ORIGINAL PAPER

An Investigation of How Clinicians use Anatomical Knowledge in Diagnostic Reasoning: A Grounded Theory Study of Clinicians in Zambia

S.S. Banda

Cavendish University Zambia, School of Medicine
PO Box 34625, Lusaka, Zambia
E-mail: ssbanda@zamnet.zm

ABSTRACT

Background: The role of biomedical sciences in diagnostic reasoning is contentious but diagnostic reasoning is a principal activity in clinical settings. Such ambiguity creates a tension for medical educators who use clinically oriented anatomy teaching.

***Purposes*:** The aim of this paper is to contribute to the debate in the literature via a novel grounded theory about use of anatomy in diagnostic reasoning.

***Methods*:** Systematic grounded theory procedures were used to collect data using forty-six weeks-long participant observations, self-administered questionnaires from 168 respondents (140 doctors and 28 medical students at UTH), and unstructured interviews with doctors working in hospitals.

***Results*:** Use of anatomy in diagnostic reasoning is a 5-stage cognitive process: patient information data gathering; ascribing the information gathered to anatomical descriptors; interpretation; anatomical representation of the clinical circumstances; and diagnosis.

***Conclusion*:** Use of anatomy in diagnostic reasoning is a 5-stage cognitive process: patient information data gathering; ascribing the information gathered to anatomical descriptors; interpretation; anatomical representation of the clinical circumstances; and diagnosis. The conceptual model presented provides a framework for future research and comparison with existing theories.

BACKGROUND

We conducted a study that investigated how anatomy is used in clinical settings in hospitals in our country (designated the parent study). The study reported in this paper was an offshoot of the parent study because preliminary analyses from there showed that cognitive processes (diagnostic reasoning included) was one of the ways that doctors used anatomy in clinical settings. Our review of the literature at that point revealed that use of basic science in diagnostic reasoning was contentious in the discourses of medical problem solving and diagnostic reasoning.[1,2,3,4,5] A scan of methodological approaches also revealed an ongoing debate concerning the appropriateness of 'think aloud' protocols and 'computer modelling approaches' discussed in depth by Ericson and Simon[6]. Our parent study was predominantly qualitative using participant observations, critical incident technique and content analysis. This methodological background and the nature of questions that emerged about use of anatomy in diagnostic reasoning influenced our selection of the grounded theory methodology. In conformity with the grounded theory approach the literature on diagnostic reasoning was not reviewed comprehensively at that point and as such did not influence the study design any further. Only methodological literature was utilised.

***Key words*:** Anatomy, Diagnostic Reasoning, Grounded Theory, Clinically Oriented Anatomy Teaching

METHODS

Systematic grounded theory[7] was used to generate substantive theory about use of anatomy in diagnostic reasoning. In grounded theory methods the researcher formulates a theory, abstract, analytical schema, or model to explain a process or interaction[7]. The theory or model emerges from the data and it depicts the relations of categories (themes) earlier generated from the data. Grounded theory does not test a hypothesis. The use of grounded theory to develop theoretical constructs and/or concepts in medicine has increased[8,9,10].

The methods and duration used for the work reported here were not exclusively for the diagnostic-reasoning sub-study but were used concurrently with other components of the parent study. However, the methodology track for this work was clearly delineated.

The Research Question

When it emerged from the data from the parent study that anatomy was used in cognitive processes during clinical work, specifically diagnostic reasoning, we formulated the following research question: 'When and how is knowledge of anatomy used for diagnostic reasoning?"

Data Collection Methods

Data were generated from participant observations of doctors working in clinical settings for 46 weeks totalling 2,216 contact hours. The researcher (a medical doctor and anatomists by qualification) rotated through clinical departments as a hospital registrar: 28 weeks in surgery, eight weeks in obstetrics and gynaecology, six weeks in internal medicine and four weeks in paediatrics and child health. Data were also collected from 140 doctors and 28 medical students from a self-report written questionnaire that asked them to describe specific clinical encounters in which they judged that knowledge of anatomy was responsible for the successful outcome or lack of knowledge of anatomy for an unsuccessful outcome. Data related to cognitive processes and diagnostic reasoning was selected for the diagnostic reasoning sub-study. In addition we conducted informal individual interviews and group discussions in lounge settings. The interviews were not tape recorded. The interview guide (table 1) provided guidance for the interviews, participant observations and questionnaire analyses.

Interview and Participant Observer Guide

1. Tell me about your clinical experiences: do you ever use anatomical knowledge in your practice? (What kind of situations demand knowledge of anatomy, what kind of knowledge of anatomy do you use, how do you use it?)
2. How is your use of anatomy similar or different from those of your colleagues? Tell me about their clinical experiences with regard use of anatomy in clinical settings.
3. What are the positive consequences of having a sound knowledge of anatomy? What are the negative consequences of not having sound knowledge of anatomy? Are these similar for other people with your kind of clinical responsibilities?
4. Tell me about your experiences with making a diagnosis: do you ever use anatomical knowledge in making a diagnosis? (What kind of situations demand knowledge of anatomy for diagnosis, what kind of knowledge of anatomy do you use, how do you use it?)
5. How is your use of anatomy in making a diagnosis similar or different from those of your colleagues? Tell me about their clinical experiences with regard use of anatomy in making a diagnosis.
6. What factors or influences do you feel contribute to use of anatomy in clinical settings?

* Questions were adapted to the context of the situation observed or interviewed about.

Sampling

The doctors observed, interviewed and those that responded to the questionnaire were not recruited or identified before the study. Theoretical sampling was used to select information-rich respondents or those involved in clinical situations that had theoretical relevance to diagnostic reasoning.

Data Analysis

Data collection, coding and analysis were run concurrently from the beginning of the study (also concurrently with the parent study). We followed the grounded theory steps of Strauss and Corbin as described by Stern[11]. The researcher wrote field notes from participant observations, interviews and questionnaires each day. On a continuous basis the field notes were collated, read and re-read. As the researcher read the field notes labels and categories were created. Constant comparison of data with previous data continued but later related to more to the categories that had emerged. The products of labelling and categorising were concepts which later became the building blocks of our grounded theory construction. The categories and concepts generated in the coding schemes were later condensed into broader categories that were mutually exclusive. Table 2 shows the axial coding sheet.

Concept Development

Reduction, selective sampling of the literature and selective sampling of data were involved in indentifying one emergent core variable. Working with a reduced number of categories and informed by selective reference to the literature on the concepts that had emerged tentative explanatory theories were considered. Collapsing labels, categories and concepts and propositional theorising continued until when no new ones were emerging (saturation). Only then did the researcher commence the identification of a core variable. The selection of the core variable was aided by memos (notes about concepts or theories the researcher was contemplating) generated continuously from data collection to analysis and selective literature reviews. Strauss requires the core variable to have six important features including high frequency counts, linkages to various data, centrality in explaining variations in the data, implications for general or formal theory and promotes maximum variation and analyses[11]. In our study, 'anatomical representation', the abstract transformation of the clinical data into a composite anatomical explanation (representation) of how the clinical problem is explained anatomically and how it represents the clinical diagnosis, was the core variable. For example, when "bi-temporal hemianopia" is anatomically represented as "a lesion at the optic chiasma then anatomical representation has been achieved. Continuous 'memoing' and reference to extant literature facilitated the transition from description of the data to a theoretical level.

RESULTS

All the reported results were derived inductively from the interviews, field notes, and written questionnaires.

Information Gathering

The respondents agreed that the first encounter with patients involved collecting information about the

Axial Coding Sheet

<table>
<tr><th>Labels, Categories</th><th colspan="2">Concepts</th><th>Core Variable</th></tr>
<tr><td>History Taking

Chief complaint, Systems Review, Medical History, Family History, Social History</td><td rowspan="3">Patient information data gathering</td><td rowspan="7">(Clinical Reasoning Process)

Interpretation
1. Problem Identification
(analysis)
2. Explanation
(pathogenesis)
3. Understanding
(conceptualising)
4. Problem solving
(intervention)</td><td rowspan="7">Anatomical Representation</td></tr>
<tr><td>Physical Examination

General examination
Systemic examination</td></tr>
<tr><td>Investigation

Laboratory
Imaging</td></tr>
<tr><td>Systems

Respiratory, nervous, cardiovascular, gastro-intestinal, genital-urinay, integumentary, musculoskeletal, blood</td><td rowspan="4">(Pre-existing Knowledge of anatomy)

Anatomical Descriptors</td></tr>
<tr><td>Regions

Head and neck, thorax, abdomen, pelvis, upper limb, lower limb</td></tr>
<tr><td>Organs

Brain, heart, lungs, liver, spleen, intestines, pancreas, thyroid etc.</td></tr>
<tr><td>Tissues

Nervous, muscle, epithelia, connective tissue</td></tr>
</table>

patient using history-taking, and physical examination, after which laboratory and/or imaging investigations were ordered. In some cases the information generated from these activities helped to confirm or rule earlier suspicions of the diagnosis. For example, "if you are suspecting cerebral malaria, it is important to do a lumbar puncture to rule out meningitis". In other situations a combination of symptoms and signs alone lead to immediate recognition of the disease, for example, "a history of extreme thirst, excessive desire for food, and passing a lot of urine lead to the automatic diagnosis of diabetes mellitus." The consideration of data from the data gathering stage was followed by interpretation of the data. We now report the findings of that interpretation when it was limited to situations that required knowledge of anatomy to formulate a diagnosis.

Interpretation

For the cases that required knowledge of anatomy participants considered the data generated from data gathering in four aspects. The following are examples from the data. The context is described and then followed by an anatomical note to show the authors reflections on the experience of the context described:

Problem Identification

"Ward round…consultant reviewing patient with hydrocephalus and increased intracranial pressure. Anatomical note: Noted that necessarily the first step is to notice the gross abnormal size of the head…"

"…loss of contour of the shoulder in a patient with a dislocated shoulder. X-rays confirmed the dislocation – subcoracoid anterior dislocation of the right shoulder. Anatomical note: Familiarity with normal form is important for one to identify altered form."

When doctors assessed a patient the form was inspected for deviation from the norm. Recognition of such deviation served as a beginning point in problem identification. Knowledge of normal structure and function enabled the doctor to identify altered structure and function.

Explanation

"Reviewing a patient with a patient with complete heart block (pulse 45 – 50 per minute)." Anatomical note: The consultant relied on the knowledge of the electrical conducting system of the heart (in this case the role of SA and AV nodes) to explain the slow rate and even consider heart block as a differential diagnosis."

"…patient had multiple septic spots on the head. Consultant asked students why it would be important to examine the neck thoroughly. It was not immediately apparent to the final-year students that the issue under consideration was the lymphatic drainage of those septic spots into the lymph node groups of the neck."

"Post-admission round, reviewing patient with head injury. Anatomical note: the worsening level of consciousness was explained using anatomical concepts i.e., brain herniation through the foramen magnum and tentorial notch."

There were many instances in clinical practice in which the doctor could only explain the clinical condition encountered, anatomically. In some situations the pathogenesis of the clinical condition was anatomical (e.g. for spina bifida), in others knowledge of anatomical relations explained why pathology on a particular site manifested elsewhere. The example above was a case in point.

Understanding

To understand, in this context, refers to the ability to evaluate the appropriate knowledge one possesses and to make meaningful interpretation and offer explanations, and interventions based on this knowledge. As a result of this understanding, one can then conceptualise – have a mental grasp of what is 'going on' in a disease process.

"On a ward round in paediatrics reviewing patient with hydrocephalus . Anatomical note: Discussed the cerebrospinal fluid (CSF) circulation, and the ventricular system of the brain. Noted that the SRMO was not conversant with the CSF circulation and the ventricular system."

Anatomical knowledge was essential, in some clinical conditions, for the doctor to conceptualise what was going on in the patient. It helped understand the signs and symptoms, complications, and interventions. Lack of this anatomical knowledge, in such cases, prevented understanding of the clinical phenomenon.

Problem-solving

"Patient with cardiac tamponade was considered in a patient diagnosed with TB pericarditis. Physician referred patient to cardiac surgeon for pericardial tap and explained the patients symptoms would be relieved as a result."

Problem-solving is a wide and encompassing concept. It can literally include all the situations cited above. In this case it is being applied to those circumstances in which the relief of the problem was the aim. Knowledge of anatomy had dramatic implications for perceiving the pathological mechanism and the result of an intervention.

The work of a doctor invariably involves some cognitive processes. Anatomy did have a role in these cognitive processes in many clinical conditions.

Selective Literature Review

In the contemporary literature on diagnostic reasoning there is no clear consensus on the use of anatomy and other basic sciences for diagnostic reasoning[1,12,13,14]. However, three approaches are widely acknowledged:

(a) hypothetico-deductive models[15] which are similar to the "Test Operate Test Exit (TOTE) programmes" from cognitive psychology[16]. Such rubrics help to overcome limitations of memory capacity and help make the problem space searchable become manageable[15]. Many scholars consider the hypothetical-deductive reasoning a primary clinical reasoning strategy[17,18].

(b) Structural semantics[19,20,21,22] and prototype theory[5] agree that expert diagnosticians use semantic qualifiers and representative exemplars to build a repository of information about diseases (illness scripts) and use it to recognise disease patterns and select an appropriate diagnosis in a non-analytical process (pattern recognition).

(c) Encapsulation theory[23,24,25,26] suggests that in earlier stages medical knowledge exists as pathological mechanisms which through 'compilation'[26] becomes stored as parts of information about disease.

Although participants in our study were not asked to define diagnostic reasoning nor prompted about what is known in the literature about diagnostic reasoning their responses matched closely with these three concepts described above.

Use of Anatomy in Diagnostic Reasoning: Tissue Organ Region System Analysis

Ascription

For some clinical cases, our data suggests that the purpose of the routine history and physical examination and investigations was to consider possibilities of involvement (assigned +) or non-involvement (assigned -) of body systems, regions, organs and tissues. In this paper we use the phrase 'anatomical descriptors' to collectively refer to systems, regions, organs, and tissues. Systems include: respiratory, cardiovascular, central nervous, gastro-intestinal, musculoskeletal, genital-urinary, and blood, while regions include the head and neck, thorax, abdomen, pelvis, upper limb and lower limb. The organs include, for example, the brain, heart, lungs, gut, spleen and reproductive one, etc. Lastly, tissues refer to nervous tissue, muscle, epithelia and connective tissue. The ascription of involvement or non-involvement was a product of testing possibilities and confirming or disconfirming them. Respondents also reported assigning a system or region etc, purely by recognising a phenomenon from previous encounters (theoretical or experiential). The process of ascription (attribution) was a function of both knowledge of function and structure of the anatomical descriptors and knowledge of diseases/clinical conditions.

For ease of reference we have selected the acronym TORS, the reverse order of the first letters, for **S**ystems **R**egions **O**rgans **T**issues.

Anatomical Representation

The 'anatomical representation' stage constituted the abstract transformation of the clinical data into a composite anatomical representation of how the clinical problem is explained anatomically and how it represents the clinical diagnosis. In the transformation process for example, "paralysis" becomes " a severed nerve resulting in muscle denervation", "enlarged head of hydrocephalus" becomes "resultant enlargement of head due obstruction in the cerebral ventricular system" and "bi-temporal hemianopia" becomes " a lesion at the optic chiasma." This way, clinical problems are transformed into anatomical representation, a process akin to problem representation described in semantic qualifier literature[12,27,28].

It appears knowledge of basic anatomical concepts regarding systems, regions, organs, and tissues enhanced the establishing of associations between anatomical descriptors and symptoms, signs and other relevant clinical information.

The stages of ascription, interpretation and representation were dependent on depth and scope of knowledge of anatomy of the doctor as well as on theoretical or practical experience with clinical encounters. The findings described above are represented in a conceptual model: "Tissue Organ Region System (TORS) Analysis Model of Diagnostic Reasoning".

DISCUSSION

The model of diagnostic reasoning presented in this paper has identified three forms of use of anatomy in diagnostic reasoning – anatomical representation by identifying which anatomical descriptors can account for signs, symptoms and other related clinical information; use of hypothetical-deductive reasoning to confirm or disconfirm explanatory hypotheses about which anatomical descriptor is involved; and tacit retrieveal of anatomy knowledge that over time has become incorporated into information about disease. However, these processes apply mostly when in the first instance the kind of case demands explicit knowledge of anatomy. Some cases do not require much anatomy for a diagnosis[29,30].

Several limitations of this model should be noted. It is a conceptual framework and has not been empirically tested. The model may not be exhaustive and universal in its forms and elements about diagnostic reasoning. The model has however, concordance with the 'dual-process'[31] which puts forward two systems, system 1 (heuristics, intuitive) and system 2 (systematic, analytical) approaches of diagnostic reasoning. This is advantageous for educators because explicitly promoting the use of both analytical and experiential knowledge has already been shown to be an effective pedagogic strategy[32]. There is a dearth of works that render pedagogic advice with regard diagnostic reasoning[12,13] our study could contribute in this regard.

CONCLUSION

The model has several implications for medical education, especially for, clinically oriented anatomy teaching (COAT). It serves as a reminder that anatomy is actually being used in diagnostic reasoning. It also assures that early use of clinical context in anatomy teaching may have merit because the anatomy being learned in clinical context becomes embedded into the students' developing repository of clinical information. However, it also reminds us of the need for clear elucidation of the anatomy that is important in diagnostic reasoning, and the circumstances in which it is required - the problem-solving fraternity appears to be agreed that mastery of content supplants problem-solving strategy [1,17,19]. Testing the TORS analysis conceptual model naturally should be the next steps for further research. This could be important because the model can help students build up a coherent stable mental representation of disease categories due to the explicit connections between anatomy and clinical information that the TORS model promotes.

REFERENCES

1. Norman, G.R. (2005). Research in Clinical Reasoning: Past history and current trends. *Medical Education*, 39:98-106.
2. Schmidt, H.G., Norman, G.R., Boshuizen, H.P. (1990). A congnitive perspective on medical expertise: theory and implications. *Academic Medicine*, 65: 611-621.

3. Patel, V., Groen, S.J., and Scott, H.M. (1988). Biomedical knowledge in explanations of clinical problems by medical students. *Medical Education*, 22:398-406.
4. Patel, V.L., Arocha, J.F., Kaufman, D.R. (1994). Diagnostic reasoning and expertise. In: Medin D.L. (ed). The Psychology of Learning and Motivation. San Diego: Academic Press.
5. Bordage, G. (2007). Protypes and Semantic Qualifiers: from past to present. *Medical Education*, 41:1117-1121.
6. Ericson, K. And Simon, H. (1993). Protocol analysis: verbal reports as data. Revised edition. Cambridge, MA: The MIT press.
7. Strauss, A.L and Corbin, J.M (1998). Basic of qualitative research: Grounded theory procedures and techniques. Newbury Park (CA): Sage.
8. Tavakol, M., Torabi, S. And Zeinaloo, A. (2006). Grounded Theory in Medical Education Research. *Medical Educ Online*; 11:30 Available from http://www.med-ed-online.org
9. Jeon Y.H. (2004). The application of grounded theory and symbolic interactionism. *Scand J Caring Sci*; 18: 249-56.
10. Kennedy, T. And Lingard, L. (2006). Making sense of grounded theory in medical education. *Medical Education;* 40(2):101 – 108.
11. Stern P.N. (1980). Grounded theory methodology: its uses and process. *Image* (IN); 12:20-3.
12. Bowen, J (2006). Educational Strategies to Promote Clinical Diagnostic Reasoning. *New England Journal of Medicine*, 355:2217-2225.
13. Norman, G. (2006). Building on Experience – The Development of Clinical Reasoning. N*ew England Journal of Medicine;* 355 (21): 2251-2252.
14. Elstein, A.S., Schwarz, A. (2002). Clinical Problem Solving and Diagnostic Decision Making: Selective Review of the Cognitive Literature. *BMJ;* 324:729-732.
15. Elstein, S.A., Shulman, L.S., Sprafka, S. A. (1978). Medical Problem Solving: An Analysis of Clinical Reasoning. Cambridge, MA: Harvard University Press; 276.
16. Cohen, G. (1977). The Psychology of Cognition. Academic Press. London. ISBN 0-12-1787750.
17. Bloch, R.F., Hofer, D., Feller, S., and Hodel, M. (2003). The role of strategy and redundancy in diagnostic reasoning. *BMC* 3: 1, doi:10.1186/1472-6920-3-1.
18. Yoshinori, N., Kunihiko, M., Hiroshi, I., Masatomo, K., and Tuguya, F. (2002). Quantitative Evaluation of the Diagnostic Thinking Process in Medical Students. *J Gen Intern Med.* 17 (11):848-853.
19. Coderre, S., Mandin, H., Harasym, P.H., Fick, G.H. (2003). Diagnostic reasoning strategies and diagnostic success. *Medical Education;* 37:695-703.
20. Eva, K., Norman, G., Neville, A., Wood, T, Brooks, L. (2002). Expert-Novice Differences in Memory: A Reformulation. *Teaching and Learning in Medicine*, 14 (4): 257 – 263.
21. Mandin, H., Jones, A., Woloschuck, W and Harasym, P. (1997). Helping Students to Learn to Think Like Experts When Solving Clinical Problems. *Academic Medicine*, 72 (3): 173-178.
22. Bordage, G, and Zacks, R. (1984). The structure of medical knowledge in the memories of medical students and general practitioners: Categories and Prototypes. *Medical Education;* 18:406-16.
23. Woods, N. (2007). Science is fundamental: the role of biomedical knowledge in clinical reasoning. *Medical Education*, 41: 1173-1177.
24. Donnon, T, and Violato, C. (2006). Medical Student's Clinical Reasoning Skills as a Function of Basic Science Achievement and Clinical Competency Measures: A Structural Equation Model. *Academic Medicine*, 81(10) October supplement.
25. De Bruin, A.B., Schmidt, H.G., Rikers, R.M (2005). The Role of Basic Science Knowledge and Clinical Knowledge in Diagnostic Reasoning: A Structural Equation Modelling Approach. *Academic Medicine*, 80(8): 765-773.
26. Schmidt, H., and Boshuizen, H. (1992). Encapsulation of biomedical knowledge. In: Evans, D., Patel, V. Eds. Advanced Models of Cognition for Medical Training and Practice. New York: Springer Verlag; 265-82.
27. Bordage, G. (1999). Why did I miss the diagnosis? Some cognitive explanations and educational implications. *Academic Medicine,* 75: Suppl: S138-S143.
28. Custers E.J., Regehr, G., Norman, G.R. (1996). Mental Representations of Medical Diagnostic

Knowledge: A Review. *Academic Medicine;* 71: Suppl: S55-S61.

29. Banda, S.S. (2009a). The Case Anatomical Knowledge Index (CAKI): A Novel Method Used to Assess Anatomy Content in Clinical Cases. *Anatomical Sciences Education;* 2(1):9-18.
30. Banda, S.S. (2009b). The Case Anatomical Knowledge Index as a Tool for Selecting Clinical Cases for Clinically Oriented Anatomy Teaching: Approach and Content. *Medical Journal of Zambia*; 36(1):43-50.
31. Croskerry, P (2009). A Universal Model of Diagnostic Reasoning. *Academic Medicine;* 84 (8):1022-1028. Doi:10.1097/ACM.obo13e311ace703.
32. Ark, T.K., Brooks, L.R., Eva, K.W. (2006). Giving learners the best of both worlds: do clinical teachers need to guard against teaching pattern recognition to novices? *Academic Medicine;* 81:404-409.