A dynamic Bayesian network model for self-monitoring of rheumatoid arthritis

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Abbreviated abstract: We propose a dynamic Bayesian network (DBN) model to self-monitor the disease activity of rheumatoid arthritis (RA). The structure and parameters of DBN are learnt based on the knowledge elicited from domain experts and supported by literature. The model represents the interactions between disease manifestation factors and provides promising results in predicting disease activity and the occurrence of flare-up. In the next phase, we will involve treatment in the model.

Related publications:

– E. Kyrimi, S. McLachlan, K. Dube, M. R. Neves, A. Fahmi, N. Fenton, Artificial Intelligence In Medicine (submitted) (2020)

– A. Fahmi et al, International Conference on Health Informatics, 2020 (accepted paper)

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Previous work and challenge

One of the major challenges of managing chronic diseases like RA is the lack of self-monitoring tools. Clinicians usually schedule quarterly follow-up visits to monitor the activity of disease and prescribe medications. Patients can call clinicians in emergency or if a flare-up happens. Some guidelines are proposed to improve the quality of care delivery; however they do not address the discontinuity of monitoring and care. We collaborate with two rheumatologists to capture the current care pathway for RA monitoring. We drew the pathway of RA, as shown in Fig. 1, which contains the main activities (rectangular shapes) and decisions (diamond shapes). It has three entries: the regular clinic visit by a rheumatologist, the review of test results by a clinician, and when patient feels flare-up.

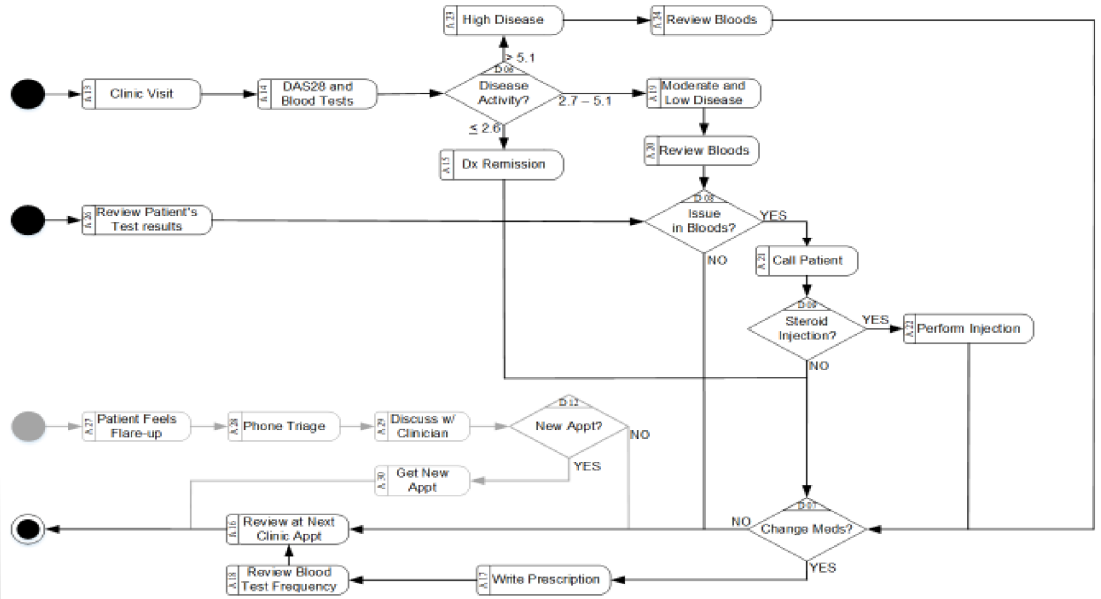
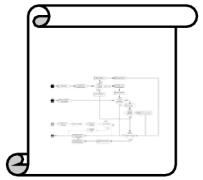


Fig 1. Pathway of RA monitoring with clinician and patient entries

Rheumatologists check signs, symptoms, and blood test results of patients and calculate their disease activity score 28 (DAS28) to categorise them into high, moderate, low, and remission. Patients receive their prescription of medications and steroids based on their DAS28. This process repeats every 3 to 6 months. We intend to create a DBN model which can predict RA disease activity and flare-ups. This model can be used for a self-monitoring system that patients enter their signs and symptoms in a weekly manner and clinicians can control their disease activity remotely.

Design



Evidence variables extracted from care pathway

Latent variables derived from experts, literature, and care pathway

Dependencies between variables and parameters of variables learnt from experts and literature

Variable Type	Variable	States	Description
Signs	TJC	None, Some, Many	Number of tender joints examined by pressing between two fingers
	SJC	None, Some, Many	Number of swollen joints observed by patient
Symptoms	GH	Low, Medium, High	Patient's general health
	Fatigue	Low, Medium, High	Patient's feeling of fatigue
	Pain	Low, Medium, High	Patient's feeling of pain
	HAQ	Mild, Moderate, Severe	Patient's disability measured by health assessment questionnaire
Blood results	ESR	Normal, Moderate, High	ESR measured in a patient's blood
	CRP	Normal, Moderate, High	CRP measured in a patient's blood

Table 1. List of evidence variables – namely signs, symptoms, and serology results – , their states and descriptions.

Variable Type	Variable	States	Description
Monitoring	Disease State	Low, Moderate, High	Categorised DAS28
	Disease Progression	Deteriorating, Stable, Improving	Disease progression trend
	Flare-up Occurrence	None, Minor, Major	Occurrence of a Flare-up
	Flare-up Duration	Short, Medium, Long	Duration of a flare-up
	Flare-up Frequency	Rare, Some, Many	Frequency of flare-up occurrence in 3 months
	Overall Flare-up	None, Mild, Severe	Patient's overall flare-up combining flare-up occurrence, duration, and frequency
	Overall Flare-up Trend	Deteriorating, Stable, Improving	Overall flare-up trend
	Overall Disease Control	Good, Alarm, Poor	Disease being overall under control, on alarm, or unmanaged
Advice	Advice	Call Hospital, Attend Appointment, Self-manage	Advice based on overall disease control, overall flare-up trend, and disease progression trend

Table 2. List of latent variables for monitoring, an advice variable , and their states and descriptions.

Latent variables involved in building model structure and parameters

Evidence variables involved in model

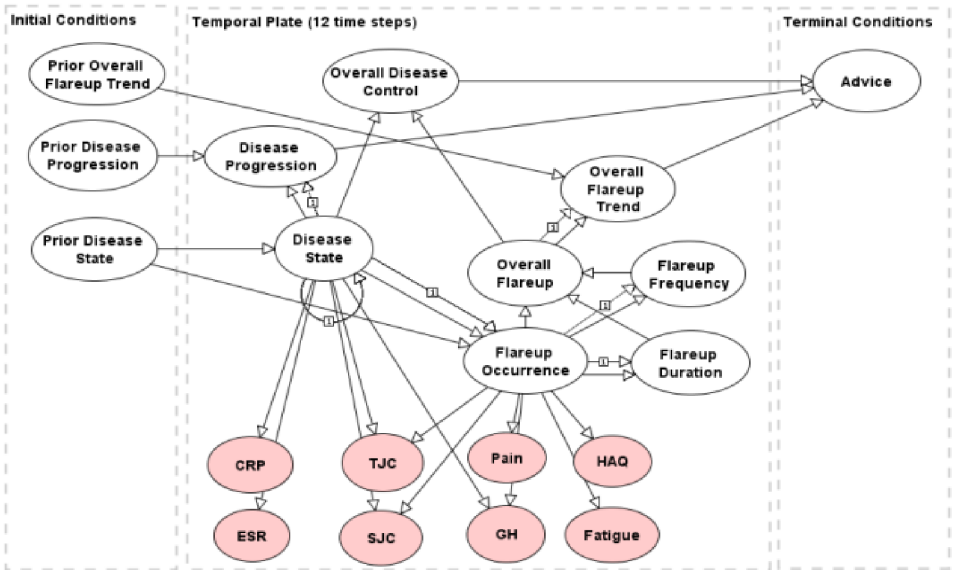


Fig 2. DBN model for self-monitoring of RA.

Results

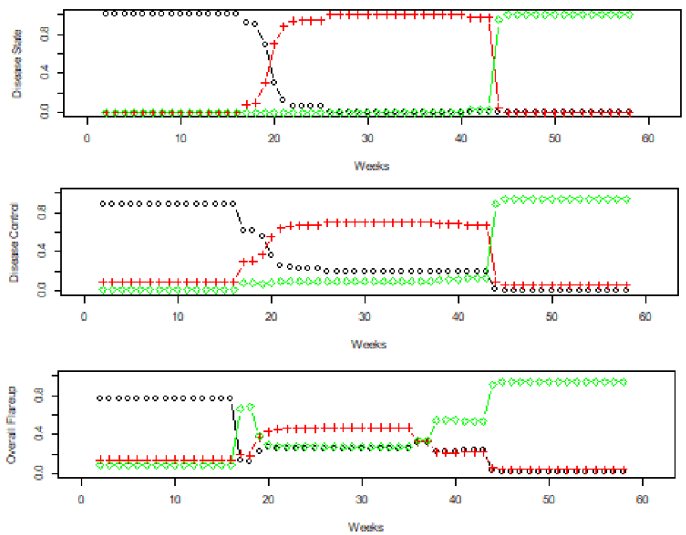


Fig 3. Improving scenario with High, Medium, and Low states (black, red, and green, respectively) for Disease State, Disease control, and Overall Flare-up.

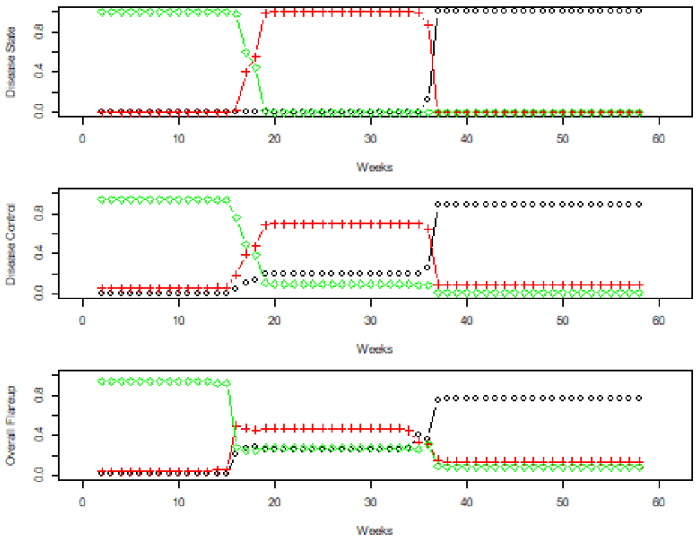


Fig 4. Worsening scenario with High, Medium, and Low states (black, red, and green, respectively) for Disease State, Disease control, and Overall Flare-up.

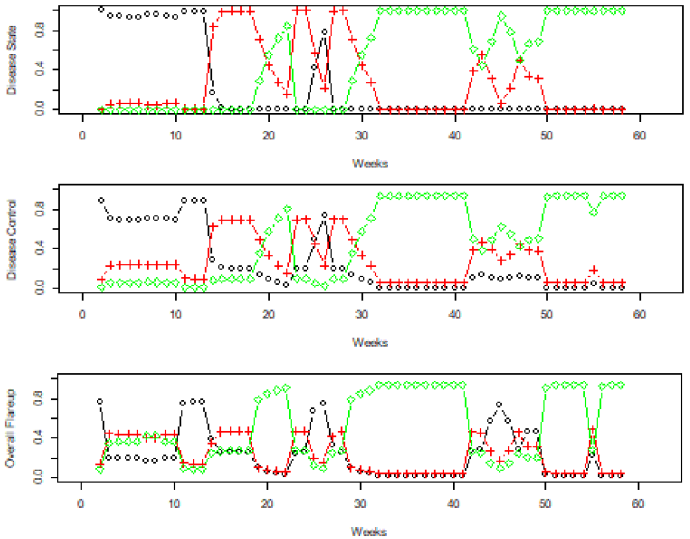


Fig 5. Fluctuating scenario with High, Medium, and Low states (black, red, and green, respectively) for Disease State, Disease control, and Overall Flare-up.

We defined three scenarios – namely, improving, worsening, and fluctuating – containing SJC, TJC, GH, ESR, and CRP evidences. These scenarios illustrate the changes of the major outcome variables: Disease State, Disease Control, and Overall Flare-up.

Two extreme scenarios of improving and worsening merely show the ability of the model to estimate the activity of disease. The fluctuating scenario expresses an active disease in the beginning which is put into remission after 12 weeks. However, it includes one major but short flare-up between 24th and 27th weeks and later a minor but long flare-up during 42nd to 49th weeks. We will add treatment variables – medication type, medication dose, and side-effects – and will further evaluate the ability of this model to monitor the disease and provide helpful advice.