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Investigating the appropriateness of physician-ordered diagnostic computed tomography for patient management in a rural hospital in New South Wales, Australia

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AIM: To examine the performance of "appropriate" versus "inappropriate" computed tomography (CT) and to examine whether physicians who practise in a rural hospital in NSW Australia, achieved imaging appropriateness in their ordering of diagnostic CT examinations.

MATERIALS AND METHODS: An audit of the electronic medical records of medical ward inpatients (during the 2016/2017 financial year) was carried out. De-identified data were extracted for all patients who had undergone diagnostic CT while on admission. Using the SPSS analytical software, chi-square tests for independence were conducted to check for difference between appropriate and inappropriate CT imaging.

RESULTS: Of all the CT procedures, 92% were found to be appropriate. Appropriate CT confirmed the provisional diagnosis in more instances than inappropriate CT (132 versus three). This observed difference was significant with a small size effect (chi-squared [1, n=362]=8.58, p=0.003, φ=0.16). Similarly, appropriate CT significantly facilitated a change in the proposed direction of care (140 versus 40) (chi-squared [1, n=362]=7.75, p=0.005, φ=0.16). In addition, appropriate CT which confirmed diagnosis, resulted in a change in the proposed direction of care as opposed to inappropriate CT (115 versus one; chi-squared [1, n=362]=8.11, p=0.004, Cramer's V=0.24).

CONCLUSION: Specialist physicians who practise in a rural hospital setting achieved CT appropriateness. Appropriate CT is beneficial to patient care. Adhering to recommended imaging guidelines is essential for achieving imaging appropriateness.

Introduction

In clinical practice, the use of diagnostic radiological imaging, such as magnetic resonance imaging (MRI) and computed tomography (CT), is essential for accurate

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diagnosis and appropriate treatment of many medical and surgical conditions. The use of these imaging procedures has been shown to positively influence clinical outcomes for many patients who present with various medical and surgical conditions[1]; however, the availability of such imaging procedures vary from one health district to another,[2–4] and the cost of performing these procedures contribute significantly to the state and national health budgets.[2–5] The availability may influence their use by clinicians and patients alike. Some authors have suggested that overuse of imaging is more likely to occur in clinical settings where access to such procedures is somewhat unlimited.[6–8] Other factors that may influence the use of imaging procedures include: health system factors, cost to patients, presumed usefulness, defensive medicine, skill level of referring physician, and nature of illness.[6–8]

The concept of imaging appropriateness was proposed following the observation that geographic areas with similar populations tend to show variations in their use of diagnostic imaging for clinical management of patient conditions.[9] This is particularly important if the possible risks of imaging procedures (e.g., exposure to ionising radiation, false-positive and false-negative results, and unexpected incidental findings) are factored into the clinical scenario.[10–14] Therefore, it is proper that the use of diagnostic imaging procedure is guided by acceptable standardised evidence-based referral guidelines, the advantages of which include early exclusion of potentially dangerous disease, reassurance to patients, prompt and accurate diagnosis, institution of effective treatment, appropriate referral, and cost-effective utilisation of available resources.[6,15] In other words, when acceptable standardised imaging guidelines are utilised (together with recommended clinical decision support tools), medical practitioners are more likely to achieve imaging appropriateness, thereby reducing unnecessary patient exposure to radiation whilst also limiting wastage of health resources and reducing the overall cost of healthcare.[6,12,15,16]

As per the recommendation of the Royal Australian and New Zealand College of Radiologists (RANZCR), the use of guidelines for diagnostic imaging procedures are encouraged, and the guidelines prepared by the Royal College of Radiologists of the UK and the American College of Radiologists are recommended for use by the RANZCR[17]; however, the decision to order an imaging investigation or refer a patient for an imaging procedure is most likely influenced by a multiplicity of factors which may vary based on the clinical settings, treating physician, health district location, and availability of resources.[6] This is particularly important as available guidelines do not generally declare when a test is necessary, as the final decision with regards to ordering an imaging procedure rests on the shoulders of the treating physician. More so, when the use of appropriate clinical decision support tools are not mandatory, a diagnostic approach for referring patients for diagnostic imaging procedure may develop among physicians who work together in a health district and acquire group skills as they feed on each other's knowledge, skills, and clinical expertise. This may lead to over-utilisation of imaging procedures. Conversely, it is also possible that a varied application of imaging guidelines by an individual physician may occur, with the possibility of disregard or poor application of recommended imaging guidelines in clinical practice.

In this study, the research team sought to understand if specialist physicians, who practise in a rural hospital setting in New South Wales (NSW) Australia, achieve imaging appropriateness in referring patients for diagnostic CT imaging. Therefore, an audit of all CT examinations ordered by the five specialist physicians who were practising in the rural hospital during the financial year (2016/2017) was carried out. The diagnostic relevance and impact of appropriate imaging procedures on patient care and management were also investigated. Thus, the present study examined whether appropriate CT helped confirm the clinical diagnosis and whether it facilitated a positive change in the proposed direction of care.

Materials and methods

Ethics approval for this study was granted by the Human Research Ethics Committee (HREC) of the Local Health District. A waiver of consent was approved by the HREC as the study involved review of existing case notes and was categorised as low-risk human research. Using the local hospital electronic medical records, an audit of all the medical ward inpatient admissions during the 2016/2017 financial year (i.e., 1 July 2016 to 30 June 2017) was undertaken. De-identified data were extracted for all patients who had diagnostic CT (as ordered by specialist physicians) while admitted to the medical ward of a rural hospital in regional NSW. All follow-up imaging was excluded from this study as the primary focus of interest was diagnostic CT imaging. For each patient who underwent CT while on the ward, the following information was collected and entered into an Excel spreadsheet for the purpose of data collection and data analysis: age, gender, presenting complaints, provisional diagnosis, and results of CT imaging. In addition, by simply recording "yes" or "no" for each CT examination performed, the data collection process also answered the following questions: do the results confirm the provisional diagnosis and did the findings change the proposed direction of care?

In many clinical scenarios, a number of diagnoses (with equal weighting) are usually investigated during the CT examination. Hence, the differential diagnoses should be considered when determining if the CT examination confirmed a provisional diagnosis. Therefore, for the purpose of this study, the differential diagnoses as indicated by the physician on the CT referral forms (which were all stored in the electronic case notes) were all considered. If the CT results confirmed any of the stated differential diagnoses, the CT examination was recorded as "yes" for confirming the provisional diagnosis.

The determination of a change in the proposed direction of care was made by reviewing the electronic case

records of all patients before and after CT referrals to confirm if new or additional treatment was commenced after the CT examinations were reported. A change in the proposed direction of care is defined as commencing an entirely new treatment regime or addition of other treatments that otherwise would not have been commenced in the absence of the findings revealed by CT imaging. In some instances, the absence of findings on CT may also result in the introduction of new or additional treatment; this was also classified as a change in the proposed direction of care.

By using a combination of the American College of Radiology Appropriateness Criteria and Canadian Association of Radiologist Diagnostic Imaging Referral Guidelines, all CT examinations were classified as either appropriate or inappropriate. CT was considered appropriate if it fitted both guidelines simultaneously. In addition, the electronic case records were reviewed to confirm that relevant/required preliminary laboratory investigations (e.g., inflammatory biomarkers) and preliminary imaging (e.g., radiography), which may contribute to the diagnostic process, were undertaken before CT was requested. By this, all the CT referrals were appropriately classified. Furthermore, the level of the appropriateness of all CT was also determined and subclassified as:

Optimal: consistent with the guidelines and the imaging choice is rated highest in the guidelines/criteria; adequate: consistent with part of the guidelines, confirms diagnosis without further imaging required and rules out other differentials; suboptimal: potentially part of the guidelines, potentially inappropriate use of resources despite confirming diagnosis/exclusion of other differentials; and inadequate: not part of the guidelines, inappropriate use of resources, further imaging required, unnecessary repeat of imaging (see the Electronic Supplemental Material for additional explanations).

In order to fully examine the appropriateness of the imaging referrals, the research questions listed in Box 1 were formulated.

Appropriate statistical analyses were performed on the data collected using the Statistical Package for the Social Science analytical software (SPSS, IBM, Armonk, New York, USA). More specifically, appropriate chi-squared tables of categorical variables were generated by cross-tabulations (Electronic Supplementary Material, Tables 1–3), and chi-square tests for independence were performed to check for significance association between the following pair of categorical variables: “Do the results confirm the provisional diagnosis” and “Did the findings change the proposed direction of care?”; “Appropriateness of CT referrals” and “Do the results confirm the provisional diagnosis?”; “Appropriateness of CT referrals” and “Did the findings change the proposed direction of care?”. In addition, a 3×3 cross-tabulation was performed (Table S4) and a chi-square test for independence was conducted to check for significance association between “Appropriateness”, “Do the results confirm the provisional diagnosis?” and “Did the findings change the proposed direction of care?”

Results

Of a total of 2,139 admissions during the 2016/2017 financial year, a total of 365 CT referrals for diagnostic purpose were conducted. Three CT referrals were excluded due to incomplete data, thus only 362 CT referrals were included in the final analyses. The mean age of the 362 patients (187 women and 175 men (F:M=52:48) who were admitted in the medical ward during this period was 69.2 (SD=15.33).

Of the 362 CT referrals done for diagnostic purposes, 333 CT were deemed appropriate, representing 92% of all CT procedures. Only 29 CT (8%) examinations were found to be inappropriate (Table 1). As shown in Table 1, most CT referral examinations (69.6%) were appropriately ordered and categorised as optimal use of CT for diagnostic purposes. Of all the CT examinations, 13.8% were deemed adequate, whereas, 8.6% and 8% were found to be suboptimal and inadequate, respectively.

The results of the CT did not confirm the provisional diagnosis in a higher proportion of cases (227, 62.7%; Electronic Supplementary Material, Table S1). CT facilitated a change in the proposed direction of care (or additional

Box 1. Research questions answered during the study.

Appropriateness
Are the CT referrals appropriate or not?
What are the categories of appropriateness of the CT referrals?
Appropriateness related to diagnosis
Do the results of the CT confirm the provisional diagnosis?
Do the findings of the CT change the proposed direction of care?
How often do CT examinations that confirm the provisional diagnosis result in a change in the proposed direction of care?
Based on appropriateness, are there any difference in CT examinations that confirm the provisional diagnosis when compared to CT examinations that did not confirm the provisional diagnosis?
Based on appropriateness, are there any differences in CT examinations that resulted in a change in the proposed direction of care compared to CT findings that did not result in a change in the proposed direction of care?
Based on appropriateness, how often do CT examinations confirm the provisional diagnosis and cause a change in the proposed direction of care?

Table 1
Frequencies and categories of appropriate and inappropriate diagnostic CT imaging.

Appropriateness	Appropriateness level	Frequency (%)	
Yes	Optimal	252 (69.6)	333 (92)
	Adequate	50 (13.8)	
	Suboptimal	31 (8.6)	
No	Inadequate	29 (8)	29 (8)
Total		362 (100)	362 (100)

care) in 144 cases (39.8%) as opposed to 218 cases (60.2%) when the CT referrals did not facilitate a change in the proposed direction of care (Electronic Supplementary Material, Table S1).

Do the results confirm the provisional diagnosis and did the findings change the proposed direction of care?

The results obtained from the chi-square test for independence of the two categorical variables indicated that, in a higher number of cases, CT that confirmed the provisional diagnosis facilitated a change in the proposed direction of care (116, representing 80.6%), when compared to CT that did not confirm the provisional diagnosis (28, representing 19.4%; Fig 1). The observed difference was statistically significant with a large effect size (chi-squared [1, n=362]= 188.32, p<.001, φ=0.73; Electronic Supplementary Material, Table S1).

Appropriateness of CT referrals and do the results confirm the provisional diagnosis?

The chi-squared table for these categorical variables is presented in Electronic Supplementary Material, Table S2. The result obtained from the chi-square test for independence of the two categorical variables showed that appropriate CT resulted in confirmation of the provisional diagnosis in more instances than inappropriate CT (132 versus three; Fig 2). This observed difference was significant with a small size effect (chi-squared [1, n=362]=8.58, p=0.003, φ=0.16).

Appropriateness of CT referrals and did the findings change the proposed direction of care?

The results obtained from the chi-square test for independence of the two categorical variables indicated that appropriate CT resulted in a change in the proposed direction of care in more instances than inappropriate CT (140 versus four; Fig 3). This observed difference was significant with a small effect size (chi-squared [1, n=362]= 7.75, p=0.005, φ=0.16; Electronic Supplementary Material, Table S3).

Appropriateness, do the results confirm the provisional diagnosis, and did the findings change the proposed direction of care?

The 3×3 table for these categorical variables is presented in Electronic Supplementary Material, Table S4. The result obtained from the chi-square test for independence of the three categorical variables indicated that appropriate CT which confirmed diagnosis, resulted in a change in the proposed direction of care in more instances than inappropriate CT which confirmed provisional diagnosis (115 versus one; Fig 4). This observed difference was significant with a small size effect (chi-squared [1, n=362]=8.11, p=0.004, Cramer's V=0.24).

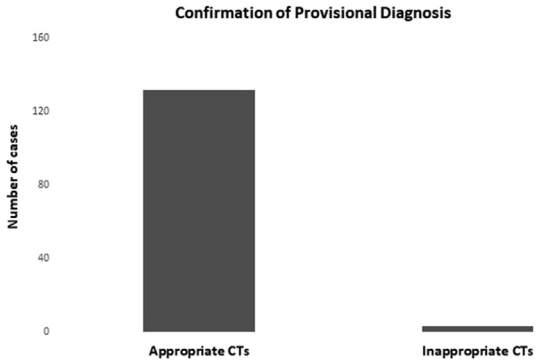

Figure 2 Frequencies of cases that confirmed the provisional diagnosis for appropriate versus inappropriate CT.

Discussion

CT referral

From the findings of the present study, 92% of all the CT referrals, which were carried out for diagnostic purposes, were found to be appropriate. This suggests a higher level of

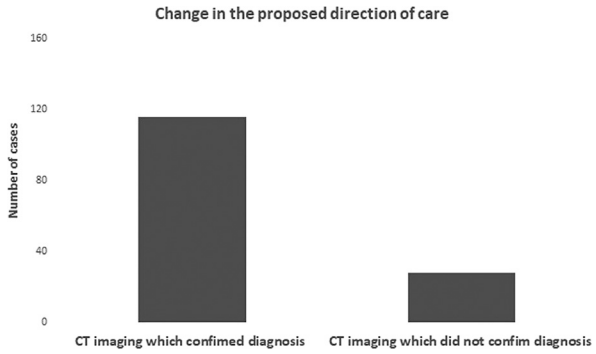

Figure 1 Frequencies of cases with a change in the proposed direction of care for CT that confirmed the provisional diagnosis versus CT that did not confirm the provisional diagnosis.

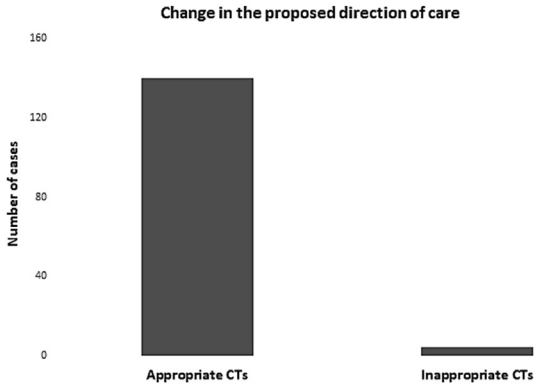

Figure 3 Frequencies of cases with a change in the proposed direction of care for appropriate versus inappropriate CT.

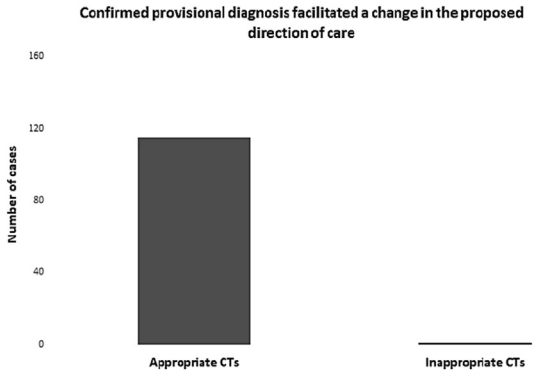

Figure 4 Frequencies of cases where the confirmed provisional diagnosis facilitated a change in the proposed direction of care for appropriate versus inappropriate CT.

performance with regards to the use of CT for diagnostic processes. Therefore, it can be deduced that the specialist physicians who practise in this rural hospital achieve imaging appropriateness at a very high standard. In the Australian health system, a major index for measuring performance and excellence in healthcare delivery is what is referred to as the "Key Performance Index" (KPI).[18,19] This index is determined by the health department of individual states and territories. Generally, most KPIs are set at a value between 90% and 95% to encourage excellence in health service delivery.[18,19] Going by this reference, a minimum value of 90% appropriateness will be expected for the use of CT for diagnostic purposes. Therefore, the performance of the specialist physicians at this rural hospital (regarding appropriate use of CT for diagnostic purpose) was commensurate with what will be expected by the health service department.

In the light of previous publications suggesting that inappropriate imaging could be up to 35% of all imaging (especially in urban settings),[20,21] the performance of the specialist physicians with regards to imaging appropriateness (at 92%) in this rural hospital is somewhat better than what has been previously reported in some urban medical facilities.[21,22] This is a significant finding considering that this was a small/medium size local health facility, with only five specialist physician servicing a population of over 40,000 people. Thus, the correct and judicious use of imaging resources is not limited to specialist practitioners in urban and large cities, because, similar (or better) outcomes can be achieved in rural and regional areas. Furthermore, this finding may be a justification for the provision of health resources for use in regional areas, and can also serve as evidence that the provision of standard healthcare and the utilisation of advanced technological based imaging procedures in rural and regional areas by health practitioners may be as good as that obtained in large cities; however, regarding health service delivery, "suboptimal" and "inadequate" imaging may both be considered as functionally and possibly economically inappropriate imaging, and they may represent CT examinations that could have been avoided in the care of patients. From the current study, these two sub-categories of imaging constitute 16.6% of all CT referrals that were carried out in this rural health facility during the study period. Therefore, there is still room for performance improvement in ordering CT examinations.

Characteristics and usefulness of appropriate CT

With regards to CT "confirming provisional diagnosis" and facilitating a "change in the proposed direction of care", 37.3% of all imaging referrals confirmed a provisional diagnosis or produced positive findings, while 39.8% of all CT referrals facilitated a change in the proposed direction of care. In other words, at least 30–40% of all presenting patients will benefit from CT diagnostic imaging with regards to their clinical care. The results obtained in the present study indicated that, in a higher number of cases (80.6%), the CT examination that confirmed the provisional diagnosis significantly facilitated a change in the proposed direction of care. In essence, the use of CT as a vital health resource in clinical practice is essential for quality patient care,[22] and evidently assists clinicians in making a diagnosis and influencing patient care, thus facilitating a better health outcome for patients.[23] Therefore, the provision of such diagnostic tool cannot be overemphasised; however, it is also important to highlight the need for clinicians to always consider imaging appropriateness when ordering CT for diagnostic purposes. As revealed by the significant findings of the present study, when compared with inappropriate CT imaging, appropriate CT resulted in confirmation of the provisional diagnosis in more instances than inappropriate CT (132 versus 3). Similarly, appropriate CT resulted in a change in the proposed direction of care in more instances than inappropriate CT (140 versus 4). More so, appropriate CT that confirmed the diagnosis facilitated a change in the proposed direction of care more than inappropriate CT, which confirmed provisional diagnosis (115 versus 1). Importantly, these differences were statistically significant and these results bear evidence to the fact that appropriate use of imaging procedures, as supported by acceptable clinical guidelines and standard protocols, will achieve the best possible outcomes for patient care in most circumstances.[24] Therefore, with regards to the use of CT in clinical practice, in order to achieve the best outcomes for patients, clinicians should always consider if ordering a diagnostic imaging procedure is appropriate or not,[13,24] and their decision should always be guided by appropriate guidelines and protocols.

Importance of imaging guidelines and clinical decision support

The findings from this study highlight the importance of using imaging guidelines and clinical decision support tools in clinical practice. In line with the principles of 'Good Clinical Practice', the utilisation of recommended imaging guidelines facilitates the delivery of ethical and scientific-based quality healthcare service.[25] In addition, the issues regarding balancing usefulness/risk and cost are mostly resolved when recommended guidelines and clinical

decision support tools are applied when ordering imaging procedures.[12,26,27] As recommended by the International Atomic Energy Authority and World Health Organization, the use of a clinical decision support tool may be essential in enhancing justifiable imaging procedures whilst limiting exposure to radiation,[12] and such clinical decision support systems has been shown to be clinically advantageous in facilitating improvement in imaging appropriateness.[16] In fact, the introduction of clinical decision support tools significantly facilitated increased overall yield and confirmation of diagnosis by CT imaging, whilst reducing inappropriate use of CT in numerous studies where such clinical decision support tools were applied.[28–31] Hence, the use of clinical decision support as a tool to aid appropriate ordering of CT for diagnostic purposes is therefore advocated.

Although some authors opined that most clinical practice guidelines and recommendations may be negatively influenced by the opinions and clinical experience/expertise of the practitioners comprising the "guideline development group",[32,33] from the current study, it was noted that the guidelines prepared by the Canadian Association of Radiologists[34] and the American College of Radiology appropriateness criteria[35] were in agreement in all cases, despite being from two different countries. This observation may suggest that the presumed negative impact of the experience/expertise of the clinicians that make up the guideline development group may be somewhat exaggerated. Instead, it may be argued that the experience/expertise of the clinicians that make up the guideline development group should be viewed as a positive influence upon the quality of the clinical guidelines being developed. For instance, from the application of these two guidelines in the current audit, it was clear that these imaging referral guidelines have a wide repertoire of differential diagnosis to which they can be applied, plus the referral guidelines were presented in simple tables, which described what investigation is recommended for each differential diagnosis. In addition, clinical comments (to help treating physician in making appropriate decisions) as per the choice of preferred imaging procedure were also presented under each possible differential diagnosis, and the level of radiation for each type of imaging procedures were also highlighted.[34,35] Thus, it is appropriate to use such quality guidelines especially when a wide range of cases and differential diagnosis is to be considered.

The role of history taking and physical examination

In clinical practice, sometimes medical dilemmas make it difficult to have a working diagnosis, and clinicians in such situations may be tempted to resort to inappropriate imaging as a fishing exercise. Although such medical dilemmas are rare, most patients present with conditions that can be diagnosed if history taking and physical examinations are undertaken appropriately, coupled with the appropriate use of medical imaging by following standard procedures and guidelines.[28–31] The argument is that, history taking and patient examination should help arrive at some working diagnosis and possible differentials,[36] thus, medical imaging should not be used as a "go to" process to cover for inadequate diagnostic skills (which commonly results from inadequate history, poorly conducted physical examination and inappropriate use of laboratory investigations). More so, as shown from the significant findings of this study, for all categories of CT referrals, when a CT examination was found to confirm a provisional diagnosis, it is more likely to facilitate a change in the proposed direction of care or facilitate the introduction of an additional care, thus influencing the clinical management of the patient. Therefore, regarding the clinical management of patients, the findings from this study reinforce the importance of adequate history, detailed physical examination, and appropriate use of laboratory investigations to reach a provisional diagnosis. When these things are carried out appropriately, they generally influence the choice of appropriate CT referrals, and thus facilitate the best possible outcomes for the patients. This message is essential for all practitioners of all stages including clinicians in postgraduate training and medical students alike. Otherwise, clinicians may end up becoming dependent entirely on diagnostic imaging procedure and this may result over time in the loss of clinical confidence as clinical skills, clinical acumen, and the ability to make timed clinical judgement are eroded.

In the present study, specialist physicians practising in a rural hospital setting achieved CT appropriateness. Significantly, appropriate CT confirmed the diagnosis and facilitated a positive change in patient care more often than inappropriate CT imaging. Adequate history taking and complete physical examination of patients are also important, otherwise imaging procedures will be utilised as a "fishing" tool, and these may not necessarily contribute to the overall clinical management of the patient. Therefore, adhering to recommended imaging clinical guidelines/criteria and the use of clinical decision support tools are essential for achieving imaging appropriateness in clinical practice, irrespective of locality.

Conflict of interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crad.2019.08.022.

References

1. European Society of Radiology. The future role of radiology in healthcare. *Insights Imaging* 2010;**1**:2–11.
2. Levinson DR. *Office of Inspector General report: growth in advanced imaging paid under the Medicare physician fee schedule*. Washington, DC: Office of Inspector General; 2007.
3. Bernardy M, Ullrich CG, Rawson JV, *et al*. Strategies for managing imaging utilization. *J Am Coll Radiol* 2009;**6**(12):844–50.
4. Efficiency in Health. *Productivity commission research paper*. Canberra, Australia: The Australian Government Productivity Commission; 2015.

5. Emanuel EJ, Fuchs VR. The perfect storm of overutilization. *JAMA* 2008;**299**:2789–91.
6. Hendee WR, Becker GJ, Borgstede JP, *et al*. Addressing overutilization in medical imaging. *Radiology* 2010;**257**(1):240–5.
7. Ho E. Overuse, overdose, overdiagnosis… overreaction? *Biomed Imaging Interv J* 2010;**6**(3):1–3.
8. Lysdahl KB, Hofmann BM. What causes increasing and unnecessary use of radiological investigations? A survey of radiologists' perceptions. *BMC Health Serv Res* 2009;**9**:155–63.
9. Sistrom CL. The appropriateness of imaging: a comprehensive conceptual framework. *Radiology* 2009;**251**(3):637–49.
10. Sodickson A, Baeyens PF, Andriole KP, *et al*. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. *Radiology* 2009;**251**(1):175–84.
11. Brenner DJ, Hall EJ. Cancer risks from ct scans: now we have data, what next? *Radiology* 2012;**265**(2):330–1.
12. *Bonn call-for-action: joint position statement by the international conference on radiation protection in medicine and the World Health Organization*. Bonn, Germany: The World Health Organization; 2012.
13. Fine B, Dhanoa D. Imaging appropriateness criteria: why Canadian family physicians should care. *Can Fam Physician* 2014;**60**:217–8.
14. Mendelson R, Montgomery B. Towards appropriate imaging: tips for practice. *Aust Fam Physician* 2016;**45**:391–5.
15. Pérez Mdel R. Referral criteria and clinical decision support: radiological protection aspects for justification. *Ann ICRP* 2015 Jun;**44**(Suppl. 1):276–87.
16. Blackmore CC, Mecklenburg RS, Kaplan GS. Effectiveness of clinical decision support in controlling inappropriate imaging. *J Am Coll Radiol* 2011;**8**(1):19–25.
17. The Royal Australia and New Zealand College of Radiologists. *Position statement on radiation safety in medical imaging*. Faculty of Clinical Radiology; 2015.
18. NSW Health. *2018-19 KPI and improvement measure data supplement*. NSW Ministry of Health; 2018. Available at: https://www1.health.nsw.gov.au/pds/ActivePDSDocuments/IB2018_048.pdf. [Accessed 7 July 2017].
19. NSW Health. *NSW health performance framework*. NSW Ministry of Health; 2017. Available at: https://www.health.nsw.gov.au/Performance/Documents/performance-framework.pdf. [Accessed 7 July 2017].
20. Brenner DJ, Hall EJ. Computed tomography — an increasing source of radiation exposure. *N Engl J Med* 2007;**357**(22):2277–84.
21. Melnick ER, Szlezak CM, Bentley SK, *et al*. CT overuse for mild traumatic brain injury. *Jt Comm J Qual Patient Saf* 2012;**38**(11):483–9.
22. Mosadeghrad AM. Factors influencing healthcare service quality. *Int J Health Policy Manag* 2014;**3**(2):77–89.
23. Axel L, Arger PH, Zimmerman RA. Applications of computerized tomography to diagnostic radiology. *Proc IEEE* 1983;**71**(3):293–7.
24. Boland GW, Weilburg J, Duszak R. Imaging appropriateness and implementation of clinical decision support. *J Am Coll Radiol* 2015;**12**:601–3.
25. Vijayananthan A, Nawawi O. The importance of Good Clinical Practice guidelines and its role in clinical trials. *Biomed Imaging Interv J* 2008;**4**(1):1–4.
26. Dai S, Nahas S, Murphy JK, *et al*. Impact and cost of preoperative computed tomography imaging on the management of patients diagnosed with high-grade endometrial cancer. *Int J Gynecol Obstetr* 2019;**145**(2):219–24.
27. Kothari S, Kalinowski M, Kobeszko M, *et al*. Computed tomography scan imaging in diagnosing acute uncomplicated pancreatitis: usefulness versus cost. *World J Gastroenterol* 2019;**25**(9):1080–7.
28. Prevedello LM, Raja AS, Ip IK, *et al*. Does clinical decision support reduce unwarranted variation in yield of CT pulmonary angiogram? *Am J Med* 2013;**126**(11):975–81.
29. Dunne RM, Ip IK, Abbett S, *et al*. Effect of evidence-based clinical decision support on the use and yield of CT pulmonary angiographic imaging in hospitalized patients. *Radiology* 2015;**276**(1):167–74.
30. Jenkins HJ, Hancock MJ, French SD, *et al*. Effectiveness of interventions designed to reduce the use of imaging for low-back pain: a systematic review. *CMAJ* 2015;**187**(6):401–8.
31. Tajmir S, Raja AS, Ip IK, *et al*. Impact of clinical decision support on radiography for acute ankle injuries: a randomized trial. *West J Emerg Med* 2017;**18**(3):487–95.
32. Woolf SH, Grol R, Hutchinson A, *et al*. Clinical guidelines: potential benefits, limitations, and harms of clinical guidelines. *BMJ* 1999;**318**(7182):527–30.
33. Geleris P, Boudoulas H. Problems related to the application of guidelines in clinical practice: a critical analysis. *Hellenic J Cardiol* 2011;**52**(2):97–102.
34. The Canadian Association of Radiologist. *CAR Diagnostic Imaging Referral Guidelines*. 2012. Available at: https://car.ca/patient-care/referral-guidelines/.
35. The American College of Radiology. *ACR Appropriateness Criteria*. 2018. Available at: https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria.
36. Eskelinen M, Ikonen J, Lipponen P. Usefulness of history-taking, physical examination and diagnostic scoring in acute renal colic. *Eur Urol* 1998;**34**:467–73.