

# Bayesian Belief Network Model of the Radical Prostatectomy Pathway

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**Wojtek Michalowski**

University of Ottawa, Canada

**Szymon Wilk**

Poznan University of Technology, Poland

**Anthony Thijssen**

The Ottawa Hospital – Civic Campus, Canada

**Migmei Li**

University of Ottawa, Canada



# Outline

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- Clinical Pathway and Radical Prostatectomy Pathway (RPP)
  - Bayesian Belief Network (BBN)
  - BBN Model for RPP
  - Mobile Pathway Monitor (MPM)
  - Discussion
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# Clinical Pathway

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- ❑ Operationalizes best practices and represents sequencing and timing of interventions by clinicians for a particular clinical presentation.
- ❑ Designed to minimize delays, improve resource utilizations and enhance the quality of tertiary care.
- ❑ Used to monitor and control patient's progress measured according to standard process and clinical outcomes, e.g., length of stay (*LOS*).

*Radical prostatectomy pathway (RPP) describes patient's management (activities, outcomes, variance record) from a post-op to a fourth day of stay in the hospital.*

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Patient Day # Date	CRITICAL PATH									
	Pre-Admit Unit	Same Day Admit	OR Day (PACU)	Post-op Day 1	Post-op Day 2	Post-op Day 3	Post-op Day 4	Clinic Visit #1	Clinic Visit #2	
<b>Consults</b>	<ul style="list-style-type: none"> <li>Anesthesia</li> <li>PACU assessment</li> </ul>			<ul style="list-style-type: none"> <li>Home Care</li> </ul>						
<b>Medications</b>	<ul style="list-style-type: none"> <li>Review patient medications</li> </ul>	<ul style="list-style-type: none"> <li>Heparin in SB</li> <li>po-IV medications as ordered</li> <li>if N/A at 50 units for all patients where IV medications are ordered</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> <li>if as ordered</li> <li>Oxygen Titration Protocol</li> <li>s.c. Heparin 5000 units at 2h</li> <li>NSMD as ordered</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> <li>if as ordered</li> <li>Oxygen Titration Protocol</li> <li>s.c. Heparin 5000 units at 2h</li> <li>NSMD as ordered</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> <li>DC/TZ if timing well</li> <li>Oxygen Titration Protocol</li> <li>s.c. Heparin 5000 units at 2h</li> <li>NSMD as ordered</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> <li>DC Heparin</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> </ul>	<ul style="list-style-type: none"> <li>Patient specific medications</li> <li>Analgesic Intrathecal Protocol</li> </ul>	
<b>Tests</b>	<ul style="list-style-type: none"> <li>Type &amp; screen</li> <li>CBC</li> <li>Max K, Cl, glucose, creatinine</li> <li>Chem 7/14g</li> <li>ESR</li> <li>Urinal R &amp; M</li> <li>C &amp; S</li> <li>1 Adiposonite</li> <li>1 color test</li> <li>1 patients in Corneal</li> <li>1 ANP/NT</li> </ul>	<ul style="list-style-type: none"> <li>Patients with checked renal failure</li> <li>1 Soften, autotune, stretch, vital</li> <li>or ANP</li> <li>10 diabetes patients</li> <li>1 glycohem</li> <li>1 patients in Corneal</li> <li>1 ANP/NT vital on arrival</li> <li>1 Adiposonite Med done</li> <li>1 CBC</li> </ul>	<ul style="list-style-type: none"> <li>CBC 1 hour post-op</li> </ul>		<ul style="list-style-type: none"> <li>CBC</li> <li>Max K, Cl, creatinine</li> </ul>					
<b>Assessments/Treatments</b>	<ul style="list-style-type: none"> <li>Wound signs</li> <li>Monitor for TED stockings</li> <li>Patient/caregiver specific assessment</li> </ul>	<ul style="list-style-type: none"> <li>Wound signs</li> <li>SpO<sub>2</sub></li> <li>Apply TED stockings</li> <li>Complete pre-op checklist</li> </ul>	<ul style="list-style-type: none"> <li>RS with</li> <li>1 &amp; 2 gtt</li> <li>SpO<sub>2</sub> with</li> <li>TED stockings</li> <li>Monitor dressing, change if soiling</li> <li>Intending arterial catheter</li> <li>Jackson Post</li> <li>Systems assessment</li> <li>respiratory, GI, E, cath &amp; pin</li> <li>Jackson Post</li> </ul>	<ul style="list-style-type: none"> <li>RS with</li> <li>1 &amp; 2 gtt</li> <li>SpO<sub>2</sub> with</li> <li>TED stockings</li> <li>Monitor dressing, change if soiling</li> <li>Intending arterial catheter</li> <li>Systems assessment</li> <li>respiratory, GI, E, cath &amp; pin</li> <li>Jackson Post</li> </ul>	<ul style="list-style-type: none"> <li>RS with</li> <li>1 &amp; 2 gtt</li> <li>SpO<sub>2</sub> with</li> <li>TED stockings</li> <li>Remove dressing – open to air</li> <li>Intending arterial catheter</li> <li>Systems assessment</li> <li>respiratory, GI, E, cath &amp; pin</li> <li>Jackson Post</li> </ul>	<ul style="list-style-type: none"> <li>RS</li> <li>Monitor incision</li> <li>Intending arterial catheter output</li> <li>Remove dressing over drain site</li> <li>open to air</li> <li>Home with clips</li> </ul>	<ul style="list-style-type: none"> <li>Remove clips</li> <li>Assess wound, pack with saline soaked gauze if applicable</li> </ul>	<ul style="list-style-type: none"> <li>Remove incision catheter</li> <li>Assess wound, wound care as indicated</li> </ul>		
<b>Activity</b>	<ul style="list-style-type: none"> <li>AA1</li> </ul>	<ul style="list-style-type: none"> <li>AA1</li> </ul>	<ul style="list-style-type: none"> <li>Bed rest</li> <li>Depth = 1</li> </ul>	<ul style="list-style-type: none"> <li>Chair = 3</li> <li>Activities for pre-walk</li> </ul>	<ul style="list-style-type: none"> <li>Progressive ambulation with minimal assistance</li> </ul>	<ul style="list-style-type: none"> <li>AA1 independent</li> </ul>	<ul style="list-style-type: none"> <li>AA1</li> </ul>	<ul style="list-style-type: none"> <li>AA1</li> </ul>	<ul style="list-style-type: none"> <li>AA1</li> </ul>	
<b>Nutrition/ Eliminate</b>		<ul style="list-style-type: none"> <li>MPJ less than 240 kcal</li> </ul>	<ul style="list-style-type: none"> <li>MPJ</li> </ul>	<ul style="list-style-type: none"> <li>Sign clear fluids</li> </ul>	<ul style="list-style-type: none"> <li>Feet fluids to D4T</li> </ul>	<ul style="list-style-type: none"> <li>D4T</li> </ul>	<ul style="list-style-type: none"> <li>D4T</li> <li>Assess bowel function</li> <li>Assess urine output (color, consistency)</li> </ul>	<ul style="list-style-type: none"> <li>D4T</li> <li>Assess bowel function</li> <li>Assess urine output (color, consistency)</li> </ul>		
<b>Patient Teaching</b>	<ul style="list-style-type: none"> <li>Initial Radical Prostatectomy Teaching Session</li> <li>Patient specific medications for timing of surgery</li> <li>Pre-op preparations: <ul style="list-style-type: none"> <li>Urology based prep day before surgery</li> <li>Wound exercises</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Reinforce pre-surgery teaching</li> <li>Care of patient belongings</li> </ul>	<ul style="list-style-type: none"> <li>Reinforce <ul style="list-style-type: none"> <li>Wound dressing &amp; coughing</li> <li>leg exercises</li> <li>airway splinting</li> <li>pain management</li> <li>diel</li> <li>incision care</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Reinforce <ul style="list-style-type: none"> <li>Wound dressing &amp; coughing</li> <li>airway splinting</li> <li>activity</li> <li>pain management</li> <li>diel</li> <li>incision care</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Reinforce <ul style="list-style-type: none"> <li>activity</li> <li>pain management</li> <li>airway care</li> <li>incision care &amp; drainage system</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Review discharge instructions: <ul style="list-style-type: none"> <li>activity</li> <li>pain management</li> <li>airway care</li> <li>incision care and drainage system</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Reinforce discharge instructions</li> </ul>	<ul style="list-style-type: none"> <li>Reinforce <ul style="list-style-type: none"> <li>incision care and drainage system</li> <li>airway care</li> <li>Discuss continence care</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Reinforce <ul style="list-style-type: none"> <li>incision care and drainage system</li> <li>airway care</li> <li>airway care</li> <li>Refer to Pre-Discharge Support Group</li> </ul> </li> </ul>	
<b>Discharge Planning</b>	<ul style="list-style-type: none"> <li>Discuss Care Map and expected length of stay</li> <li>Initial Surgical Portable Discharge Assessment &amp; Planning Care Map</li> </ul>			<ul style="list-style-type: none"> <li>Complete Surgical Portable Discharge Assessment &amp; Planning Care Map</li> </ul>	<ul style="list-style-type: none"> <li>Confirm discharge plans with patient/family</li> <li>Pre-call plan written pre</li> <li>Follow-up appointment within 2 days at hospital's best clinic</li> </ul>	<ul style="list-style-type: none"> <li>Complete Discharge Summary section of Surgical Portable Discharge Assessment &amp; Planning Care Map</li> </ul>	<ul style="list-style-type: none"> <li>Modify Home Care referral if applicable</li> <li>Follow-up appointment in one week at urologist's clinic</li> </ul>	<ul style="list-style-type: none"> <li>Registration for PSA and follow-up appointment</li> </ul>		
<b>Patient progress corresponds with Care Map</b>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	<p>Nursing</p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No _____ N</p>	

# Bayesian Belief Network (BBN)

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- Models a stochastic process composed of the events with associated conditional probabilities and relationships between these events.
  - Generates an answer to conditional-type queries, e.g., *considering the patient's health status on a given day, what impact would "x" have on meeting the expected day of discharge.*
  - Used to predict the impact of observed outcomes and activities on the *LOS* on the basis of current observations recorded in the pathway.
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# Variables in the RPP (1)

Code	Name	Values	Descriptions or examples	Post-op day		
				1	2	3
Psycho	Patient psychological condition	abnormal	e.g. Patient's anxiety;	+		
		normal	Patient can understand and is compliant	+		
Vs	Vital signs	abnormal	e.g. The pulse rate of the patient is abnormal	+	+	+
		normal	Vital signs of the patient are normal	+	+	+
Temp	Temperature	abnormal	Patient's temperature is abnormal		+	+
		normal	Patient's temperature is normal		+	+
ActW	Activity with the RPP	no	Patient does not ambulate	+	+	+
		ambulate	Patient does (progressive) ambulation	+	+	+
NutriW	Nutrition with the RPP	fluid	Patient drinks fluid	+	+	+
		regular	Patient has regular foods		+	+
NutriO	Nutrition outcome	vomit	Patient vomits	+	+	+
		nausea	Patient feels nausea	+	+	+
		normal	None of the above	+	+	+
PainR	Pain at rest	medium	The verbal pain score at rest of the patient is between 4-7	+	+	+
		mild	The verbal pain score at rest of the patient is between 1-3	+	+	+
		nopain	Patient has no pain at rest	+	+	+
Resp	Respiratory function	mild	e.g. Crackle, difficult to breath	+		
		normal	The respiratory function of the patient is normal	+	+	+

# Variables in the RPP (2)

Code	Name	Values	Descriptions or examples	Post-op day		
				1	2	3
Jp	JP output	large	The amount of JP is large	+	+	+
		medium	The amount of JP is medium	+	+	+
		small	The amount of JP is small	+	+	+
		d/c	JP is discontinued		+	+
Hema	Evidence of hematuria	yes	Patient has evidence of hematuria	+	+	+
		bt	Patient has blood-tinged	+	+	+
		no	Patient has no evidence of hematuria	+	+	+
UrineO	Urine output	inadequate	The amount of urine is inadequate	+	+	+
		adequate	The amount of urine is adequate	+	+	+
BowelS	Bowel sounds outcome	absent	The bowel sound is absent	+	+	
		present	The bowel sound is present	+	+	
PainM	Mobility outcome	medium	The verbal pain score with mobility of the patient is between 4-7	+	+	+
		mild	The verbal pain score with mobility of the patient is between 1-3	+	+	+
		nopain	Patient has no pain with mobility	+	+	+
Wound	Wound outcome	medium	Patient's incision has severe infection		+	+
		mild	Patient's incision has mild infection		+	+
		normal	Patient's incision has no evidence of redness, swelling, rash, dehiscence		+	+
LOS	Length of patient stay	delayed	Patient is discharged after Post-op day 3			
		met	Patient is discharged on or before Post-op day 3 (LOS is 4 days or shorter)			

# Developing BBN Model for the RPP

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## □ Learning data set:

- Charts and pathways of 75 patients managed by various clinical teams between 2002 and 2003 at The Ottawa Hospital – Civic Campus.
- Data transcribed from patient's records and evaluated by urology specialists for consistency and correctness.

## □ Learning method:

- K2 algorithm used to develop the BBN structure and calculate the conditional probabilities from data.

sw1

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## Slide 8

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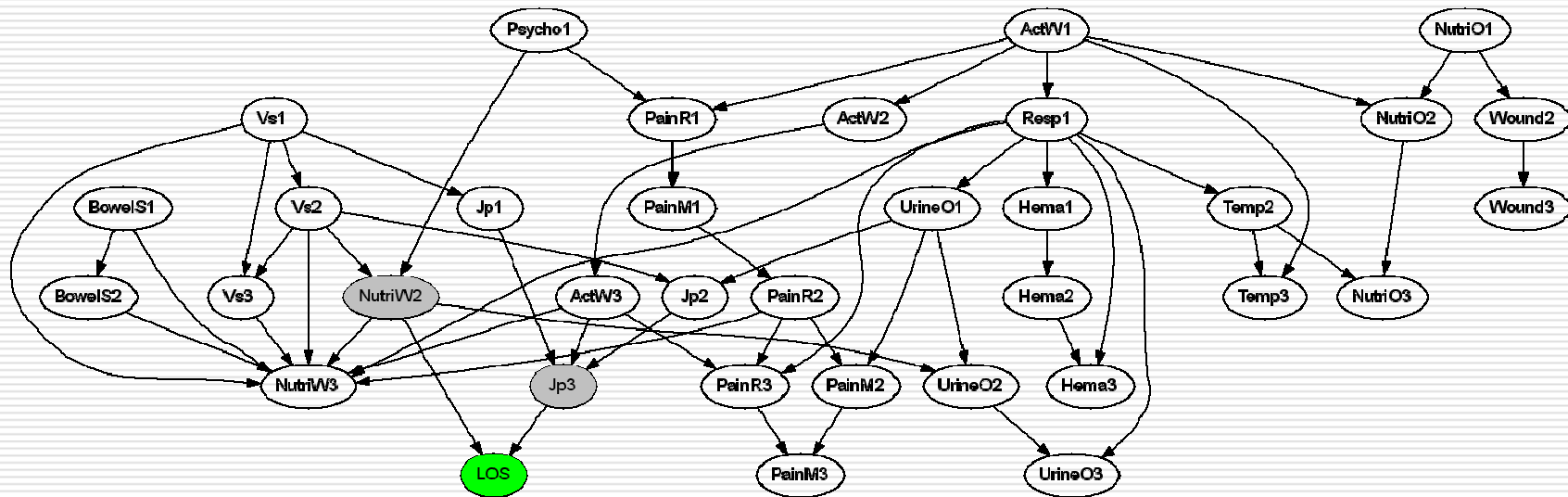
**sw1**

I would remove the reference to Bayesware Discoverer. K2 seems to be a well-known "generic" algorithm.

Szymon Wilk, 27/12/2005

# Structure of the BBN Model for the RPP

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# Verification of the BBN Model for the RPP

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## □ Testing data set:

- Charts and pathways of 50 patients managed by various clinical teams between 2002 and 2003 at The Ottawa Hospital – Civic Campus.
- Independent from the learning set.
- Data reviewed according to the same regimen as learning data set.

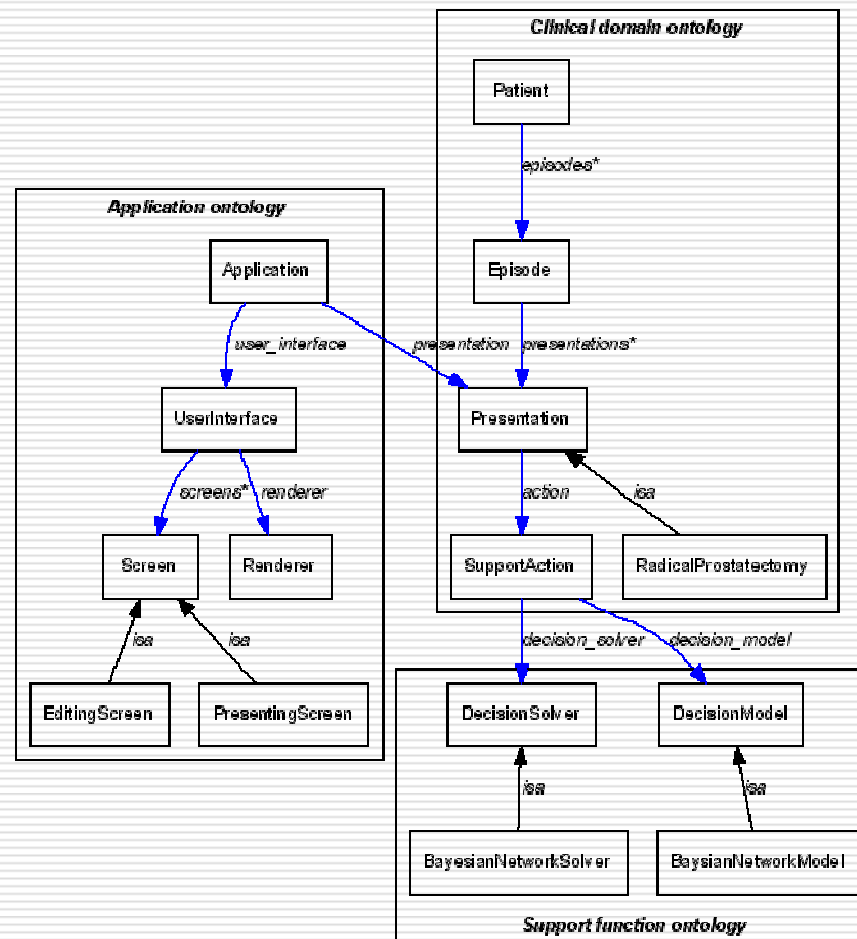
## □ Test results:

Accuracy	BBN	Decision tree	Logistic regression
<i>Met LOS</i>	90.9%	90.9%	93.9%
<i>Delayed LOS</i>	64.7%	41.2%	41.2%
Overall	82.0%	74.0%	76.0%

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# BBN RPP Mobile Pathway Monitor

- MPM implementation in *MET* environment using ontologies



# MET-MPM Interface

## Desktop computer

Application: Met2  
Patient: Wilk, Szymon  
Procedure: RadicalProstatectomy

Day 1	Day 2	Day 3
Activity with the RPC: <input checked="" type="checkbox"/> Ambulate <input type="checkbox"/> No	Activity with the RPC: <input type="checkbox"/> Ambulate <input checked="" type="checkbox"/> No	Activity with the RPC: <input checked="" type="checkbox"/> Ambulate <input type="checkbox"/> No
Bowel sounds: <input type="checkbox"/> Absent <input checked="" type="checkbox"/> Present	Bowel sounds: <input checked="" type="checkbox"/> Absent <input type="checkbox"/> Present	Evidence of hematuria: <input type="checkbox"/> Blood-tinged <input checked="" type="checkbox"/> No
Evidence of hematuria: <input type="checkbox"/> Blood-tinged <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes	Evidence of hematuria: <input type="checkbox"/> Blood-tinged <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes	<input type="checkbox"/> Yes
JP output: <input type="checkbox"/> Discontinued <input type="checkbox"/> Large <input checked="" type="checkbox"/> Medium <input type="checkbox"/> Small	JP output: <input type="checkbox"/> Discontinued <input type="checkbox"/> Large <input checked="" type="checkbox"/> Medium <input type="checkbox"/> Small	JP output: <input type="checkbox"/> Discontinued <input type="checkbox"/> Large <input type="checkbox"/> Medium <input checked="" type="checkbox"/> Small
Nutrition outcome: <input checked="" type="checkbox"/> Nausea <input type="checkbox"/> Normal <input type="checkbox"/> Vomit	Nutrition outcome: <input type="checkbox"/> Nausea <input checked="" type="checkbox"/> Normal <input type="checkbox"/> Vomit	Nutrition outcome: <input type="checkbox"/> Nausea <input checked="" type="checkbox"/> Normal <input type="checkbox"/> Vomit
Pain at rest: <input checked="" type="checkbox"/> Medium <input type="checkbox"/> Mild <input type="checkbox"/> None	Nutrition with the RPC: <input type="checkbox"/> Fluid <input type="checkbox"/> Regular	Nutrition with the RPC: <input type="checkbox"/> Fluid <input type="checkbox"/> Regular
Pain with mobility: <input type="checkbox"/> Medium <input checked="" type="checkbox"/> Mild <input type="checkbox"/> None	Pain at rest: <input type="checkbox"/> Medium <input type="checkbox"/> Mild <input checked="" type="checkbox"/> None	Pain at rest: <input type="checkbox"/> Medium <input type="checkbox"/> Mild <input checked="" type="checkbox"/> None
Psychological condition: <input type="checkbox"/> Abnormal <input checked="" type="checkbox"/> Normal	Pain with mobility: <input type="checkbox"/> Medium <input type="checkbox"/> Mild <input checked="" type="checkbox"/> None	Pain with mobility: <input type="checkbox"/> Medium <input type="checkbox"/> Mild <input checked="" type="checkbox"/> None
Respiratory function: <input checked="" type="checkbox"/> Mild <input type="checkbox"/> Normal	Temperature: <input type="checkbox"/> Abnormal <input type="checkbox"/> Normal	Temperature: <input type="checkbox"/> Abnormal <input type="checkbox"/> Normal
Urine output: <input type="checkbox"/> Adequate <input checked="" type="checkbox"/> Inadequate	Urine output: <input checked="" type="checkbox"/> Adequate <input type="checkbox"/> Inadequate	Urine output: <input checked="" type="checkbox"/> Adequate <input type="checkbox"/> Inadequate
Vital signs: <input type="checkbox"/> Abnormal <input checked="" type="checkbox"/> Normal	Vital signs: <input type="checkbox"/> Abnormal <input checked="" type="checkbox"/> Normal	Vital signs: <input type="checkbox"/> Abnormal <input checked="" type="checkbox"/> Normal
	Wound outcome: <input type="checkbox"/> Medium <input checked="" type="checkbox"/> Mild <input type="checkbox"/> Normal	Wound outcome: <input type="checkbox"/> Medium <input type="checkbox"/> Mild <input checked="" type="checkbox"/> Normal

## Handheld computer

Application: Met2  
Patient: Wilk, Szymon  
Procedure: RadicalProstatectomy

Day 1	Day 2	Day 3
Nutrition outcome: Nausea	Pain at rest: None	JP output: Small
Pain at rest: None	Evidence of hematuria: Adequate	Urine output: Inadequate
JP output: Small	Urine output: Inadequate	Bowel sounds: Ok
Evidence of hematuria: Adequate	Pain with mobility: None	Pain with mobility: None
Urine output: Inadequate	Wound outcome: Normal	Wound outcome: Normal
Bowel sounds: Ok	Temperature: (no value)	

# Discussion

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- ❑ BBN models the RPP and very well describes probabilistic inferences.
  - ❑ The use of a BBN model facilitates identification of the events directly associated with the *LOS*.
  - ❑ Revising the conditional probabilities of the variables provides information that can be used in re-evaluating a patient's management.
  - ❑ MPM implementation can be used to provide new insight into patient's clinical condition given current observation.
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# A Challenge

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*Health care is one of the slowest IT-adopting industries .... It is like Detroit putting out futuristic hydrogen cars but using paper processing and manual labor for manufacturing*

*Jeff Miller, Hewlett-Packard*

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# Thank You

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