ORIGINAL ARTICLE

Interactive Diagram-based Reporting of Bone Scintigraphy

WY Ho, WH Ma

Nuclear Medicine Unit, Department of Radiology, Queen Mary Hospital, Pokfulam, Hong Kong

ABSTRACT

Objective: Rapid development of information technology has facilitated routine use of structured reporting systems in clinical settings. These reporting systems commonly employ checkboxes, radio buttons, text boxes, and pick lists for data entry. In bone scintigraphy, each of the >200 bones that compose the human skeleton is of potential interest. Therefore, it is impractical to select from a long list containing all possible anatomical sites for reporting. This study aimed to develop an application for reporting metastatic bone disease by clicking on a diagram of a human skeleton, and to devise a simple method to input the report to the Radiology Information System (RIS).

Methods: The template contains a human skeleton diagram for input of the anatomical sites of lesions. Radio buttons allow the user to select among metastasis, degeneration and trauma/fracture as the pathology of a lesion. Optional activation of the compare mode allows the user to specify the metastatic lesions as new, progressed, stable, improved or resolved. A text report can be automatically generated for input into the RIS.

Results: The template was developed using Microsoft Visual Studio 2008 and compiled as a stand-alone Windows application, running simultaneously with the RIS. Reports in conventional narrative report format can be generated using mouse clicks only.

Conclusion: Use of a diagram circumvents the limitations of templated reporting for complex anatomy.

Key Words: *Automatic data processing; Computer graphics; Nuclear medicine; Radiology information systems; Skeleton; User-computer interface*

中文摘要

以圖為本的互動骨骼同位素掃描報告

何偉然、馬慧嫻

目的：資訊科技的快速發展促進臨床日常使用結構化報告系統。這些報告系統通常使用複選框、單選按鈕、文本框和數據輸入選擇列表。在骨骼同位素掃描，構成人體骨骼的超過200塊骨頭均值得關注。因此，在包含所有可能解剖部位的長列表中選擇以生成報告不切實際。本研究旨在開發以

點擊人體骨骼圖生成骨病變轉移報告的應用程式，並設計簡易方法將報告輸入放射學資料管理系統（RIS）。

方法：該模板包括用於輸入病變解剖部位的人體骨骼圖。單選按鈕為使用者在病理學中選擇病變轉移、退化和創傷／骨折。比較模式的可選激活功能為使用者將病變轉移狀況指定為新、惡化、改善或緩解。程式可自動生成文本報告後輸入RIS。

結果：使用Microsoft Visual Studio 2008開發模板，並編譯為獨立的Windows應用程式，與RIS同時運行。只透過鼠標點擊生成傳統敍述報告格式的報告。

結論：使用圖表可規避複雜解剖結構模板化報告所受的限制。

INTRODUCTION

Rapid development of information technology has led to paper health records being replaced by electronic health records. Better methods of storing, analysing, and sharing health information electronically is intended to improve quality, reduce costs, and increase access and coverage of healthcare practices. Structured radiology reporting systems may lead to faster report turnaround times, reduced reporting costs, improved communication, more satisfied referring providers, and simpler high-quality compliance reporting.[1] However, most radiology reports are currently free-text reports rather than structured reports.

Three progressive tiers are generally recognised in structured reporting in radiology.[2] The first tier relates to the presence of common headings, such as "Indication" and "Impression". The second tier, sometimes called "Itemised reporting," includes subheadings specifying categories such as organs and organ systems within the "Findings" section. Like the first tier, itemised reporting is relatively easy to implement. The third tier of reporting requires the use of standardised and constrained language. Sophisticated data entry methods are needed to generate third-tier structured reports.

Structured reporting can be implemented with text-based templates, standard reports and text blocks, and reporting forms with pick lists, buttons, and other form elements. Text-based templates can be retrieved and edited to generate new reports. This semi-structured data entry method assists the reporting clinicians in manually entering data and producing first-tier or second-tier reports.[3] To produce a third-tier report, consistency in the use of words has to be enforced and free-text entry should be avoided. To implement computerisation of endoscopy reports, a working group of two universities and four general hospitals in the Netherlands developed 316 standard reports and 1571 text blocks.[4] Standard reports were based on a list of distinct diagnoses; text blocks were based on anatomic landmarks and individual procedures. Selecting one diagnosis produces a minimally complete report; combinations of text blocks are used to generate full reports. Another implementation of third-tier structured reporting uses pick lists, buttons, and other form elements.[5,6] One interactive report generator for bone scan studies has been designed using an adaptive user interface with multiple lists for 400 anatomical concepts, 150 concepts for observation and diagnoses, 120 attributes, and 50 composite texts or text fragments.[5] For report generation, findings can be assembled and entered only by mouse clicks.

Structured reporting systems are most widely accepted in breast imaging,[7] cardiology,[8] and gastroenterology.[9] These disciplines pertain to a limited anatomic area and a restricted set of disease for which manageable template sets and straightforward user interfaces can be developed.[1] Moreover, a large proportion of the examinations performed for these subspecialties are normal or screening studies, which often can be reported in a single click by invoking a template.

Early structured reporting systems were said to require much time and energy for data input, and to require the eyes and mind of the radiologist to remove focus from image interpretation to report creation.[10] Radiologists have found that the software tends to decrease productivity and has the potential to cause distraction during image interpretation. Therefore, newer software providing an improved workflow is needed, to achieve widespread adoption of structured reporting of radiology and nuclear medicine studies. Artificial intelligence (AI) can be applied to various steps in the radiology consultation process, including procedure selection, image interpretation, diagnosis, and results reporting.

Structured reporting using AI techniques can increase the speed and improve the quality of imaging study reports.[11]

In addition to the difficulties in designing structured reporting templates, implementing structured reporting within a nuclear medicine unit poses multiple organisational and technical challenges. In Hong Kong, all radiology and nuclear medicine departments in public hospitals report examinations using the same Radiology Information System (RIS). Currently, the RIS provides an abbreviation function which can be used to store text-based templates, standard reports, and text blocks. To add a new module to the RIS with new reporting forms would need the support and consensus of multiple parties within this huge organisation. To achieve this goal, it is necessary to build prototypes of new structured reporting systems that can be used immediately in clinical settings. These prototypes can gain buy-in from radiologists, nuclear medicine physicians, information technology specialists, and administrators necessary for widespread adoption.

We report our developed template for bone scan reporting of metastatic bone disease. Instead of choosing from multiple long lists for the anatomical sites for the lesions mentioned in the bone scan report, we implemented a new method of generating a bone scan report by clicking on a diagram of a human skeleton. We also devised a simple method to export a report for input into the RIS, thus allowing the template to be used in a clinical setting.

METHODS
The template was a stand-alone 1.85-MB Windows application developed using Visual Studio 2008 (Microsoft Corp.; Redmond [WA], United States). Visual Studio is an integrated development environment from Microsoft to develop computer programs for Microsoft Windows. It can be used to create a Windows Forms application, by dragging form elements from the toolbox

and dropping them on the form. The first author, who is a nuclear medicine physician and amateur programmer, developed the template.

The template contains an image box with a diagram of a human skeleton for selection of anatomical sites using mouse clicks. Seven list boxes are present for input of injected activity, scan time post-injection, single-photon emission computed tomography/computed tomography (SPECT/CT) sites, diagnostic certainty, and the date of previous scan for comparison. A group of radio buttons allows for selection among metastasis, degeneration, and trauma/fracture as the pathology of a lesion. Another group of radio buttons is used for selection among new, progressed, improved, or resolved lesion for a metastatic lesion if the optional compare mode has been activated, while leaving this group of radio buttons non-selected will specify the metastatic lesion as a stable lesion by default. Three checkboxes are used for selection of SPECT/CT, removal of marked lesion, and activation of the compare mode. Four buttons initiate actions to list out the selected lesions, to generate the scan report, to send the text report to the Windows clipboard, and to reset the template to the default settings. A textbox is used for displaying the instructions, listing the selected lesions, and displaying the scan report. Details of the form elements in the template form are listed in the Table. The default layout of the template is shown in Figure 1.

The core of the template is a human skeleton diagram. This was modified from two public-domain diagrams downloaded from the Internet. The modification was carried out in Microsoft Paint. The modified human skeleton diagram includes the anterior skeleton and part of the posterior skeleton and contains 211 anatomical sites identified by their physical locations and selectable with mouse clicks. When the mouse pointer is moved to the appropriate site, a popup box with the name of the anatomical site will appear. The user can then apply

Table. Form elements in the developed template form.

Form element	Quantity	Use
Image box with diagram	1	Select from 211 anatomical sites by mouse clicks
List boxes	7	Input dose, scan time, SPECT/CT sites, diagnostic certainty, and day/month/year of previous scan
Radio buttons	2 Groups	Select pathology (metastasis/degeneration/trauma or fracture)
		Select new/progressed/improved/resolved lesions
Checkboxes	3	Select SPECT/CT, remove lesion, and compare mode
Buttons	4	Actions to list lesions, generate report, send report to clipboard, and reset template
Textbox	1	Display message, list lesions, and display scan report

Abbreviation: SPECT/CT = single-photon emission computed tomography/computed tomography.
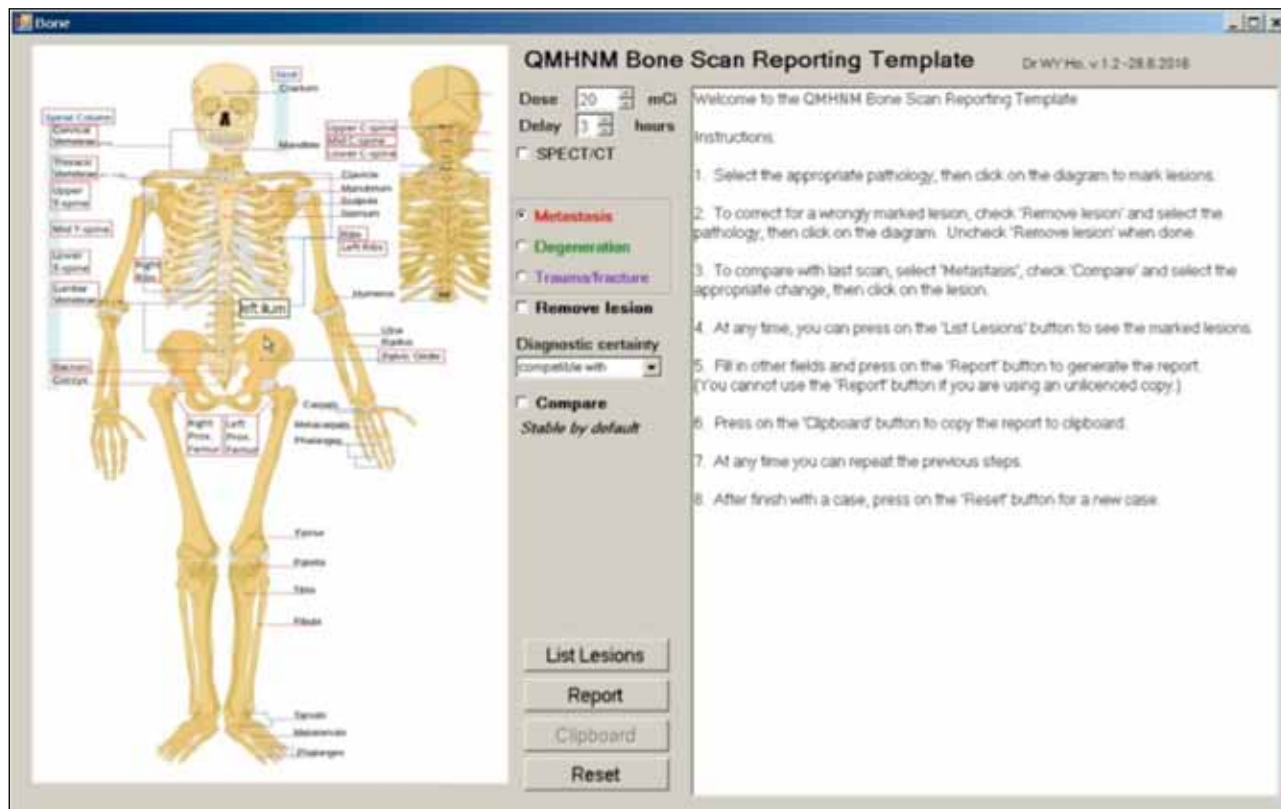
Figure 1. Screen capture showing the default layout of the developed bone scan reporting template. Note the popup text "left ilium" when the mouse pointer moves over the left ilium in the skeleton diagram.

a mouse click to select the site. Seventeen rectangles with collective terms are also selectable. For instance, the user can select the rectangle for cervical spine with one mouse click, or select C1 to C7 by selecting each of the seven cervical vertebrae in the diagram with seven mouse clicks.

Clicking on an anatomical site will lead to a mark appearing on the diagram, with the colour and the shape of the marking representing different pathologies, or different interval changes of a metastatic lesion if the compare mode has been activated. Each anatomical site can only be selected once for each type of pathology, avoiding the mistake of duplication of the same lesion. Mistakenly selected lesions can also be removed by checking the "Remove lesion" checkbox and clicking on the wrongly marked lesions. At any time, the lesions selected can be listed on the textbox by pressing the "List Lesions" button. The "Report" button invokes automatic generation of the scan report in the textbox. The "Clipboard" button sends the scan report to the Windows clipboard. The generated report can then be pasted

onto the RIS report with two mouse clicks. If free text amendment is needed, this can be added in the text box window or directly in the RIS report. Figure 2 shows the reporting process of a bone scan study. A diagrammatic representation of the steps in the generation of a bone scan report using the template is shown in Figure 3.

A rule-based reasoning AI technique, consisting of 60 if-then rules, was applied in the template. The AI built into the template provides multiple functions. It provides interactive changes to the form during the data entry process, activating only those input fields that are relevant in a certain context. The AI also segregates the non-metastatic lesions into subtypes of normal variants, dental diseases, degenerative changes, arthritis, vertebral collapses, and trauma according to pre-set rules based on the lesion location. The AI avoids duplication of lesions in the report and consolidates several lesions into a single anatomical site where appropriate. For example, selection of C1 to C7 will cause "cervical spine" to appear in the scan report. The AI also ensures correct spelling, grammar, and style in the scan report.
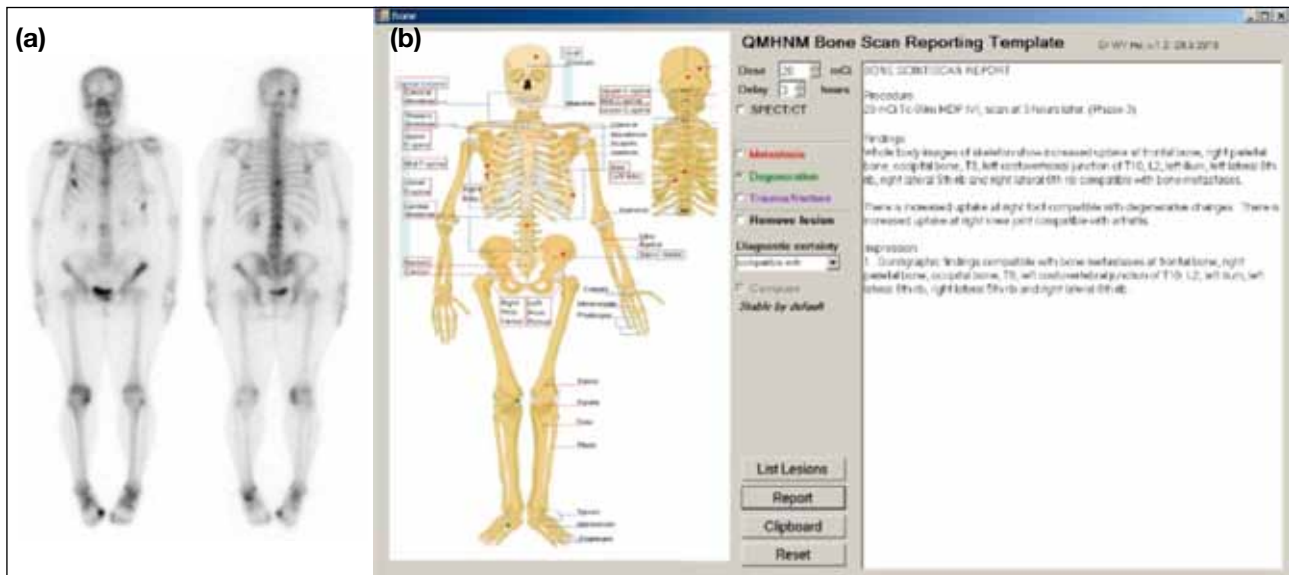
Figure 2. Images illustrating the reporting process of a bone scan study using the developed template. (a) Images of a whole-body bone scan study. (b) Screen capture box of the developed template showing how the lesions are marked on the skeleton diagram corresponding to the whole-body bone scan and how the text of the scan report is displayed.
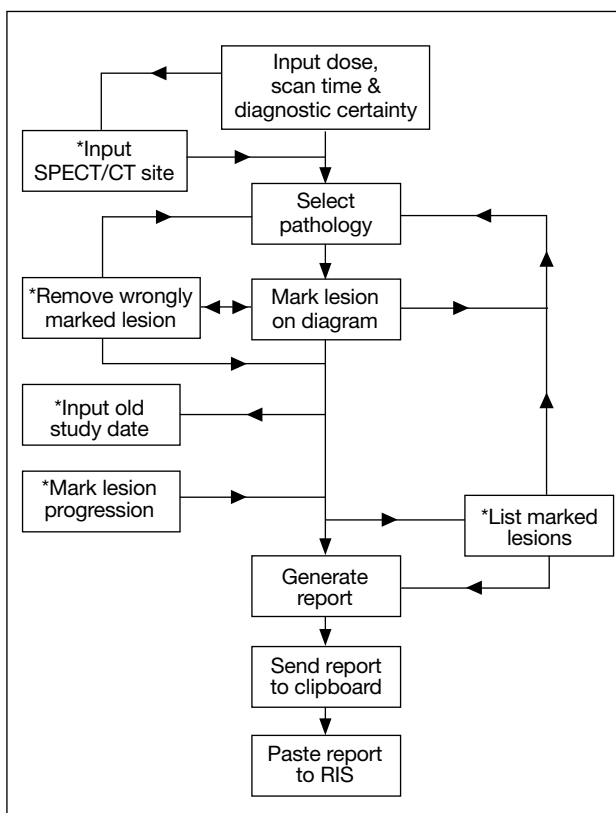

Figure 3. Flowchart showing the steps required to generate a bone scan report using the developed template.
* Optional steps

RESULTS AND DISCUSSION

The scan report generated by the template is of the same narrative report style in current use. While this new reporting template was being tested, both conventional and template reporting were carried out simultaneously. It is advantageous to have the two different methods generating reports in a similar format. Thus, the changeover from conventional to templated reporting was invisible to referral clinicians.

Structured reporting systems have several potential advantages over conventional narrative reporting.[1] Routine reports are created faster using structured reporting systems. Computer-generated reports typically have fewer errors than those generated using speech recognition. Owing to improved efficiency in the reporting process, structured reporting can lead to shorter report turnaround time and can achieve cost savings for the departments adopting these systems. As an illustration, there are two nuclear medicine specialists and one resident working in the authors' institution, providing about 5800 physician man-hours per year. Each year 1500 bone scans were performed in the nuclear medicine unit. If the time spent on reporting one bone scan can be reduced by 5 minutes by using this interactive diagram-based reporting system, this will generate a total savings

of 125 physician man-hours annually, equivalent to 2% of the nuclear medicine physician manpower.

Reporting of bone scan studies poses special difficulties. In reporting a bone scan study, every part of the skeleton may be of possible interest, and the number of lesions present in a bone scan may vary from none to many. Text-based templates, standard reports, and standard text blocks are suitable for simple reports, but they are inefficient for reports with complex anatomy or no predetermined number of lesions. The template presented in this study has the unique advantage that it can handle a large number of anatomical sites associated with any number of lesions. If the anatomical delineation needs to be more specific, more anatomical sites can be incorporated into the diagram in future. It is also possible to include multiple diagrams in a single template, to expand the possible uses of this template. For example, a report template for oncology studies may need to have diagrams for the internal organs and the lymph nodes, in addition to the skeleton.

Most structured reporting systems advocate the use of outlined reports, with findings presented in a list, rather than in a conventional narrative format.[12] In contrast, although the developed template also uses a third-tier structured reporting data entry system, reports are produced in a first-tier structured report format, with defined sections containing paragraphs. This decision was made for two reasons. Firstly, use of reporting templates was advised by some but rejected by others.[13] Some clinicians dislike ready-to-use or computer-generated reports, thinking that they cause too many errors. Generation of reports in a narrative style circumvents the problem of acceptance by the referring clinicians. Secondly, many lesions may be present in a bone scan report, which can be presented better using the conventional narrative format. For instance, it is more natural to state on the report, "arthritis in both knee joints" rather than "arthritis: left knee joint, right knee joint". In addition to correct spelling, correct style and structure in the report are considered important by some clinicians.[13] The AI used in the template ensures that correct spelling, grammar, and style are applied in the generated reports.

Text-based searches are important for retrieving information from narrative reports to obtain data for subsequent research. However, these searches can be time-consuming and inaccurate compared with from outlined structured reports.[6] The narrative reports generated by the developed template are based on a third-tier structured data entry system with constrained language and defined format. Therefore, a modern text search engine can quickly and efficiently search through the reports.

The developed template is a prototype developed by an amateur programmer. The purpose of the template is to demonstrate the feasibility and potential advantages of using an interactive diagram to produce clinically useful bone scan reports. The project has many limitations. At present, this template allows for selection of "SPECT/ CT" and the region scanned leading to the appearance of this acquisition information in the "Procedure" section of the scan report. Findings of SPECT/CT need to be input by the users using free-text. Clinical use of this template is also limited. Indications for bone scan other than metastatic bone disease are not yet supported, including findings such as osteomyelitis and postoperative changes. The template was made for use by the authors; other nuclear medicine physicians may not be comfortable with the reports generated by the template. Moreover, although it is a general impression that applying mouse clicks is faster than writing a report using traditional text-based templates or voice recognition systems, the actual benefits in terms of time saved are difficult to measure, as the time spent on reporting bone scans is highly operator dependent. Finally, the developed template is a stand-alone application; a web-based application would be more effective method for large-scale implementation of structural reporting at the organisational level.

In future, better and more intelligent web-based systems developed by professional information technology experts would allow for user-customisable settings and expanded usage scenarios. The successful development of this template is a milestone for structured reporting of radiology and nuclear medicine studies. It opens a window for the use of diagrams embedded in computerised reporting forms for structured reporting of sophisticated studies with complex anatomical details, such as CT, magnetic resonance imaging, SPECT/CT, or positron-emission tomography/CT.

CONCLUSION

The developed template demonstrates that the use of a diagram rather than multiple pick lists circumvents the limitation of reporting complex anatomy when using a structured reporting template. Computer technology is now ready for the development of structured reporting templates for routine clinical uses.

The greatest hurdle to the implementation of structured reporting may be whether the stakeholders are prepared for the changes.

ACKNOWLEDGEMENTS

REFERENCES

1. Langlotz CP. Structured radiology reporting: are we there yet? Radiology. 2009;253:23-5. **Cross**ref
2. Cramer JA, Eisenmenger LB, Pierson NS, Dhatt HS, Heilbrun ME. Structured and templated reporting: An overview. Appl Radiol. 2014 Aug 5. Epub ahead of print.
3. Wilcox AB, Narus SP, Bowes WA 3rd. Using natural language processing to analyze physician modifications to data entry templates. Proc AMIA Symp. 2002:899-903.
4. Groenen MJ, Kuipers EJ, van Berge Henegouwen GP, Fockens P, Ouvendijk RJ. Computerization of endoscopy reports using standard reports and text blocks. Neth J Med. 2006;64:78-83.
5. Bernauer J, Gumrich K, Kutz S, Lindner P, Pretschner DP. An interactive report generator for bone scan studies. Proc Annu Symp Comput Appl Med Care. 1991;858-60.
6. Morgan TA, Helibrun ME, Kahn CE Jr. Reporting initiative of the Radiological Society of North America: progress and new directions. Radiology. 2014;273:642-5. **Cross**ref
7. American College of Radiology. Mammography. In: Breast Image Reporting and Data System (BI-RADS) Atlas. 4th ed. Reston, VA: American College of Radiology; 2003.
8. Stillman AE, Rubin GD, Teague SD, White RD, Woodard PK, Larson PA. Structured reporting: coronary CT angiography: a white paper from the American College of Radiology and the North American Society for Cardiovascular Imaging. J Am Coll Radiol. 2008;5:796-800. **Cross**ref
9. Gouveia-Oliveira A, Raposo VD, Salgado NC, Almeida I, Nobre-Leitão C, de Melo FG. Longitudinal comparative study: the influence of computers on reporting of clinical data. Endoscopy. 1991;23:334-7. **Cross**ref
10. Weiss DL, Langlotz CP. Structured reporting: patient care enhancement or productivity nightmare? Radiology. 2008;249:739-47. **Cross**ref
11. Kahn CE Jr. Artificial intelligence in radiology: decision support systems. Radiographics. 1994;14:849-61. **Cross**ref
12. Bell DS, Greenes RA. Evaluation of UltraSTAR: performance of a collaborative structured data entry system. Proc Annu Symp Comput Appl Med Care. 1994:216-22.
13. Bosmans JM, Peremans L, De Schepper AM, Duyck PO, Parizel PM. How do referring clinicians want radiologists to report? Suggestions from the COVER survey. Insights Imaging. 2011;2:577-84. **Cross**ref