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Integral Theory Diagnostic System artificial intelligence "Wayfinding" software helps unravel the complexity of multiple symptom causation prior to ligament surgery

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ABSTRACT

Background: A principal reason for developing diagnostic software is to reduce diagnostic error and facilitate a more accurate diagnosis. The National Academies of Sciences, Engineering, and Medicine publication "*Improving Diagnosis in Health Care*", has three main themes: reduce diagnostic errors, patient involvement and how to address "the increasing complexity of health care".

Aim: To describe in principle a computerized decision-tree software Integral Theory Diagnostic System (ITDS).

Materials and Methods: A node system of individual symptoms guided placement into three zones of ligament damage, anterior, middle, posterior. Percentage probabilities guided diagnosis. The system was tested against a Bayesian Network method

Results: The ITDS works well as a diagnostic aid. The diagnosis of zone of damage is displayed pictorially, with deepening colours of red indicating probability of damage. A separate button describes the iteration to the diagnosis. The Bayesian method was tested only in a fairly small number of women, it was found to be equivalent or even superior to that made by the expert.

Conclusion: The Integral Theory is holistic and its control non-linear. The contribution of the six main ligaments to pathogenesis and particular symptom causation may vary from patient to patient. A more developed version of the ITDS would be very helpful in assisting a more accurate diagnosis and reducing diagnostic error.

Keywords: Artificial intelligence; software; ITDS Integral Theory Diagnostic System; Bayesian Network

INTRODUCTION

The National Academies of Sciences, Engineering, and Medicine publication *"Improving Diagnosis in Health Care"*,[1] has three main themes: ("to err is human"), diagnostic errors which "continue to harm an unacceptable number of patients", patient involvement in their problem and "the increasing complexity of health care". The artificial intelligence ITDS* "Wayfinding" diagnostic software (pictorially summarized by Figure 1), addresses these three interdependent themes with relevance to the female pelvic floor.

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*Integral Theory Diagnostic System

The Integral Theory System (ITS)[2] is the basis of the midurethral sling, the gold standard operation for cure of stress urinary incontinence (SUI).[3] Since 1990, the ITS has evolved into a practical management system for the female pelvic floor.[2] The ITS is based on ligament pathogenesis: prolapse/bladder/bowel/pain dysfunctions, are related, mainly caused by connective tissue (collagen) damage to ligaments or related fascia, Figure 1, improved or cured by ligament repair thereof.[2] High cure rates for pelvic symptoms in the three zones of vagina, Figure 1, can be achieved by suspensory ligament repair, native tissue plication,[4] or slings.[3,5] However, singular ligament weakness may cause multiple symptoms, Figure 1. For example, urgency and frequency may be caused by ligament weakness in all three zones, Figure 1: anterior (pubourethral "PUL"); middle (cardinal "CL"); posterior (uterosacral "USL"). Therefore, accurate diagnosis is required to decide which ligament(s) to repair.

This research letter demonstrates how the Integral Theory Diagnostic System (ITDS) Artificial intelligence "Wayfinding" software and future developments applying a Bayesian Network system may help to unravel the diagnostic complexity of multiple symptom causation, Figure 1, prior to ligament surgery.

MATERIALS AND METHODS

The ITDS software is based on a decision tree approach, Figure 1. Input data include answers to a self-administered patient questionnaire, clinical tests during routine examinations and "simulated operations": supporting specific ligaments e.g., pubourethral "PUL" and observing control of stress urinary incontinence "SUI" (see video https://youtu.be/0UZuJtajCQU).

During ITDS development, a human expert trained in ITS supplied a diagnosis for each patient: inferring laxity defects in a combination of anterior, middle and posterior zones of the pelvic floor. To limit computational complexity, parameters with continuous values were mapped to discrete ranges.

Network nodes correspond to questionnaire items, specific clinical tests, physician observations during routine examinations: SUI, deficient emptying problems, urge, frequency, pelvic pain, bowel problems, previous surgery, Figure 1. Nodes were assigned approximate diagnostic probabilities

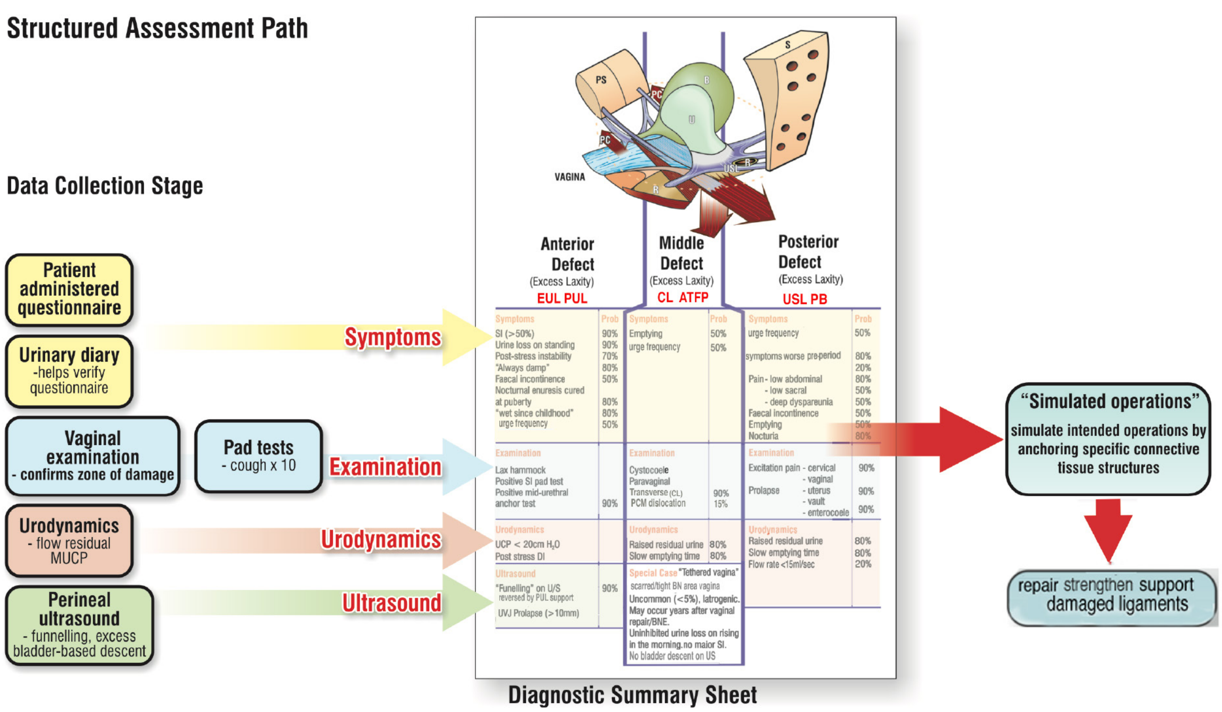

Figure 1. The ITDS diagnostic decision tree.

On the left are the six separate diagnostic "nodes" which are assessed and graded by the ITDS and Bayesian software. Both can reach a diagnosis using only the questionnaire and vaginal examination nodes.

The diagnostic Summary Sheet (middle section, Figure 1) assigns specific elements of each node into the three anatomical zones of ligament damage, anterior, (EUL, PUL), middle (CL ATFP), posterior (USL PB), with probabilities for each element. "Simulated operations" use a finger, hemostat, speculum or even pessary to mechanically support specific ligaments to reduce the symptom, e.g., SUI, urge, pain to confirm ligament pathogenesis prior to performing surgery.

ITDS: Integral Theory Diagnostic System; EUL: external urethral ligament; PUL: pubourethral ligament; CL: cardinal ligament; ATFP: arcus tendinous fascia pelvis; USL: uterosacral ligament; PB: perineal body; SUI: stress urinary incontinence

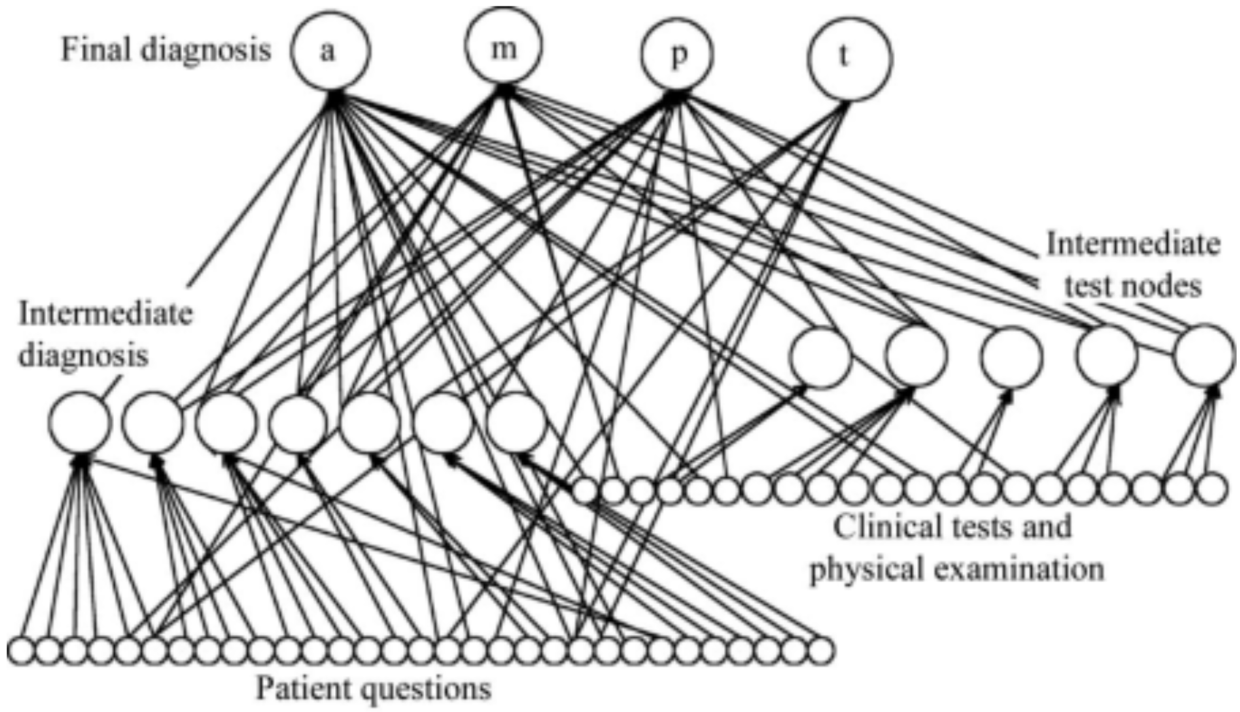

Figure 2. Bayesian Network output nodes (top row) predicting the likelihood of defects in the anterior (a), middle (m), or posterior (p) zones, or a diagnosis of tethered vagina syndrome (t). Intermediate diagnosis and test, and patient questions and clinical test nodes are as shown.

from the human expert. All nodes, Figure 1, were computed to diagnose ligament specific pathogenesis in the three zones.

The Bayesian Network connected nodes to all four final diagnoses. Matlab and BN Toolbox were used to build and train the Bayesian networks. The toolbox has facilities that enable model specification, inference and learning. Computational complexity was alleviated by using a technique called divorcing. Intermediate nodes were introduced, Figure 2, representing simplifying assumptions.

RESULTS

The ITDS decision tree approach is summarized in Figure 1. Inputs with estimated probabilities compute zone of ligament damage which needs repair: anterior, middle, posterior, pictorially displayed.

In both Bayesian Decision Tree approaches, results for accuracy, sensitivity and specificity ranged from 90% to 100% for each diagnosis. Initial assessments indicated superiority of the Bayesian Network approach.

DISCUSSION

Both software models addressed "Wayfinding" criteria[6] and the Academy's three principal themes:[1] reducing diagnostic error, patient participation (self-administered questionnaire/clinical tests), simplifying the "increasing complexity of health care". Figure 1.[1]

The Decision Tree approach, Figure 1, is a working model. While attaining reasonable levels of accuracy, it did not address the interconnectedness of the diagnoses. In the Decision Tree method, the classifier had to be executed four separate times, once for each diagnosis. The Bayesian Network approach is still experimental. Its advantage is it addresses the defects concurrently and can train the diagnostic process. Further development is required.

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ETHICS

Ethics Committee Approval: Since this article is a modelling study, it is not necessary.

Informed Consent: Since this article is a modelling study, it is not necessary.

Peer-review: Both internally and externally peer-reviewed.

DISCLOSURES

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