1% respectively. Even though the superiority of specificity over the sensitivity may be due to relatively small number of continent women that became incontinent, improving the sensitivity and specificity would be ideal. However, although the false positive value is higher than anticipated, a very low false negative value of only 8.1% is very reassuring that the Index will capture most women with high likelihood of future incontinence.

The availability of four separate longitudinal data sets collected from the same group of women is a strength of the study. Furthermore, we were able to repeatedly test the index's predictive abilities by examining the transition in continence status between the first and second, and first and fourth datasets. Limitations of the study include the inability to use the third dataset because the continence status variable was missing, constraints imposed by mining already existing data such as lack of ability to follow up with respondents, and inability to generalize findings to other races/populations because MESA respondents were mostly white.

To our knowledge, this study's results represent the first UI predictive index, called the Continence Index, with potential to predict future UI in older women. This screening tool could be applied in clinics as well as community based settings to identify those at most risk for future incontinence. Since a reasonable next step would be to validate the Index in a prospectively followed population of older women, we intend to conduct a prospective, longitudinal survey to further test the Continence Index as well as examine the remaining risk factors that were highly significant but did not make it in this round of development.

Conclusion

As behavioral modification programs are being accepted not only as a treatment modality but as a tool to prevent urinary incontinence and other lower urinary tract symptoms, it is increasingly imperative that a screening tool be developed to identify those women who might benefit most from preventative measures. Targeting at risk women spares low risk women from unnecessary interventions. This approach saves not only time and effort for the subjects, their families, health care providers and health systems, but also reduces the cost of unnecessary preventive measures.

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Figure 1. Schematic Illustration of Construction and Validation of Proposed Predictive Index for Urinary Incontinence

Note: Logistic regression on Training (A) and Validation (B) with baseline predictors from 2nd and 4th Surveys' datasets, respectively.

C: continent

I: incontinent

Figure 2. Strong Agreement Between Training and Validation Predicted Probabilities

Figure 3. Sensitivity vs. Specificity

HH1(Baseline Factors) and HH2 (training data) and HH1 and HH4 (validation data) with Strongly Inconsistent Cases Removed**Table 1**

<i>Factor</i>	<i>Description</i>	HH1 to HH2 (training data)		HH1 to HH4 (validation data)	
		<i>P-value</i>	<i>OR 95% C.I.</i>	<i>P-value</i>	<i>OR 95% C.I.</i>
F1	Body Mass Index (BMI) Base category (0): At most 24.4 Other category (1): Greater than 24.4	0.0330	(1.032, 2.086)	0.0328	(1.192, 2.330)
F2	Do you sneeze often; sometimes, rarely or never? Base category (0): Never/rarely Other category (1): Often/sometimes	0.0058	(1.167, 2.489)	0.0249	(1.072, 2.809)
F3	Any urine loss problems that started after deliveries: Yes; no Base category (0): No Other category (1): No	0.0234	(1.118, 4.669)	0.0076	(1.381, 8.193)
F4	Trouble getting to the bathroom on time: Yes; no Base category (0): Never Other category (1): Yes	0.0354	(1.035, 2.666)	0.0109	(1.170, 3.331)
F5	Frequency of wetting/soiling yourself day/night: Never; 1/week; 1 or 2/week; > 3/week Base category (0): Never Other category (1): Others	0.0021	(1.422, 4.881)	0.0086	(1.265, 5.036)
F6	When you are urinating into a toilet, can you shut off the flow of urine in the middle of your stream by using your muscles if you want to? Base category (0): Yes Other category (1): No	0.0149	(1.109, 2.602)	0.0032	(1.243, 2.951)
F7	As you know some people experience memory problems as they get older. What about remembering names? Base category (0): Well/very well Other category (1): Very poorly/poorly	0.0204	(1.070, 2.221)	0.0093	(1.114, 2.161)
F8	Possibility of future incontinence Base category: A little or not Other category: Very or somewhat	0.0062	(1.148, 2.304)	0.0077	(1.124, 2.148)

Table 2
Values of Areas Under ROC

	Inconsistent Cases Included	Inconsistent Cases Excluded
Training Data	0.740	0.802
Validation Data	0.689	0.799