

**Structured radiology reporting:
a 4-year case study of 160,000 reports**

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Abstract

This paper analyzes the use of structured radiology reports since 1997 at Midway Hospital Medical Center, which is a full-modality 150-bed community hospital located in Los Angeles, California. We describe the transition from a conventional transcription-based reporting system to one in which radiologists create reports for twelve radiology modalities directly through a structured reporting system. More than 160,000 structured radiology reports have been produced with the structured system. Compared to transcription, the structured reporting system has: (1) Improved the quality and consistency of reports. (2) Enabled instantaneous dissemination of reports to improve patient care and to decrease hospital stays. (3) Eliminated transcription costs. (4) Automated abstraction of reports with CPT and ICD-9 codes. The success of this system depends crucially on the completeness of structured report templates, as well as the ability to produce natural English sentences from structured input.

Keywords: Radiology reporting systems, Software reviews, Technology assessment

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1. Introduction

This paper describes StructuRad's experience producing structured radiology reports in a community hospital since 1997. The work actually began in 1995, when StructuRad's cofounders began developing algorithms and then report templates for generating structured reports. Those initial efforts focused on CT and MRI studies of the cervical, thoracic, and lumbar spines. The motivation for developing templates was to improve the interpretation and reporting abilities of the non-neuroradiologists who sometimes read these studies. By 1996, they had developed a general template structure for all modalities, although the detailed work focused on structured reports for chest x-rays, because they make up about 40% of the workload at the hospital. In 1997, StructuRad began to implement its report templates with software from their PACS vendor, ALI Technologies. From mid 1997 until early 1998, StructuRad continued to develop and deploy templates for use in all twelve of the hospital's modalities. During that transition period, some reports were generated through transcription, while others were produced with the new templates as they became available. By mid 1998 the transition was complete and since that time all radiology reports are produced with the structured reporting system.

Since 1997, more than 160,000 structured radiology reports have been produced with the structured system. Compared to transcription-based reporting, the structured reporting system has:

- (1) Improved the quality and consistency of reports.
- (2) Enabled instantaneous dissemination of reports to improve patient care and to decrease hospital stays.
- (3) Eliminated transcription costs.
- (4) Automated abstraction of reports with CPT and ICD-9 codes.

The success of this system depends crucially on the completeness of structured report templates, as well as the ability to produce natural English sentences from structured input.

Others have discussed the problems associated with transcription-based reporting, as well as the advantages and disadvantages of structured reporting[1,2]. Much of that work is based on research systems or reporting systems that are specialized for one modality. The purpose of this paper is to provide a case history for a structured reporting system that is used for a wide range of modalities in a clinical setting in a community hospital.

2. Taxonomy of radiological reporting systems

Before discussing the details of the StructuRad structured radiology reporting system, we will review several types of reporting systems, in order to establish a context for comparing and contrasting the strengths and weaknesses of the StructuRad system.

The most widely used method for radiology reporting is transcription, where a radiologist dictates findings, which are then transcribed by a transcription service. When the report is returned from the transcription service, the radiologist verifies the correctness of the report and signs it. The report is then distributed to other departments in the hospital. In some cases, reports are returned to the transcription service, in order to correct transcription errors. With transcription, the final output is a printed report, or perhaps a text file, that is distributed outside the radiology department.

Given recent advances in natural language processing, the transcription method may be modified slightly by using a speech recognition application to perform the transcription, rather than relying on stenographers[3,4]. The end result is still a printed report or

unstructured text file. The only difference is the way in which the transcription is performed.

Unfortunately, free-form text does not lend itself to quantitative analysis in the way that a structured database does. Therefore, some groups have attempted to apply natural language processing to free-form text reports, in order to produce structured reports[5,6,7,8]. In this case, findings are still recorded verbally, followed by transcription. However with the extra processing step at the end, text-based radiology reports are turned into structured data, which may be mined at a later time for research into individual studies, analysis for trends, or outcomes research.

Given the desirability of producing structured data, another approach is to capture findings as structured data just at the point where the radiologist is observing study results. In this case, there is no separate step of transcription. The radiologist enters findings directly, enabling software to capture the findings as structured data. Some systems allow for speech input, while others use pointing devices, such as a mouse or touch-sensitive screen. The StructuRad reporting system is in this category of radiology reporting systems that capture structured data at the point of observation, as are several other structured radiology reporting systems that provide for menu-based data entry, such as cMore GI[9], eDict[10], PointDx[11], PenRad[12], and SPIDER[13].

3. Description of the StructuRad system

3.1. Environment

The StructuRad structured radiology reporting system is used at Midway Hospital Medical Center, which is a full-modality 150-bed community hospital located in Los Angeles, California. There are 2 radiologists and 20 technologists in the radiology department, which produces approximately 40,000 reports per year for twelve modalities: x-ray, mammography, fluoroscopy, ultrasound, CT, CTA, MR, MRA, nuclear medicine, conventional angiography, ultrasound angiography, and interventional radiology. Radiology findings are printed as paper reports, which are scanned into an electronic patient record.

3.2. Usage

The reporting process begins when a technologist enters demographic data into the system. This creates a file for the study, which appears in the radiologist's inbox. The radiologist periodically checks the inbox, which may be sorted by the attributes of the studies. The inbox contains new studies for which no report has been generated, as well as work in process where the radiologist has started, but not yet completed, a report.

The reporting system contains templates for the modalities and anatomic sites for which exams are performed in the hospital. Each template is a complete knowledge base of possible findings that are appropriate for the given modality and anatomic site. Therefore, the reporting task for the radiologist is to navigate the menus of possible findings, selecting those items that correspond to observations from the given study.

Most of the data entry occurs by selecting items in a sequence of cascading menus. Thus, selecting one menu item will cause another submenu to be displayed with additional options. Any of these menu items may contribute standard text to the report. Some items cause an input box to pop up, so that the radiologist can enter a value. For example, the radiologist might be prompted to enter the size of a mass in centimeters.

As the radiologist makes selections and enters values, the system keeps a running record of the corresponding report that is generated from the menu selections. Unlike

dictation, this provides immediate feedback of the exact representation of the resulting report.

The radiologist may save a partially completed report. Eventually when the report is complete, the radiologist approves the report, which causes an electronic signature to be applied and the report may be distributed at that time.

3.3. Integration with other systems

The StructuRad reporting system is built on ALI Technologies' radiology reporting framework. The reporting system is integrated with the ALI Technologies PACS system, so for digital images captured within the PACS, images and reports are linked together by the PACS. For images captured outside the PACS, e.g. analog x-ray film, the reporting system is used to generate a report with no computerized link to the image.

Previously, the reporting system produced paper reports, which were scanned into an electronic patient record. However, the reporting system is currently being integrated with other computerized hospital records systems at Midway, so that the reports will be integrated with the hospital information system (HIS).

3.4. Deployment

In 1996, all radiology reports were produced through a conventional transcription process, in which a radiologist dictated findings. The dictation was transcribed by an outside transcription service. When the report was returned from the transcription service, the radiologist verified the correctness of the report, which was then distributed to other departments in the hospital. In some cases, reports were returned to the transcription service, in order to correct transcription errors.

In 1997, the menu-based computer system was introduced, in which a radiologist reports findings by selecting from menus of all possible choices. During that year, about half of the reports were produced through transcription and half were produced through the structured reporting software. The original software was developed and deployed over a period of six months during 1997 and 1998. As templates for each modality and anatomic site were developed, transcription was phased out and use of the reporting application was phased in. The system continues to evolve, so "deployment" is really part of an on-going process of continuous improvement.

Since 1999, 100% of the radiology reports are produced through the StructuRad software. After the initial deployment, reporting templates continue to be expanded and improved based on feedback from referring physicians and based on new requirements that are discovered by reporting radiologists at Midway. These enhancements include:

- (a) Developing additional content within existing templates.
- (b) Improving the navigation within templates.
- (c) Revising the underlying reporting model, in order to improve the naturalness of the English report that is generated from the structured data.

3.5. Training requirements

StructuRad has not had typical training requirements for the reporting system, because the radiologists who developed the report templates are the same radiologists who create reports. However, StructuRad will be training new users as part of the planned beta testing phase at several facilities in early 2002.

4. Results

The StructuRad reporting system has been in clinical use since 1997. In this section, we will compare radiology reporting using the StructuRad system to conventional transcription, which was the reporting method at Midway Hospital prior to 1997.

4.1. Quantitative results

The results presented in this section are based on a comparison of operations in 1996 when the hospital used only transcription and operations in 1999 when the hospital used only the StructuRad reporting system.

4.1.1. Transcription costs

Introduction of the new system provided direct operational cost savings to the hospital by eliminating the cost of transcription. The average cost per report in the transcription system was \$3.50 per report. In contrast, the transcription cost per report with the structured reporting system is \$0 per report, because the transcription step is eliminated from the reporting process.

Transcription Costs	1996 Transcription	1999 StructuRad	Cost Savings
\$ per report	\$3.50	\$0	\$3.50
Number of reports	40,000	38,000	
Total cost	\$140,000	\$0	\$133,000

For an average 40,000 reports per year, this results in a savings of \$140,000 per year for the hospital. The table shows the actual results, in which there were fewer than 40,000 reports produced at the hospital in 1999. However, the important figure is the savings per report, rather than the total cost for any particular year.

4.1.2. Report turnaround time

Use of the StructuRad reporting system resulted in significant reductions in the amount of time required to submit a complete report to the various stakeholders within the hospital, as well as outside the hospital.

Turnaround time	1996 Transcription	1999 StructuRad
Release report after recording findings (average)	29 hours	60 seconds
Release report after recording findings (range)	6 - 52 hours	60 seconds
Final report available to fax to physician	30 hours	immediate
Final report on chart	30 hours	1 hour
Final report to HIS	40 - 48 hours	immediate
Final report to billing company	40 - 60 hours	12 - 24 hours
Billing abstraction	5 days	immediate
Submit to 3rd party payer	12 days	8 days

These time savings are achieved primarily by removing the transcription step from the reporting process. We will see later that the actual time spent by the radiologist to record findings is roughly the same for the two systems. There is an additional savings of 4 - 5 elapsed days by the billing company, because the ICD-9 and CPT codes are automatically abstracted by the software, which removes one manual step from the billing process.

4.1.3. Billing abstraction

As shown in the previous table, the StructuRad reporting system completely removes the coding step from report processing, because report templates already carry ICD-9 codes for clinical indications and CPT codes for radiographic techniques. In addition to eliminating this time consuming step, the coding accuracy improved from 95% when performed manually to 100% when captured through the structured reporting system.

4.1.4. Transcription errors

Due to the elimination of the transcription step, the StructuRad system eliminates the need to edit transcription errors, which previously occurred 13% of the time in the transcription system used at Midway.

	1996 Transcription	1999 StructuRad
Transcription errors	13%	0%

The equivalent of a transcription error occurs in the new system when the radiologist mis-selects an item from the menus. The number of these types of errors has not been studied within the new system. However, the experience of two of the authors is that these errors are very rare in final reports. The system tends to limit such errors, because the report is immediately reviewed upon completion before it is signed off. This immediate review in the StructuRad system is more efficient than reviewing transcriptions at a much later time.

4.1.5. Incomplete reporting leading to rework

The StructuRad reporting system resulted in a dramatic elimination of rework on the part of the radiologist, which was previously caused by incomplete procedure descriptions, inaccurate clinical information, or incomplete protocol description.

Radiologist coding errors	1996 Transcription	1999 StructuRad
Incomplete or inaccurate descriptions	20%	0%

This improvement is due to several differences in the structured reporting system. First, the radiologist receives immediate feedback by seeing the reported results, allowing the radiologist to self-correct at the time of recording the findings. Second, the report templates already contain complete descriptions, so that the radiologist only needs to select them, rather than generate them.

The consequences of reworking a report are very costly. When a third party payer returns a report to the billing company, this delays payment for the procedure and causes additional work on the part of the billing company. For more than 50% of these rejected reports, the billing company can do the rework and resubmit the report to the third party. However, in the remainder of cases, which in 1996 was about 7% of all reports, the billing company returns the report to the radiologist for rework, which adds to the cost of producing that report.

4.1.6. Interruption of radiologist for results

The StructuRad system provided an unexpected benefit to reporting radiologists, because it reduced the number of interruptions from referring physicians seeking results.

Interruptions	1996 Transcription	1999 StructuRad
Physician seeking results	4 per hour	0.5 per hour

This reduction of interruptions results from the final report being back in the hands of the referring physician in a shorter period of time.

In addition to reducing the number of interruptions, the StructuRad system provides a qualitative improvement for dealing with interruptions. Upon returning from an interruption to a report in process, the radiologist may view the partially complete report nearly instantaneously as a text document. In contrast, when returning after an interruption to a dictation, the radiologist typically replays the partially complete

dictation, in order to reestablish the context before resuming further dictation. Thus, the StructuRad system provides a time savings for recovering from interruptions.

4.1.7. Radiologist time to create a report

In comparing structured reporting to transcription, there was no difference in time spent recording findings, which averages 5 minutes per report for both methods. However, there is a slight overall advantage to the structured reporting system, because there is no need to review a report or sign it when a transcription comes back. This results in an overall gain of 1 or 2 minutes per report.

Radiologist time (average)	1996 Transcription	1999 StructuRad
Record findings	5 minutes	5 minutes
Review transcription and sign	1 minute	0 minutes

This may appear as a surprising result, because most people assume that dictation is a faster form of data entry for the radiologist than use of a computer-based system. After all, people without typing skills can speak faster than they can type. However, the StructuRad system involves almost no typing. It is a menu-based system where the user selects pre-defined items. This means that a single selection may insert a block of text, such as the following example, where the radiologist makes one selection for each paragraph and types the values for two quantity parameters, shown as <x mCi> in the following text, in order to generate a complex procedure protocol:

```
Lung V/Q scan protocol:
Ventilation:
  Phase 1 (single breath). Inhalation of <x mCi> of Xe133 for 10-20
  seconds in the supine position.
  Phase 2 (equilibration phase) Closed loop rebreathing of Xe133 for 3-
  5 minutes.
  Phase 3 (washout phase) Xe133 exhaled into charcoal trap.
  Scintigrams performed in the <posterior/anterior/right lateral/left
  lateral> position.
Perfusion:
  IV injection of <x mCi> of Tc99mMAA in the supine position. Routine
  views including anterior, posterior, right lateral, left lateral,
  RAO, LAO, RPO and LPO were performed.
```

In this case, the radiologist would have selected each of the phases. Upon selecting "Phase 1", the system prompts the radiologist to supply a quantity in millicuries. The value that the radiologist enters will replace the "x" shown in this template. Similarly, the radiologist is prompted to enter a quantity value for the "Perfusion" paragraph. The radiologist may also choose the ventilation position in the "Phase 3" paragraph.

Therefore, efficient description of the procedure is made possible by having the parameterized protocol in a template, which is then specified completely when the radiologist reports findings. A similar approach is taken in some speech recognition systems, where a keyword names a "macro" that causes an entire block of text to be inserted.[14]

Admittedly, the radiologist's familiarity with the report template will determine the speed with which selections can be made. However, it is StructuRad's experience that a well-trained user can record findings as quickly with the StructuRad system as they can dictate findings for traditional transcription.

Another factor that reduces the time spent recording findings in the StructuRad system is that findings are automatically extracted to the impressions section of the report, so there is no duplication of data entry. Upon completion of a particular finding, the radiologist may mark that finding to appear in the impressions. The StructuRad system automatically extracts the primary information to be included in the impression.

Therefore, while it might seem surprising that use of a computer-based system is just as fast as speaking, the StructuRad system provides several process improvements that enable this speed.

4.2. Subjective results

4.2.1. Advantages of menu-based systems

An important advantage of the menu-based reporting system is that it provides immediate feedback by showing the actual output of the report. This enables the radiologist to self-correct errors quickly. For example, if the radiologist accidentally selects 'left lung', rather than 'right lung', the display of the report makes this obvious immediately. In contrast, dictation is a serial process where previously spoken words "disappear" into the dictation stream, only to return again when the report is returned from the transcription service.

The StructuRad decision trees are developed and maintained by practicing radiologists who use the system themselves. Therefore, they are immediately aware of their design decisions regarding the hierarchical structure of the decision tree, because they must use the resulting system the next time they make a report. This has led to a sequence of refinements over several years, so that the templates for each modality are complete and easy to use.

The StructuRad system is not currently used for outcomes research. However, the structured representation of reports provides a more consistent database for searching than does a collection of free-form text reports.

4.2.2. Misconceptions regarding menu-based systems

Most people dismiss the usefulness of a menu-based system for radiology, because they assume that it is not possible to capture all of the possible findings and comments that a reporting radiologist would want to make. StructuRad has shown this assumption to be false, at least for the radiologists who have used the system. As mentioned previously, all radiology reports at Midway Medical Center have been produced with the StructuRad system since mid 1998. In some cases, the radiologist may need to use one of the open-ended "comment" input boxes. However over time, enough content has been added to the decision trees, so that this is a rare occurrence.

Another misconception about menu-based reporting is that the number of possible findings is so large that a decision tree must be unwieldy to navigate. StructuRad's experience shows that this is not the case. However, the way in which the options are organized has a huge effect on the usefulness of the system. Starting from the very earliest efforts in 1995, the report templates have been refined and reorganized, in order to facilitate the reporting process and to present the options in the most efficient manner. The key is to organize the decision tree so that choices are made available in the order in which a radiologist desires to specify findings. StructuRad expects to continue this refinement as they make the system available to more radiologists.

For people who have never been involved in developing a categorical analysis of a wide body of knowledge, it may appear as though there are few design decisions to be made. The thinking is that the data takes care of itself and a hierarchical structure falls out "naturally". On the contrary, it is an iterative process to develop a decision tree, let people use it, identify areas where the structure does not match typical workflow, revise the tree, and test again. While some input from a user interface expert is useful, most of this work needs to be done by a "domain expert", i.e. a practicing radiologist.

4.2.3. Acceptance by referring physicians

Referring physicians appreciate the consistent structure and organization of StructuRad's reports, even when the reports are produced by different radiologists.

This makes it easy for the referring physician to focus quickly on desired information. The consistency occurs at two levels. First, the format of the reports and overall content categories are similar, because radiologists are working from templates. For example, descriptions of pathologies and negative findings are presented in a consistent order relative to each other, regardless of the way in which radiologists navigate the template to select items in the decision tree. Second, the structure of findings statements are similar. As a simple example, physicians have gotten used to seeing a "trend" statement in the findings (terms such as new, unchanged, increased, decreased, resolved, ...) and they may inquire about the trend if they do not see it in a particular report. The radiologists are not required to select from all of the categories that are presented, so it is not obligatory to report the trend. However, the template serves as a checklist that assists the radiologist to create a more complete report, if so desired.

Another obvious advantage for the referring physician is the reduced time to receive a final report. As discussed earlier, the turn around time for delivering a final report has been dramatically reduced through StructuRad's structured reporting system as compared to previous use of a transcription-based system.

One complaint of referring physicians, especially when the system was first introduced, was the "unnaturalness" of the English text generated by the reporting system. Remember that the radiologist captures findings by making selections in a menu-based system. That structured representation of the report is then processed to generate a conventional English text report. The generated text has never caused misinterpretations, but in some cases it was mildly annoying to referring physicians. It takes quite a lot of effort on the part of the template writers to build templates that lead to well-formed English output. However, there has been steady improvement in this area of the system, so that reports are currently well received by referring physicians.

4.2.4. Acceptance by reporting radiologists

As mentioned previously, StructuRad does not have unbiased reporting radiologists using their system, because the radiologists who develop the report templates are the same ones who use the system. However, there are several important features that motivate the radiologists to keep using the system.

An essential success factor for the reporting radiologists is that structured reports are generally more complete, consistent, and comprehensive than dictated reports. The radiologists believe that they are creating better quality reports in the same time that they used to spend dictating. This results from the menus prompting the radiologist, which encourages the production of a complete and comprehensive report.

Another important feature for the reporting radiologist is the automation of technique sections. As described previously, a single menu selection (or a small number of selections) may contribute a complex procedure protocol to the report. Furthermore, producing a report that is immediately visible from a series of selections is very different than starting with a blank tape and dictating with no feedback along the way regarding previous statements. Using the menu system to manipulate the final report directly provides a feeling of control to the reporting radiologist.

Finally, the system assists the radiologist's interpretation by embedding common nomenclature in the templates. This is like having a textbook at hand when describing a complex lesion. For example, the templates use common nomenclature for orthopedic fractures. When the radiologist is reporting findings from a study, all possible types of fractures are listed in the template. Therefore, the radiologist may choose from among listed alternatives, rather than having to create the description through dictation.

4.2.5. Acceptance by administrators

There are several features of StructuRad's structured reports that are appealing to hospital administrators. One essential feature is that ICD-9 and CPT codes are contained in report templates, so they are automatically inserted into the report based on the radiologist's selection of findings. This automated billing abstraction leads to three important benefits. First, doing the coding once in a template is significantly less expensive than manually coding after a report has been produced. Second, by eliminating the step of manual coding, bills can be submitted in a shorter period of time. This feature saves the radiologists' billing company 4 days of elapsed time per report. Third, automatic coding is more accurate than manual coding, which means that insurance companies are less likely to return a StructuRad report for rework.

As shown in section 4.1.2, the StructuRad system results in a significant reduction in elapsed time from the initial analysis of a study to the submission of a reimbursement request to a third party payer. Furthermore, the report is less likely to be returned for rework, because the contents are more detailed and the coding is more accurate. This shortening of time from reporting findings to requesting reimbursement leads to better cash flow.

Another feature that appeals to administrators is the reduced cost of StructuRad reports. Costs are reduced by eliminating transcription, while also decreasing the amount of time that a radiologist spends with a report.

In summary, the factors of improved quality, reduced turnaround time, and reduced cost have been well received by hospital administrators.

4.3. Areas to be enhanced

4.3.1. Integration with PACS

The current implementation of the StructuRad structured reporting system is tightly integrated with the ALI Technologies PACS system. This enables report templates to be displayed on the same screen with digital images. However for images that are not captured by the PACS, such as x-rays, the image is viewed separately from the screen on which the report is generated. This means that the radiologist must glance back and forth between the analog film image on a traditional view box and the menu selections on a computer screen. There are several strategies available to improve this situation. First, if all images were displayed digitally in a system that integrated the x-ray and menus on a single screen, then there would be a shorter distance for the eye to travel between the image and the menus. Another approach is to provide a voice interface to the menu system, so that radiologists can keep their eyes on the image while driving the menu selections through speech commands.

4.3.2. Integration with Hospital Information System (HIS)

The StructuRad system was previously a standalone system that generated paper reports for transferring results to other systems. However, the ALI Technologies PACS that provides the reporting framework is being upgraded in November 2001, so that it will be integrated with the HIS at Midway. This will enable radiology reports to be submitted electronically to the HIS as a part of the overall PACS workflow.

4.3.3. Reporting software

There are several ways in which StructuRad intends to continue improving its reporting software. It is rewriting the underlying reporting engine to provide additional functionality that can be deployed on less expensive hardware. This includes improving the user interface, so that it will be easier to walk the decision tree. Also, the tree will be able to hold context-sensitive reference information, in order to improve the diagnosis process. In addition, the report formatter is being enhanced to improve the

readability of reports by generating more natural English text, which will improve acceptance by referring physicians.

4.3.4. Software standards

The next release of the StructuRad software will use the eXtensible Markup Language (XML) as the standard representation for reports. Even though XML is a widely used technology standard for data exchange, the actual structured content of a radiology report is not standardized by any widely-accepted XML language. However, using a standard representation method provides flexibility for the future when there may be an XML standard for radiology report content.

5. Conclusions

We have examined a structured reporting system that has been in clinical use at a community hospital since 1997. Since mid 1998, reports for all twelve modalities are produced exclusively through the structured reporting system. Transcription is no longer used for any radiology reporting.

In this environment, we found that structured reporting leads to:

- Improved quality and consistency of reports by using report templates and a menu-driven interface.
- Improved response time by eliminating process steps, so that the final report is released directly from the radiologist.
- Reduced costs by eliminating transcription without increasing the time required by a radiologist to record findings.
- Automated abstraction of billing codes for reports by embedding ICD-9 and CPT codes in the report template items, which leads to reduced billing costs, as well as improved cash flow due to shorter elapsed time to present reimbursement requests to third party payers.

These benefits were achieved even though the reporting system was not tightly integrated with hospital (HIS) or radiology (RIS) information systems. In the future, StructuRad expects to:

- Follow evolving reporting standards, so that the reporting system can be integrated with other systems.
- Improve distribution times to other information systems through application integration.
- Improve diagnoses by supplying context-sensitive reference information, which can reduce the time for radiologists to record their findings.

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