Checklist of cognitive contributions to diagnostic errors: A tool for clinician-educators

J M Naude, MB ChB, FCP (SA); **V C Burch**, MB BCh, MMed, PhD, FCP (SA), FRCP (Lond)

Department of Medicine, Faculty of Health Sciences, University of Cape Town, South Africa

Corresponding author: *J M Naude (drnaude@gmail.com)*

Background. Experienced clinician-educators readily identify trainees making diagnostic errors, but lack pedagogic expertise to make educational diagnoses and provide feedback. Simple tools are needed to address this challenge.
Objectives. To characterise cognitive contributions to diagnostic errors (CCDEs) that trainees make in patient encounters and examiners' perceptions of a checklist to document and provide feedback on these errors.
Methods. Thirty examiners used a 17-item checklist to document CCDEs made by medical residents failing patient encounters in a national specialist examination. A survey was used to explore examiners' perceptions of the checklist to document and provide feedback on these errors.
Results. There were 98/264 failed patient encounters (37%). Ninety-four completed checklists documented 691 CCDEs (median of 7 per encounter). Data synthesis was more problematic than data gathering, faulty knowledge or data interpretation ($p<0.001$ for all comparisons). The 'top 5' individual CCDEs were failure to elicit history and/or examination findings; poor knowledge of clinical features (illness scripts); case synthesis ('putting the case together'); and misinterpretation of clinical findings. Examination-related errors were more common than history-related errors ($p<0.0001$). Examiners found the checklist comprehensive and easy to use. They thought it could improve feedback on CCDEs to unsuccessful candidates and guide remediation and training at the bedside.
Conclusions. A 17-item checklist identified three priority CCDEs requiring remediation and training in medical residency programmes: improving clinical skills; developing adequate illness scripts; and putting a case together. Examiners endorsed the use of the checklist and its potential to improve feedback and training, addressing CCDEs made by trainees.

Afr J Health Professions Educ 2018;10(3):153-158. DOI:10.7196/AJHPE.2018.v10i3.1059

Up to 5 - 15% of clinical encounters lead to diagnostic errors, i.e. delayed, incorrect or missed diagnoses.[1] The mortality, morbidity and cost of these errors are considerable;[2-5] despite 40 years of technological advances they remain largely unchanged.[6] Strategies to address this major cause of patient harm must identify healthcare professionals at increased risk of making errors, characterise the errors they make and provide targeted, evidence-based intervention.[1]

Taxonomies of the 'root' causes of diagnostic errors have been developed with a view to error reduction and remediation.[1,7,8] Graber *et al.*[1] identified three types of diagnostic errors (no-fault, system and cognitive) and reported that cognitive and system factors contributed to diagnostic errors. They clustered the root cognitive contributions to diagnostic errors (CCDEs) in four categories: faulty knowledge, data-gathering errors, data synthesis difficulties and failed verification of the data used to make the diagnosis. Schiff *et al.*[7] categorised errors according to the phase of the patient consultation process: access/presentation to healthcare, patient-practitioner encounter (history and physical examination), ordering and interpreting tests, making a diagnosis (assessment) and further consultation or referral and follow-up. Retrospective studies using this taxonomy have found that practitioner-patient encounters (history and physical examination), ordering and interpreting of tests and making a diagnosis (assessment) contributed most to errors.[3,8-10]

Most of these studies were conducted in mixed populations of healthcare professionals[1,3,9,10] and did not focus on residents who are known to be at increased risk of making medical errors.[11] Two studies of residents showed that both cognitive and system factors contributed to diagnostic errors.[12,13] These studies of malpractice claims or self-reported data are, however, >10 years old and did not focus on characterising CCDEs. Furthermore, their retrospective design limits the accuracy of the data owing to hindsight and outcomes biases, incomplete patient records, variable reviewer reliability and uncertainty about the final diagnoses made.[4,7,14] Prospective studies characterising CCDEs that residents make in patient consultations are needed to better align current training needs and remediation efforts.

A central part of the diagnostic process is data gathering, i.e. taking a history and performing a physical examination of the patient. While a thoroughly conducted history and physical examination can lead to an assessment in at least 60% of cases,[6,15,16] errors related to these contribute to diagnostic errors in up to 61% of cases.[1,3,8-10] As summarised by Feddock,[17] the variable clinical competence of trainees[18,19] may be ascribed to many factors, including progressive decline in bedside teaching, limited direct observation during real patient encounters, and limited feedback regarding clinical skills and performance in the workplace. Knowledge of clinical skills deficits contributing to diagnostic errors that residents make in authentic clinical contexts is required to address this matter.

Remediation of CCDEs requires a structured approach: multiple assessments to confirm the problem; an educational diagnosis (characterisation of the causes); feedback with a targeted remediation plan; and reassessment.[20-23] While experienced clinician-educators can

readily identify trainees 'in trouble', they often lack pedagogic expertise to make an educational diagnosis and to plan remediation.[24] This situation is aggravated by a paucity of evidence to guide remediation in medical education,[20] and few practical tools to help clinician-educators address diagnostic errors in clinical settings.[20,21]

Tools to assist clinician-educators to characterise CCDEs residents make in practice are limited. Audétat *et al.*[21-23] published a taxonomy of 6 common cognitive contributions to diagnostic errors, and a guide to diagnose and manage these problems in clinical training settings. One of the ongoing challenges, however, especially for clinician-educators with limited pedagogic expertise, is a reluctance to provide feedback when there is a lack of documentation of errors and limited knowledge of what to specifically document (the educational diagnosis).[25] Simple tools to characterise, document and report on CCDES observed in trainee-led patient consultations are needed.

Using checklists to reduce or remediate diagnostic errors is gaining traction in the literature. Differential diagnosis checklists successfully prompt consideration of additional diagnostic possibilities,[26,27] and limited data suggest that they can improve diagnostic accuracy in emergency departments.[27] To date, checklists have not been used to characterise and properly document CCDEs observed during patient consultations. This may help clinician-educators to provide better feedback on, and remediation of, these errors observed during high-stakes examinations and at the bedside, where trainees simultaneously require clinical supervision and teaching.

Context of the study

In South Africa (SA), medical graduates complete 6 years of undergraduate training, 3 years of mandatory public service and 4 years of postgraduate training in preparation for the specialist physician licensing examinations of the Colleges of Medicine of SA (CMSA). The specialist examination of the College of Physicians, a member college of the CMSA, assesses theoretical knowledge of the basic sciences and medicine, interpretation of diagnostic tests and clinical competence. The latter comprises three real patient encounters followed by a bedside oral presentation and discussion of each case. Examiners mark candidates' performance using a criterion-referenced scoring rubric and write a detailed description of the case presentation and ensuing discussion. The absence of a standard method of writing these notes and characterising (diagnosing) the CCDEs in failed patient encounters make it challenging for examiners to provide detailed feedback to, and plan remediation for, unsuccessful candidates.

Checklist of cognitive contributions to diagnostic errors

In 2015, these ongoing challenges prompted the College of Physicians to develop a checklist for characterising (diagnosing) and documenting CCDEs to provide feedback and plan remediation for unsuccessful candidates. The checklist, based on the literature,[1,7,8,21] includes 17 CCDEs, grouped in four categories: knowledge gaps, data-gathering errors, data-interpretation errors and data-synthesis difficulties. The checklist was reviewed and pilot tested by a panel of examiners prior to implementation in 2015.

Research questions

The newly implemented checklist (Appendix 1) provided an opportunity to use the specialist examination setting to prospectively address two questions:

- What are the priority CCDEs clinician-educators need to address in training and remediation programmes for medical residents preparing for specialist examinations?
- What are examiners' perceptions of the utility of the new checklist to characterise, document and provide feedback on CCDEs to unsuccessful candidates and trainees making diagnostic errors on ward rounds and during bedside teaching activities?

Methods

Research setting

This study was conducted during the specialist examination of the College of Physicians held at three large SA teaching hospitals in October 2015.

Research design

This study used a prospective cross-sectional descriptive design.

Study population

All medical residents and clinician-educators involved in the examination were invited to participate in the study.

Study procedure

Before commencing the 3-day examination proceedings, a 1-hour workshop was held to orientate examiners with regard to the purpose, structure and use of the checklist. Each morning examiners were requested to complete a checklist for all failed patient encounters, i.e. use the tick boxes to record CCDEs and write a short description of each. Examiners completed a checklist immediately after assigning a final score to failing candidates. On the final day of the proceedings, examiners completed an anonymous 15-item closed-ended survey using a 5-point Likert response scale ranging from 'totally disagree' to 'totally agree'. Completed surveys and anonymised checklists were collected by a member of the research team at the conclusion of the examination proceedings.

Diagnoses of patients included in the examination

The medical illness for which a patient was included in the examination was defined as the primary diagnosis. For example, a patient with mitral stenosis was coded as primary diagnosis: valvular heart disease; discipline: cardiology. Where patients had more than one diagnosis, the one accounting for most of the key clinical features (history and examination findings) was recorded as the primary diagnosis. In most of these cases the other problems were typically related to the primary diagnosis. For example, a patient with rheumatoid arthritis and pulmonary fibrosis complicated by pulmonary hypertension was coded as: primary diagnosis: rheumatoid arthritis; discipline: rheumatology.

Data analysis

Checklist and survey data were collated using Microsoft Excel version 15.0.4823.1004 (Microsoft Corp., USA) spreadsheets, and statistical analysis was performed using Stata version 15 (StataCorp., USA). Likert-scale responses of the survey were reported in 3 categories: agree, neutral and disagree. Variables were compared using the Kruskal-Wallis test (numerical), χ^2 goodness-of-fit test (categorical) and a Bonferroni correction

for multiple comparisons. A p-value <0.05 was considered significant, except for multiple comparisons, where p<0.01 was used.

Ethical approval

Institutional approval for this study was granted by the Human Research Ethics Committee, University of Cape Town (ref. no. HREC 733/2015). Written informed consent was obtained from all participants.

Results

Patient encounters

A total of 88 candidates and 30 examiners from all 8 medical schools in SA participated in the examination. There were 98/264 failed patient encounters (37%). Four incomplete checklists were excluded and the remaining 94 (96%) were analysed.

Patient diagnoses

Forty-one unique diagnoses were present in 94 failed patient encounters. Table 1 shows that cardiac patients (28.7%) and neurology patients (18.1%) comprised 46.8% of failed encounters, and valvular heart disease was the commonest missed/incorrect diagnosis (18.1%). Failed encounters involving haematological and gastrointestinal illnesses were not reported.

Cognitive contributions to diagnostic errors

Examiners identified 691 CCDEs in 94 failed patient encounters; median (range) of 7 (1 - 14) per encounter. Only 3 candidates failed a patient encounter on the basis of 1 - 2 CCDEs. They made multiple history and physical examination errors, which they failed to recognise during the case discussion, whereas limited time prevented further discussion of the investigation and management of the respective patients. The discipline-specific CCDE rate was not significantly different (p=0.6) (Fig. 1). Nephrology was excluded because it included only 1 failed encounter.

Table 2 shows that, by category, data synthesis was more problematic than data gathering, faulty knowledge or data interpretation (35.2% v. 25.8% v. 21.9% v. 17.1%); χ^2=48.2, p<0.0001; for all comparisons).

'Top 5' cognitive contributions to diagnostic errors

The top 5 CCDEs comprised 44.7% of all CCDEs. Errors to correctly gather (38.2%) and interpret (21.7%) the history and examination findings, which collectively comprised 60% of the top 5, were more common than faulty knowledge of the clinical features of the case (23.2%) and failure to integrate and synthesise all the findings, i.e. 'put the case together' (16.8%) (Table 3).

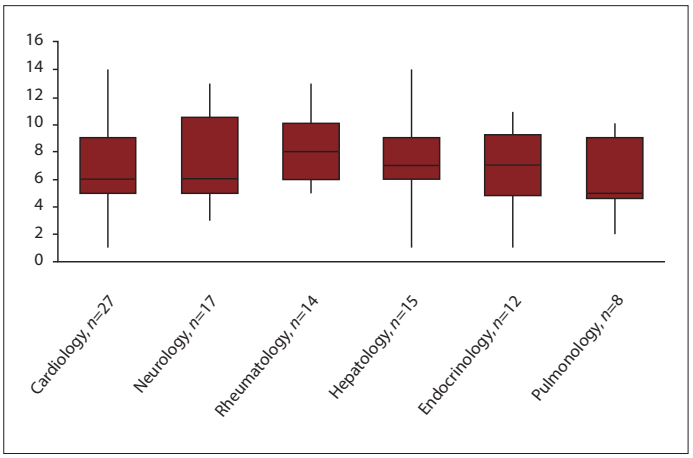

Fig. 1. Errors (median, interquartile range, range) per patient encounter grouped by discipline.

Table 1. Primary missed diagnoses in 94 patient encounters, categorised by discipline

Discipline	*n*
Cardiology (*N*=27)	
Valvular heart disease	17
Atrial septal defect	2
Atrial fibrillation	2
Hypertrophic obstructive cardiomyopathy	2
Dilated cardiomyopathy	1
Hypertensive heart disease	1
Ischaemic heart disease	1
Constrictive pericarditis	1
Hepatology (*N*=15)	
Portal hypertension	4
Chronic liver disease	4
Hepatocellular carcinoma	2
Viral hepatitis	2
Cryptogenic cirrhosis	1
Gaucher's disease	1
Drug-induced liver injury	1
Rheumatology (*N*=14)	
Systemic lupus erythematosus	6
Rheumatoid arthritis	3
Scleroderma	2
Systemic sclerosis	1
Polymyositis	1
Gout	1
Nephrology (*N*=1)	
Autosomal dominant polycystic kidney disease	1
Neurology (*N*=17)	
Cerebrovascular accident	7
Parkinson's disease	3
Spinocerebellar ataxia	2
Syringomyelia	1
Myasthenia gravis	1
Cerebellitis	1
Neurofibromatosis	1
Myeloradiculopathy	1
Endocrinology (*N*=12)	
Acromegaly	4
Hyperthyroidism	3
Diabetes mellitus	2
Cushing's syndrome	2
Prader-Willi syndrome	1
Pulmonology (*N*=8)	
Asthma	2
Sarcoidosis	2
Cystic fibrosis	1
Kartagener's syndrome	1
Post-tuberculosis bronchiectasis	1
Idiopathic pulmonary fibrosis	1

Clinical features-related errors

Table 4 shows that 40% of 691 CCDEs were ascribed to failure to correctly elicit and/or interpret the clinical features of the case. Data gathering was more problematic than interpretation (χ^2=21.96, p<0.0001). Physical examination-related errors were more common than history-related errors (χ^2=24.28, p<0.0001).

Examiners' perceptions of the checklist

All examiners completed the survey. Most (n=22; 73.3%) completed the checklists, including a written description of CCDEs, in <5 minutes; 8 required up to 10 minutes and 1 examiner required >10 minutes.

Table 5 shows that the checklist was easy to use at the bedside, efficiently identified and recorded all the CCDEs previously observed and some not previously considered or identified. Most examiners thought it would improve feedback and intended to use it. Examiners also thought that the checklist could guide trainee teaching and feedback on CCDEs at the bedside. Some even felt that the checklist could improve patient care by improving diagnostic accuracy, more efficient use of investigations, reducing treatment errors and reducing length of hospital stay.

Table 2. Cognitive contributions of diagnostic errors (N=691) reported in 94 failed patient encounters, expressed as a proportion (total number of errors in parentheses)

Category of errors	Proportion (n)	95% CI
Category 1: Knowledge gaps (n=151)		
Clinical features	0.48 (72)	0.40 - 0.56
Investigations	0.21 (31)	0.14 - 0.28
Basic science	0.17 (26)	0.12 - 0.24
Treatment	0.15 (22)	0.09 - 0.21
Category 2: Data-gathering errors (n=178)		
Missed key findings of examination	0.39 (70)	0.32 - 0.47
Missed key findings of history	0.27 (48)	0.21 - 0.34
Reported physical signs not present	0.24 (43)	0.18 - 0.31
Incorrect history obtained	0.10 (17)	0.06 - 0.15
Category 3: Data-interpretation errors (n=119)		
Inability to interpret physical signs	0.56 (67)	0.47 - 0.65
Inability to interpret history	0.27 (32)	0.19 - 0.36
Inability to interpret investigations	0.17 (20)	0.11 - 0.25
Category 4: Data-synthesis errors (n=243)		
Unsatisfactory integration/synthesis	0.21 (52)	0.16 - 0.27
Unable to identify key features	0.19 (45)	0.14 - 0.24
Unable to make connections between data	0.18 (43)	0.13 - 0.23
Unable to prioritise patient problems	0.16 (39)	0.12 - 0.21
Early to focus on a diagnosis	0.13 (32)	0.09 - 0.18
Unable to generate alternate diagnosis	0.13 (32)	0.09 - 0.18

CI = confidence interval.

Discussion

This study explored the use of a novel 17-item checklist to characterise (make an educational diagnosis) and document CCDEs that residents made during failed real patient encounters in a specialist examination in SA. It formed part of a project to educate clinician-educators/examiners about CCDEs and teach them to use a checklist to characterise and record CCDEs to provide standardised, structured feedback to unsuccessful examination candidates. The use of the checklist to guide feedback to trainees about CCDEs observed at the bedside during ward rounds and teaching was also explored.

In this study, as elsewhere,[1,3,8-10] CCDEs were multifactorial. Our median error rate per patient, which was slightly higher than that in retrospective studies,[1,3,4,9] may have been due to the prospective study design. Furthermore, unlike studies of mixed populations of doctors[1,3,9,10] or physicians only,[8] we focused on residents, where higher error rates were expected.[11,12]

History and physical examination-related errors accounted for 60% of the top 5 CCDEs identified in this study. Examination-related errors were more common. In other studies the contribution of physical examination errors range from 14% to 42%,[1,3,8-10] with higher rates in studies that include more residents.[3,9,10] This is consistent with work that reports differences in clinical competence between residents and physicians.[11,12] We observed similar CCDE rates in patient encounters across a broad spectrum of clinical disciplines. This is consistent with studies showing that trainees lack a broad range of physical examination skills.[19] The predominance of cardiology and neurology patients in this study is consistent with other work showing poorer physical examination competence in these disciplines.[19]

Faulty knowledge of clinical features contributed 23% to the top 5 CCDEs. Figures in published studies vary from 10%[1] to 84%,[5] suggesting that knowledge gaps may be underestimated in some retrospective studies. This examination-based study may have been better suited to identifying knowledge gaps at the bedside. As candidates in this study had already passed the theory examinations, inadequate illness scripts (knowledge of the clinical features of the illness applied in a real patient setting) rather than theoretical knowledge gaps may have been the problem.[1] Further studies are needed to confirm this suggestion.

As observed elsewhere, we found data gathering more problematic than data interpretation.[3,8,9] This suggests that practical clinical skills rather than knowledge of the meaning of clinical findings is the key problem. This finding may also have been influenced by the study setting, in which examiners do not pursue interpretation of missed clinical features, i.e. the examination aims to determine what candidates know rather than what they don't know. Studies in non-examination settings are needed to better understand our observation.

Table 3. Top 5 cognitive errors (N=309) made during 94 failed patient encounters, expressed as a proportion (total number of errors in parentheses)

Cognitive errors	Proportion (n)	95% CI
Knowledge gap of clinical features of presenting illness	0.23 (72)	0.19 - 0.29
Failure to elicit key physical examination findings	0.23 (70)	0.18 - 0.28
Failure to interpret physical examination findings	0.22 (67)	0.18 - 0.27
Unsatisfactory integration and synthesis of case	0.17 (52)	0.13 - 0.21
Failure to elicit key features of patient's history	0.16 (48)	0.12 - 0.20

CI = confidence interval.

Table 4. Clinical features-related errors (*N*=277) made during 94 failed patient encounters, expressed as a proportion (total number of errors in parentheses)

	History		Physical examination		
Clinical features-related errors	**Proportion (*n*)**	**95% CI**	**Proportion (*n*)**	**95% CI**	**Total**
Failure to elicit key clinical findings	0.17 (48)	0.13 - 0.22	0.25 (70)	0.20 - 0.31	118
Findings reported incorrectly/not present	0.06 (17)	0.04 - 0.10	0.16 (43)	0.11 - 0.20	60
Misinterpretation of clinical findings	0.12 (32)	0.08 - 0.16	0.24 (67)	0.19 - 0.30	99
Total	0.35 (97)	0.29 - 0.41	0.65 (180)	0.59 - 0.71	277

CI = confidence interval.

Table 5. Examiners' perceptions of the checklist of cognitive contributions to diagnostic errors

Survey item	**Disagree, *n* (%)**	**Neutral, *n* (%)**	**Agree, *n* (%)**
1. I provide verbal feedback to unsuccessful examination candidates	9 (30)	0	21 (70)
2. The quality of feedback I provide is comprehensive and additional information would not be useful*	17 (65.4)	5 (19.2)	4 (15.4)
3. The checklist provided an efficient means of *identifying* diagnostic errors	2 (6.7)	0	28 (93.3)
4. The checklist provided an efficient way of *recording* diagnostic errors	1 (3.3)	6 (20.0)	23 (76.7)
5. Based on your experience, the checklist included all the common causes of diagnostic errors I have encountered in the past	4 (13.3)	6 (20.0)	20 (66.7)
6. Compared with your current practice, the checklist could be a better way of providing structured feedback to unsuccessful candidates	1 (3.3)	0 (0)	29 (96.7)
7. This checklist listed causes of diagnostic errors you have not considered or identified previously*	7 (24.1)	10 (34.5)	12 (41.4)
8. This checklist could be a useful way of guiding bedside teaching and providing feedback for residents preparing for the examination*	1 (3.4)	1 (3.4)	27 (93.1)
9. I plan to use this checklist to provide structured feedback to unsuccessful candidates at my training centre	1 (3.3)	6 (20)	23 (76.7)
10. I would consider using the checklist to guide bedside teaching and feedback for residents	1 (3.3)	3 (10)	26 (86.7)
11. I would consider using the checklist to guide bedside teaching and feedback for undergraduate medical students	2 (6.7)	6 (20)	22 (73.3)
12. The checklist can be easily utilised at the bedside	1 (3.3)	7 (23.3)	22 (73.3)
If the checklist were to be routinely used in clinical training it may contribute to improving patient care in terms of:			
13. Improved diagnostic accuracy	1 (3.3)	7 (23.3)	22 (73.3)
14. More efficient use of investigations	2 (6.7)	14 (46.7)	14 (46.7)
15. Reduction in treatment errors	3 (10)	14 (46.7)	13 (43.3)
16. Reduction in length of hospital stay	2 (6.7)	17 (56.7)	11 (36)

*Survey items 2, 7 and 8 do not add up to 30, as they were not answered by all participants.

In this study, we found that clinician-educators without pedagogic expertise could use a simple checklist to systematically characterise (make an educational diagnosis), document and report on CCDEs contributing to poor academic performance in a structured and standardised manner. In so doing, the checklist addresses two key issues that limit clinical supervisors' willingness to report on poor academic performance, i.e. lack of proper documentation of errors and uncertainty about what to record (educational diagnosis).[25]

Study limitations

In this study, patient consultation times were longer than in clinical practice. However, despite extra time, candidates made many errors. While examination-induced anxiety may have contributed to this observation, it is known that more consultation time does not routinely improve diagnostic accuracy.[11] Although examiners were enthusiastic about the utility of the checklist to provide feedback on poor performance in high-stakes examinations and clinical teaching, the data were self-reported and reflected anticipated rather than actual behaviour. Future studies are needed to determine whether examiners adopt the checklist for feedback and remediation of CCDEs in unsuccessful candidates and those preparing for the examination.

Study strengths

Although this study only included one cycle of examination data, it represented candidates and examiners from all 8 SA medical residency programmes. This prospective study of CCDEs focusing on residents obviated some of the limitations of retrospective studies previously described.[4,7,14] We could not find similar studies conducted in other international medical residency programmes. So, while more data are needed to confirm the findings of this study, it is an important step in the right direction.

Conclusion

This study has answered the two research questions it set out to address. First, we identified 3 priority CCDEs that require focused training and remediation in residency training programmes in SA: inadequate clinical skills, limited quality of illness scripts (knowledge about the key features of an illness), and difficulty putting the case together. This does not require extensive reading and studying, i.e. 'more of the same', but rather customised remediation and

faculty support, as discussed in the literature.[22,23] Second, we showed that the simple checklist used in this study helped clinician-educators/examiners without pedagogic expertise to diagnose and record CCDEs contributing to poor performance in high-stakes examinations. Furthermore, clinician-educators/examiners were of the opinion that this tool might help them to provide comprehensive, standardised feedback to unsuccessful examination candidates and trainees making diagnostic errors at the bedside during ward rounds and teaching. This study also suggests that clinical examinations may be a rich source of prospective data to better understand diagnostic errors trainees make and potential remediation strategies.

Acknowledgements. We acknowledge the contributions of the Colleges of Medicine of South Africa and those of the examiners at the October 2015 examinations.

Author contributions. JN: drafted the research protocol, captured data, interpreted data and wrote the first draft of the manuscript. VCB: conception, study design, data interpretation and critical review of the final manuscript. Both authors approved the publication of this manuscript.

Funding. None.

Conflicts of interest. This manuscript forms part of a postgraduate dissertation of J M Naude.

1. Graber ML, Franklin N, Gordon R. Diagnostic error in internal medicine. Arch Intern Med 2005;165(13):1493-1499. https://doi.org/10.1001/archinte.165.13.1493
2. Graber ML. The incidence of diagnostic error in medicine. BMJ Qual Saf 2013;22(2):1-8. https://doi.org/10.1136/bmjqs-2012-001615
3. Singh H, Giardina TD, Meyer AND, Forjuoh SN, Reis MD, Thomas EJ. Types and origins of diagnostic errors in primary care settings. JAMA Intern Med 2013;173(6):418-425. https://doi.org/10.1001/jamainternmed.2013.2777
4. Zwaan L, Thijs A, Wagner C, van der Wal G, Timmermans DRM. Relating faults in diagnostic reasoning with diagnostic errors and patient harm. Acad Med 2012;87(2):149-156. https://doi.org/10.1097/acm.0b013e31823f71e6
5. Zwaan L, de Bruijne M, Wagner C, et al. Patient record review of the incidence, consequences, and causes of diagnostic adverse events. Arch Intern Med 2010;170(12):1015-1021. https://doi.org/10.1001/archinternmed.2010.146
6. Kirch W, Schafii C. Misdiagnosis at a university hospital in 4 medical eras. Medicine 1996;75(1):29-40. https://doi.org/10.1097/00005792-199601000-00004
7. Schiff GD, Kim S, Abrams R, et al. Diagnosing diagnosis errors: Lessons from a multi-institutional collaborative project. In: Henriksen K, Battles JB, Marks ES, et al., eds. Advances in Patient Safety: From Research to Implementation (Volume 2: Concepts and Methodology). Rockville, MD: Agency for Healthcare Research and Quality (US), 2005:255-278.
8. Schiff GD, Hasan O, Kim S, et al. Diagnostic error in medicine. Arch Intern Med 2009;169(20):1881-1887. https://doi.org/10.1001/archinternmed.2009.333
9. Kachalia A, Gandhi TK, Puopolo AL, et al. Missed and delayed diagnoses in the emergency department: A study of closed malpractice claims from 4 liability insurers. Ann Emerg Med 2007;49(2):196-205. https://doi.org/10.1016/j.annemergmed.2006.06.035
10. Singh H, Thomas EJ, Khan MM, Petersen LA. Identifying diagnostic errors in primary care using an electronic screening algorithm. Arch Intern Med 2007;167(3):302-308. https://doi.org/10.1001/archinte.167.3.302
11. Norman GR, Monteiro SD, Sherbino J, Ilgen JS, Schmidt HG, Mamede S. The causes of errors in clinical reasoning: Cognitive biases, knowledge deficits, and dual process thinking. Acad Med 2017;92(1):23-30. https://doi.org/10.1097/acm.0000000000001421
12. Singh H, Thomas EJ, Petersen LA, Studdert DM. Medical errors involving trainees. Arch Intern Med 2007;167(19):2030-2036. https://doi.org/10.1001/archinte.167.19.2030
13. Jagsi R, Kitch BT, Weinstein DF, Campbell EG, Hutter M, Weissman JS. Residents report on adverse events and their causes. Arch Intern Med 2005;165(22):2607-2613. https://doi.org/10.1001/archinte.165.22.2607
14. Wears RL, Nemeth CP. Replacing hindsight with insight: Toward better understanding of diagnostic failures. Ann Emerg Med 2007;49(2):206-209. https://doi.org/10.1016/j.annemergmed.2006.08.027
15. Peterson MC, Holbrook JH, von Hales D, Smith NL, Staker LV. Contributions of the history, physical examination, and laboratory investigation in making medical diagnoses. West J Med 1992;156(2):163-165. https://doi.org/10.1097/00006254-199210000-00013
16. Paley L, Zornitzki T, Cohen J, Friedman J, Kozak N, Schattner A. Utility of clinical examination in the diagnosis of emergency department patients admitted to the department of medicine of an academic hospital. Arch Intern Med 2011;171(15):1394-1396. https://doi.org/10.1001/archinternmed.2011.340
17. Feddock CA. The lost art of clinical skills. Am J Med 2007;120(4):374-378. https://doi.org/10.1016/j.amjmed.2007.01.023
18. Sharma S. A single-blinded, direct observational study of PGY-1 interns and PGY-2 residents in evaluating their history-taking and physical-examination skills. Perm J 2011;15(4):23-29. https://doi.org/10.7812/tpp/11-106
19. Ramani S, Ring BN, Lowe R, Hunter D. A pilot study assessing knowledge of clinical signs and physical examination skills in incoming medicine residents. J Grad Med Educ 2010;2(2):232-235. https://doi.org/10.4300/jgme-d-09-00107.1
20. Hauer KE, Ciccone A, Henzel TR, et al. Remediation of the deficiencies of physicians across the continuum from medical school to practice: A thematic review of the literature. AcadMed 2009;84(12):1822-1832. https://doi.org/10.1097/acm.0b013e3181bf3170
21. Audétat M-C, Laurin S, Sanche G, et al. Clinical reasoning difficulties: A taxonomy for clinical teachers. Med Teach 2013;35(3):984-989. https://doi.org/10.3109/0142159x.2012.733041
22. Audétat M-C, Laurin S, Dory V, Charlin B, Nendaz MR. Diagnosis and management of clinical reasoning difficulties: Part I. Clinical reasoning supervision and educational diagnosis. Med Teach 2017;39(8):792-796. https://doi.org/10.1080/0142159x.2017.1331033
23. Audétat M-C, Laurin S, Dory V, Charlin B, Nendaz MR. Diagnosis and management of clinical reasoning difficulties: Part II. Clinical reasoning difficulties: Management and remediation strategies. Med Teach 2017;39(8):797-801. https://doi.org/10.1080/0142159x.2017.1331034
24. Audétat M-C, Dory V, Nendaz M, et al. What is so difficult about managing clinical reasoning difficulties? Med Educ 2012;46(2):216-227. https://doi.org/10.1111/j.1365-2923.2011.04151.x
25. Dudek NL, Marks MB, Regehr G. Failure to fail: The perspectives of clinical supervisors. Acad Med 2005;80(Suppl):S84-S87. https://doi.org/10.1097/00001888-200510001-00023
26. Graber ML, Sorensen AV, Biswas J, et al. Developing checklists to prevent diagnostic error in emergency room settings. Diagnosis 2014;1(3):223-231. https://doi.org/10.1515/dx-2014-0019
27. Ely JW, Graber MA. Checklists to prevent diagnostic errors: A pilot randomized controlled trial. Diagnosis 2015;2(3):163-169. https://doi.org/10.1515/dx-2015-0008

Accepted 20 February 2018.

Appendix 1. Checklist of cognitive contributions to diagnostic errors

KNOWLEDGE GAPS	DATA-GATHERING DIFFICULTIES
☐ Basic sciences	☐ Failed to identify key data during interview
☐ Clinical features of illness	☐ Obtained incorrect data during interview
☐ Investigations	☐ Failed to identify key signs on examination
☐ Treatment	☐ Found clinical signs that were not present
☐ Other, please explain below	☐ Other, please explain below
DATA INTERPRETATION/MEANING/ SIGNIFICANCE	**DIFFICULY IN MAKING A DIAGNOSIS**
☐ History findings	☐ Unable to identify key features to make a Dx
☐ Physical examination findings	☐ Unable to prioritise patient's key problems
☐ Investigations	☐ Early focus on a Dx, unable to change mind
☐ Other, please explain below	☐ Unable to generate alternative diagnoses
	☐ Unable to make connections between data
	☐ Unsatisfactory integration and synthesis
	☐ Other, please explain below

COMMENTS

OTHER REASONS FOR FAILING THE CASE THAT ARE NOT LISTED ABOVE