

Effect of template reporting of brain MRIs for multiple sclerosis on report thoroughness and neurologist rated quality: results of a prospective quality improvement project

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Structured radiology report templates have been explored as a method to organize the information contained in a radiology report to improve report quality. Templates provide an inherent "checklist" that prevents omission of important in a consistent manner 1. When created in collaboration with referring physicians, report templates can educate and remind radiologists which imaging data is most relevant². Prior research has demonstrated that templates are preferred by referring physicians in a number of settings ^{3–7} and improve the

comprehensiveness of radiology Multiple sclerosis (MS) is a chronic neurologic disease that comprises a large volume of neuroimaging in which longitudinal MRI assessments are recommended and commo ¹². MRI is a critical clinical tool for the diagnosis of MS. inversion recovery) white matter hyperintensities and, in particular, gadolinium-enhancing lesions or lesions with certain spatial distributions (e.g., periventr juxtacortical, below the tentorium cerebelli) 13 can help establish the diagnosis of MS. from the International Panel on Diagnosis of MS (i.e., the updated McDonald Criteria) newly permits the use of one MRI scan withou comparison imaging to support the diagnosis of MS if it contains both contrast-enhancing (active) and quiescent (remote) lesions that are separated spatially 14. The 2015 guidelines by the

This prospective quality improvement initiative was conducted to improve the real and perceived quality of radio. reports on brain MRIs in patients

Magnetic Resonance Imaging

in MS (MAGNIMS) network

has advocated for structured

reporting to ensure inclusion of

critical report elements 16.

The institutional review board considered this quality improvement initiative to be "not regulated." All medical records were handled in a Health Insurance Portability and Accountability Act-compliant fashion. Template Development and Implementation The structured MS report template for brain MRI examinations was designed by one neuroradiologist with 6 years of experience in MS imaging familiar with the McDonald criteria 14. The template was created in collaboration with the neurologists who staff the MS clinic at the study institution. It was designed to incorporate all essential and relevant elements for the diagnosis and management of MS, including: enhancing lesions, T2-weighted/FLAIR white matter hyperintensities, T1-weighted white matter nsities, number of lesions, brain volume loss, and comparison to prior examinations (Table 1). The structured report template was introduced to the neuroradiology division at the study institution on February , 2015. Each neuroradiologist was provided training on the template and encouraged to make use of it for relevant examinations. Feedback and encouragement for template use was provided on a roughly bimonthly basis for one year. ology information system at the study institution was queried for a period ${f 12}$ months preceding

(February 2014 – January 2015) and 12 months following (February 2015 – January 2016) the introduction of the structured template to identify all contrast-enhanced MR examinations of the brain ordered by neurology attendings, neurology fellows, or neurology residents involved in MS care at the study institution. Those reports that stated "MS", "multiple sclerosis", or a similar term (e.g., "demyelinating disease") in the order requisition or report impression were selected (n=159). Reports in which the final radiology impression did not support a diagnosis of MS or other demyelinating disease were excluded (n=3). There were no other exclusion criteria. The final study population included 156 contrast-enhanced brain MRI reports created by 11 separate radiologists for 112 patients (94 males, 18 females, mean age: 52.6 [range: 20-79]), including 63 MRI examinations in the pre-template period and 93 MRI examinations in the All 156 included reports were reviewed by a PGY-5 radiology resident who was uninvolved in implementing the MS template to determine report content. Each report was graded for the presence or absence of 12MS-relevant components selected in part based on the Consortium of MS Centers revised 2015 guideline on MRI for diagnosis and follow-up of MS 17 . For quantifiable findings in the structured template (i.e., hancing lesions, T2w/FLAIR white matter hyperintensities, T1w white matter hypointensities), the ollowing were coded as present or absent: explicit discussion of the element, quantification of the element,

reports (15 template and 15 non-template) selected by random number generator were also rated by two attending neuroradiologists yielding a Fleiss's kappa of 0.84 indicating almost perfect agreement $^{18}.$ Neurologist Assessment of Report Quality

An online data collection instrument was developed to permit five neurologists with MS expertise from five other institutions who were blinded to patient identifiers and the project design to evaluate a sample (n=20)of the reports analyzed in this study. Neurologists from other institutions were used to minimize bias during report assessment and to improve the generalizability of the results. All reports were chosen from the post-template period to minimize bias related to reporting differences that may have occurred at the study institution after introduction of the template. The clarity and level of detail of each report were assessed with Likert scales, and the predicted change in management (if any) on the basis of the report content was recorded assuming a typical patient with MS undergoing surveillance MR imaging. Participating neurologists also were surveyed on their familiarity with the McDonald criteria 14 and their preferences for radiology report structure.

omparison to prior examination(s) (if any). The following were also coded: mention of presence or absence

findings likely to affect patient management (e.g., aneurysm). To confirm coding accuracy, a subset of 30

of brain volume loss, mention in the impression of enhancing lesions and/or change in number of white

matter lesions relative to prior examinations (if relevant), mention in the impression of MS-unrelated

Continuous data are expressed with means and ranges, and categorical data are expressed with counts and percentages. Mean Likert scale scores were compared with unpaired t tests. The presence of radiology findings in a report were regarded as a binomial variable and estimates of the proportion of findings reported was calculated with a binomial confidence interval. Proportions were compared with Fisher's exact test, chi square test, or Cochrane-Armitage test for ordinal categories as appropriate. Stacked divergent bar graphs were created to illustrate Likert scale responses.

The structured template was used for 0% (0/63) of the reports in the pre-template period and 71% (66/93) of the reports in the ost-template period. Use of the template in the post-template eriod increased over time (Figure 1) (p=0.04). Nearly all (97% [152/156]) reports had a comparison contrast-enhanced brain MRI

Reports using the template contained significantly more relevant findings than reports that did not use the template (11.1 \pm 0.7 findings vs. 5.8 ± 2.2 findings, p<0.001). Every relevant finding related to MS was addressed significantly more often in reports that used the template (Table 2). The greatest gains in report content were seen for the quantification of T2w/FLAIR abnormalities (100% [66/66] vs. 8% [7/93], p<0.001), inclusion of any discussion regarding T1w hypointensities (p<0.001, Table 2), and reporting of brain / white matter volume loss (92% [61/66] vs. 38% [35/93], p<0.001). Elements that have the greatest effect on patient management (e.g., presence and number of enhancing lesions) were also significantly more common in the template-containing reports (p<0.001). In the post-template period, reports that continued to use a narrative reporting style maintained significantly less content than reports that used the template (Figure 2).

Potentially important findings unrelated to MS were also reported more often in template reports, but this difference was not statistically different (14% [9/66] vs. 5% [5/93], p=0.09).

Neurologist Assessment of Report Quality

There was a per-question response rate of 97% (389/400) for the neurologist survey instrument. Neurologists outside the study institution assigned higher mean report ratings to template reports in three of four parameters assessed (Table 3, Figure 3). The likelihood of a report receiving the best possible rating on any given Likert scale was higher for template reports (56% [107/190] vs. 28% [56/199], p<0.001; conversely, reports not using the template had a significantly higher likelihood of receiving a negative rating (15% [29/199] vs. 7% [13/190], p=0.01),

The most frequent predicted course of management by the external neurologists on the basis of the reviewed reports was to maintain current MS therapy, which occurred with 83% (40/48) of templatecontaining reports and 69% (34/49) of reports without the template (p=0.15). Increasing or modifying MS therapy to better control active disease was selected for 10% (5/48) of template-containing reports and 16% (8/49) of reports without the template (p=0.6). The least likely predicted course of action was stopping MS therapy based on a suspicion that the patient did not have MS; this occurred

Table 3 in 6.2% (3/48) of template reports and 14% (7/49) of reports without a template (p=0.32). Based on this small sample (n=100), use of a template report was not associated with a management difference compared to use of a report without a template (p=0.25).

All neurologists outside the study institution (100% [5/5]) strongly agreed with statements that they were familiar with the McDonald criteria for the diagnosis of MS and that the McDonald criteria were a valid means of diagnosing MS. Eighty percent (4/5) of neurologists trongly agreed and 20% (1/5) of neurologists agreed that they relied heavily on imaging to monitor MS disease status and that they preferred template radiology reports to non-template radiology

MS template implemented at primary project institution. Brackets indicate a prompt for text entry by radiologist creating report.

Number of new enhancing lesions in periventricular, juxtacortical, infratentorial regions: []

Number of T2/FLAIR/STIR lesions that are new or larger in periventricular, juxtacortical, infratentorial, regions: []

- Number and orientation of non-enhancing T2/FLAIR/STIR lesions in periventricular, juxtacortical, infratentorial regions: []
- Number of low signal T1 lesions in periventricular, juxtacortical, infratentorial regions: []
- Presence of volume loss including the corpus callosum: [Yes/No]

There [is]/[is not] MRI evidence of involvement of two or more regions.

There [are]/[are not] new or enhancing lesions.

Other important findings (if any): []

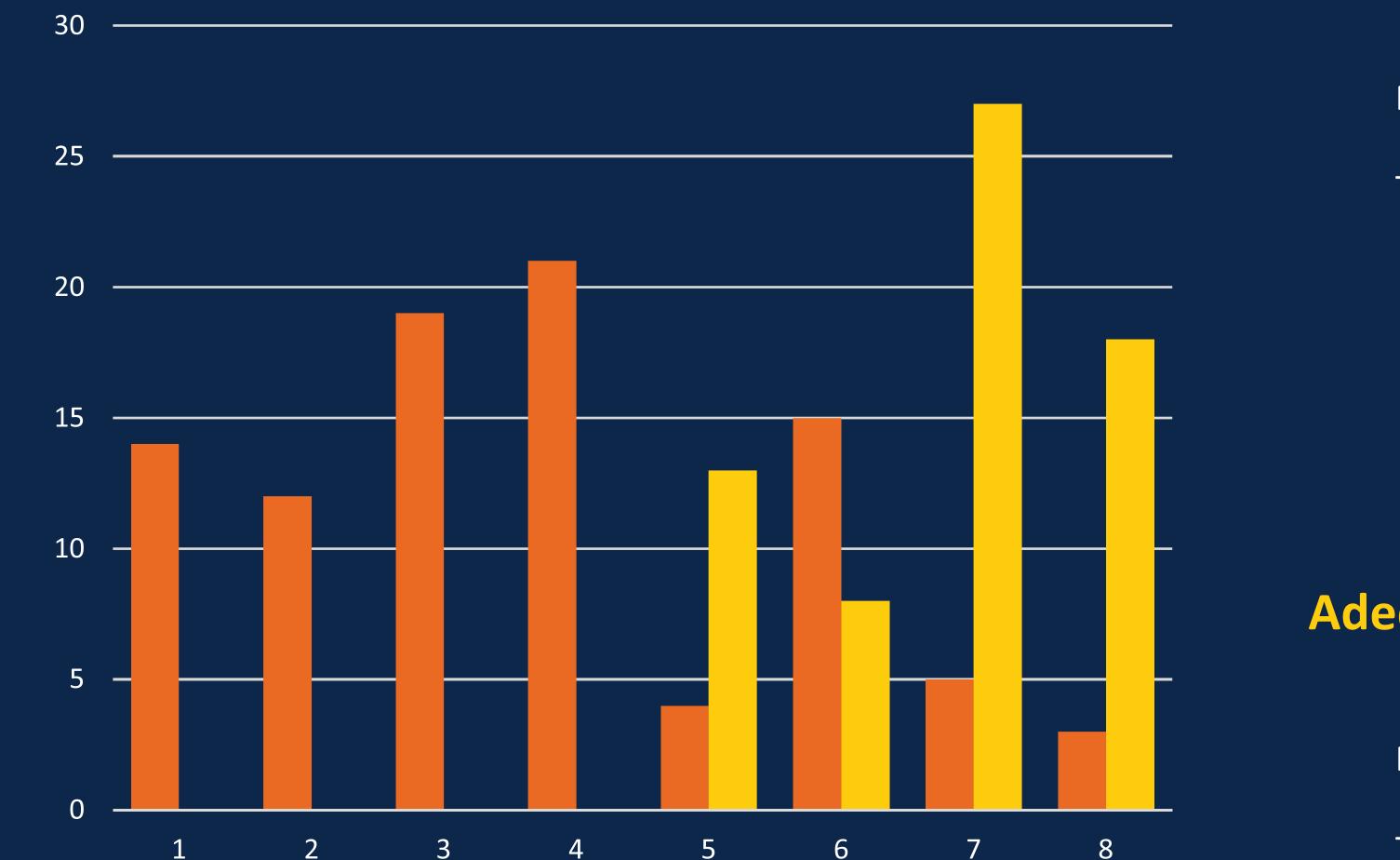
Report content stratified by report section (i.e., body, impression) and report type (i.e., non-template, template).

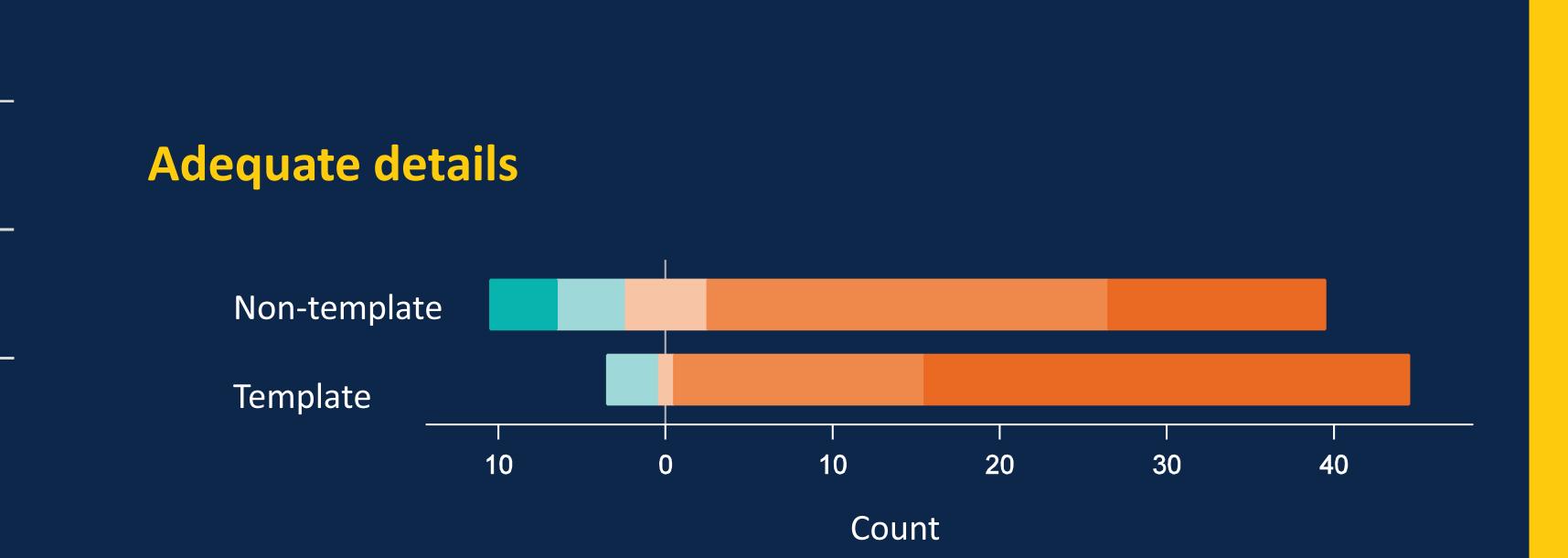
Report section		Relevant Content	Non-template reports (percent)	Template reports (percent)	p-value
	Enhancing signal abnormality	Any explicit discussion Quantification Comparison with prior (if applicable)	80/93 (86) 73/93 (79) 69/86 (80)	66/66 (100) 66/66 (100) 66/66 (100)	<0.001 <0.001 <0.001
Body	T2/FLAIR hyperintensity	Any explicit discussion Quantification Comparison with prior (if applicable)	68/93 (73) 7/93 (8) 54/86 (63)	66/66 (100) 66/66 (100) 65/66 (99)	<0.001 <0.001 <0.001
	T1 hypointensity	Any explicit discussion Quantification Comparison with prior (if applicable)	9/93 (10) 4/93 (4) 2/86 (2)	66/66 (100) 66/66 (100) 21/66 (32)	<0.001
	Other	Brain/white matter volume loss	35/93 (38)	61/66 (92)	<0.001
Impression	Explicit statement regarding presence or absence of ≥2 lesions		69/93 (74)	58/66 (88)	0.04
	Explicit statement regarding presence or absence of enhancing MS lesions		61/93 (66)	65/66 (99)	< 0.001
	Inclusion of non-MS findings likely to alter patient management		5/93 (5)	9/66 (14)	0.09

Average neurologist ratings (± standard deviation) on 1-5 Likert scale (higher scores indicate stronger agreement) of template and non-template

Accessed konort narameter	Mean rating (1-5)		n value	
Assessed report parameter	Non-template reports	Template reports	p-value	
his report was easy to understand	2.2±1.2	3.2±1.3	0.16	
his report covered all relevant MRI details regarding multiple sclerosis	2.2±1.2	3.5±0.8	<0.001	
his report provides useful information for how I will manage this patient	2.0±1.0	3.6±0.5	0.003	
verall report quality	2.3±1.0	3.2±0.9	0.01	

Run chart demonstrating the proportionate use of the report template over time by quarter (every three months). There was reports: template versus non-template reports. increasing relative use of the template from quarter 5 (first quarter the template was available) through quarter 8 (p=0.04).





Provides information useful to patient management

Divergent stacked bar chart summarizing neurologist ratings of radiology

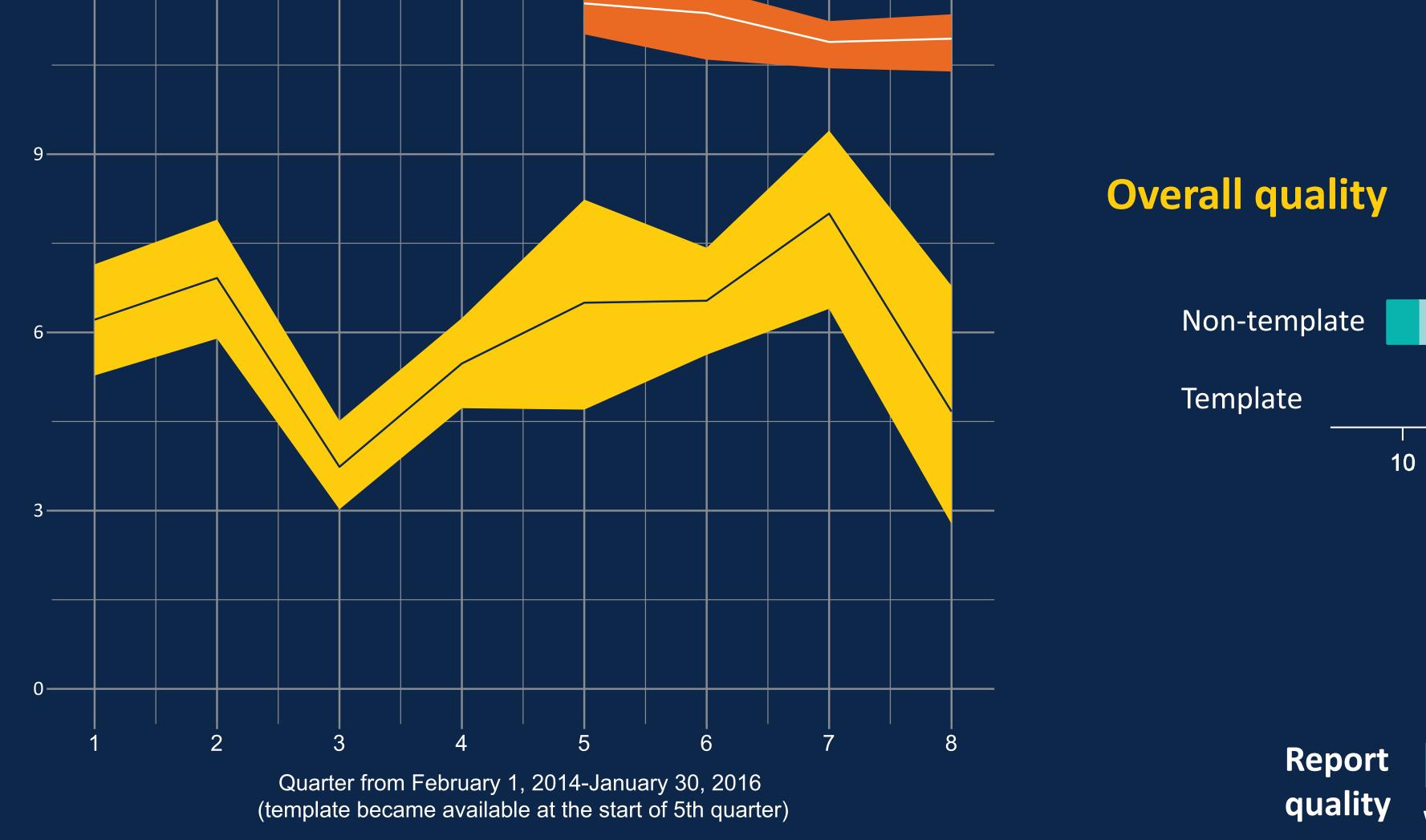
Run-chart by quarter of mean number of MS findings discussed in template and non-template reports (out of a maximum of 12 assessed findings) over 12 month periods preceding and following the introduction of MS template (24 months total) with 95% confidence intervals (shaded colors around mean center lines).

Quarter from February 1, 2014-January 30, 2016

(template became available at the start of 5th quarter)

Non-template reports

Template reports



Template reports

Non-template reports

We found that brain MRI reports that used a template designed for comprehensive and accurate reporting of findings relevant to MS contained significantly more details relevant to MS management compared to non-template reports (11.1 \pm 0.7 findings vs. 5.8 ± 2.2 findings, p<0.001), was preferred by neurologists with expertise in MS management, and was integrated effectively into clinical practice over a one-year period. These findings are consistent with the results of studies investigating template effectiveness in body imaging^{8,9}, and concordant with publications showing higher referring physician satisfaction with template reporting in general 3-7. The real and perceived improvements in report quality attained by implementation of a novel MS reporting template in this quality improvement effort supports the recommendation in the 6. Plumb AAO, Grieve FM, Khan SH. Survey of hospital clinicians' preferences regarding the format of radiology reports. Clin Radiol. The 2015 MAGNIMS guidelines 16 for structured reporting in the context of MS.

Structured templates organize information and remind the radiologist what elements are important to include in the report. They are best used in a targeted fashion for diseases that require a lengthy description of imaging details. Without organization, essential elements may be omitted. For example, despite the critical importance of enhancement in the McDonald criteria 14 , 14% of non-template reports did not contain any discussion of the presence or absence of contrast-enhancing lesions (vs. 0% of template reports). This absent information likely reflects unintentional omission rather than conscious exclusion. We hypothesize that the report template served as a checklist for radiologists in constructing reports. Checklists have been widely used in aviation and now more recently in healthcare settings to improve the rate at which critical steps are performed or considered in cognitively complex tasks. In surgical settings, the implementation and use of checklists has been associated with reductions in surgical mortality and complication rates $^{19-21}$, and reduced errors in the use of perioperative thrombosis prophylaxis 22 .

We were unable to find other investigations studying the creation or implementation of a structured reporting template for MS. Structured templates are only as effective as their content allows; development of a structured reporting system in collaboration with referring physicians is probably ideal. The Radiological Society of North America (RSNA) Reporting Initiative (http://www.radreport.org/) encourages use of template reporting by radiologists, and provides a database of publically available templates for use in general practice. However, all of the neuroimaging templates in that repository are generic with respect to the underlying disease, and specific only to the type of imaging examination (e.g., CT brain). Such templates would likely fail to improve reporting standards in the setting of complex disease states like MS because the elements most relevant to that isease are not part of usual reporting.

Our project has some limitations. Our project design did not allow determination of whether the template improved the accuracy of reporting; it only allowed determination of report completeness and perceived quality. The neuroradiology division that adopted the template was small (three full-time faculty and up to eight faculty with part-time appointments during the course of the study); larger divisions with more diverse opinions may have a more difficult time with implementation. Although the external neurologists were blinded to the study design and had not been previously exposed to the template, they may have held particular beliefs about the value of template reporting which could have biased their responses. Finally, we did not measure the effect of template reporting on report turnaround time, report creation time, or the time required by neurologists to nterpret the reports.

Future areas of research for templates in multiple sclerosis include assessing the effect of templates on neuroradiologist productivity, if templates make reports more amenable to inclusion in databases, assessing the inter-reader variability of MS reporting through a template versus a non-template report (especially for patients that receive followup scans at multiple institutions), and evaluating interactions with neuroradiologist

In conclusion, we show that template-reporting of brain MRI examinations in the setting of MS improves real and perceived report quality. Implementation of a standardized reporting mechanism can be adopted successfully and is well-received by neurologist referring physicians. These results support the recommendations in the 2015 MAGNIMS

ACKNOWLEGE COMMENDATIONS guidelines ¹⁶ for generalized structured reporting in MS and should encourage other centers to consider similar measures.

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