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NON-INVASIVE PARAMETERS FOR THE PREDICTION OF URODYNAMIC BLADDER OUTLET OBSTRUCTION: ANALYSIS USING CAUSAL BAYESIAN NETWORKS

Hypothesis / aims of study

Numerous attempts have been made to predict urodynamic bladder outlet obstruction (BOO) in benign prostatic hyperplasia (BPH), however, solitary parameters, including symptom score, prostatic specific antigen (PSA), free uroflowmetry, volume of post-void residual urine (PVR) and prostate size, have shown a poor to weak correlation with BOO. To improve prediction ability, combinations of non-invasive parameters have been sought to predict BOO. However, these attempts had limited predictive performance. Moreover, the need to use several parameters makes clinical application difficult.

To overcome these problems, other statistical prediction methods, such as artificial neural networks (ANN), have been introduced to predict BOO in BPH patients, and some researchers have composed the ANN by using various combinations of non-invasive parameters [1, 2]. These models, however, due to their 'black box' nature, could not account for non-invasive parameters that are relatively important for BOO.

Causal Bayesian networks (CBN) have emerged as a more advanced alternative to conventional statistical models in the medical field. The benefit of this model is that it can visualize the interaction of causes and rule out indirect causes of events. Hence, we aimed to identify non-invasive clinical parameters to predict BOO using a CBN model.

Study design, materials and methods

A database comprised of 2,492 patients between Oct 2004 and Aug 2013 who were older than 45 years old and had lower urinary tract symptoms (LUTS) suggestive of BPH were included. The data was retrieved from the Urodynamic Database Registry and Electronic Medical Records System. Out of 2,492 patients, 1,381 with a complete dataset eligible for BPH were selected for analysis. Non-invasive predictors of BOO were selected using CBN. BOO prediction with selected parameters was verified using logistic regression (LR) and ANN considering all non-invasive parameters.

Results

Mean age, total prostate volume (TPV) and IPSS were 6.2 ($\pm$ 7.3, SD) years, 48.5 ($\pm$ 25.9) ml, and 17.9 ($\pm$ 7.9), respectively. The mean bladder outlet obstruction index (BOOI) was 35.1 ($\pm$ 25.2) and 477 (34.5%) patients had urodynamic BOO (BOOI $\geq$ 40). CBN identified TPV, Qmax, and PVR as independent predictors of BOO (Fig. 1). With these three parameters, BOO prediction accuracy was 73.5%. LR and ANN models with all the non-invasive parameters showed a similar accuracy (LR: 77.0%; ANN: 71.5%) (Table 1). The area under the receiver operating characteristic curve (AUROC) of ANN was smaller than that of the other two methods (p-value range < 0.001 - 0.005). However, the AUROC of all three models showed some differences (CBN model: 0.772; LR model: 0.798; ANN model: 0.742; p-value < 0.05).

Interpretation of results

In general, the advantage of CBNs is that they can identify conditional independence relationships and thus make it possible to confirm the only direct independent cause of the events. We expected that this advantage of the CBN model could confirm independent parameters for the prediction of BOO. Our data showed that TPV was the most important predictive factors for BOO (R = 0.391), and then, Qmax (R = -0.253), and PVR (0.214) in that order. Our results are consistent with those of previous studies that reported that TPV had a higher correlation with BOO compared to the other non-invasive parameters. These results suggest that TPV is the most important parameter for BOO prediction in real clinical practice and that TZV and PSA do not need to be considered as predictors.

These three non-invasive parameters are also routinely checked in real clinical practice for BPH patients. Indeed, our CBN model comprised categorized values of parameters due to in nature characteristics of CBN model for clarifying interactions between the parameters. It is obscure if our lower performance of CBN originates from the elliptical non-invasive parameters or from processing the parameters to a categorical value for CBN modelling. However, it is interesting that the BOO can be predicted moderately with only three parameters. This study was unable to conclude whether the other parameters that show conditional independence can be excluded for BOO prediction.

To the best of our knowledge, this study is the first to test CBN model for BOO prediction. The strength of this study is that we made our non-missing dataset of 1,381 patients large enough to support the construction of the CBN model. Moreover, in our study, all of the urodynamic study were performed uniformly using the same protocol following ICS recommendations. However, our current study has some limitations. Our model was unable to account for the weight of each independent predictor. Therefore, the relative importance of predictors should be identified by means of indirect correlation analysis. Second, our CBN model is built from a cross-sectional database; hence, in a strict sense, our model did not show a cause-effect relationship between parameters, but showed simple correlations or interactions. It is thus impossible to confirm parameters that precede the cause.

Concluding message

Our results show that TZV, Qmax, and PVR are independent non-invasive predictors of BOO. Among them, TPV is the most important parameter for prediction of BOO. The CBN model resulted in moderate performance for BOO prediction when utilizing these three parameters. However, overall accuracy was slightly compromised compared to a conventional LR model.

Table 1. Predictive value of three predictive models for bladder outlet obstruction

	Predicted BOO		Urodynamic BOO (+)	Urodynamic BOO (-)	Total	Sensitivity	Specificity	Accuracy
LR model	Total (N=1381)	(+)	246	87	333	246/477 (51.6%)	817/904 (90.4%)	(246+817)/1381 (77.0%)
		(-)	231	817	1048			
		Total	477	904	1381			
ANN model	Training set (N=967)	(+)	170	90	260	170/339 (50.1%)	538/628 (85.7%)	(170+538)/967 (73.2%)
		(-)	169	538	707			
		Total	339	628	967			
	Testing set (N=414)	(+)	67	47	114	67/138 (48.6%)	229/276 (83.0%)	(67+229)/414 (71.5%)
		(-)	71	229	300			
		Total	138	276	414			
CBN model	Total (N=1381)	(+)	245	134	379	245/477 (51.4%)	770/904 (85.2%)	(245+770)/1381 (73.5%)
		(-)	232	770	1002			
		Total	477	904	1381			

LR, logistic regression; ANN, artificial neural networks; CBN, causal Bayesian networks

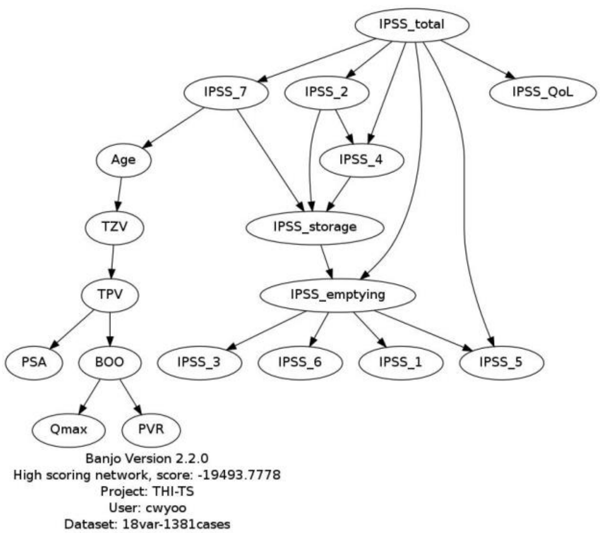

Fig. 1. Causal Bayesian network model for bladder outlet obstruction

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Disclosures

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