Adoption and Value of Multimedia Radiology Reports Assessed by Hyperlink Usage, Click Through Rates and Analytics

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Objectives

- Demonstrate adoption rates of bookmarks and hyperlinks in MERR among radiology subspecialties and modalities
- Analyze ordering provider's interaction with EMR and PACS and report hyperlinks evidenced by click through analysis
  - by referring medical subspecialties, institutes, research protocol
- Assess report value by exploring multimedia report interaction
  - by click through behaviors
  - objective evidence physicians are reading reports and content clicked

*EMR= Electronic Medical Record
Background, Development, Future

• Radiology report has not changed dramatically over the years
• Review survey radiologists & oncologists report preferences
  – verified oncologists and radiologists prefer hyperlinks

• Annotations of radiologists findings in reports now hyperlinked
  – such as lesion measurements or ovals around lung pathology
  – unique opportunity to objectively analyze referring physicians CTR
  – can use these connections to train in supervised deep learning
NIH Clinical Center Oncologist & Radiologist Survey*

• Years ago we aimed to improve prior text-only radiology reports
  – Surveyed radiologists’ and oncologists’ reporting preferences
  – Tumor quantification was disjointed, inconsistent, tedious, inefficient

• Oncologists often measure lesions independently from report
  – Or search for measurements buried in our prior text only reports
  – It was tedious trying to match oncologist target lesions on images

• Survey verified oncologists and radiologists prefer hyperlinks
  – The report hyperlinks take clinicians to annotated measurements

Are NIH CC Radiology Reports adequate for Oncology Assessment?

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"...let the 3D lab staff select and measure target lesion measurements."

*Folio LR. Quantitative Radiology Reporting in Oncology: Survey of Oncologists and Radiologists. AJR. 2015*
Radiologists’ Satisfaction with Current Clinical History

Question:
Current clinical history on imaging requests is satisfactory for radiologists to provide tumor assessments.

Question: How would you prefer tumor measurements presentation in radiology reports?
Interactive Report Components*

• Hyperlinked text to measurements, arrows, ovals, prior reports
  – Takes clinicians directly to the image slice in the CT or MR
  – Very helpful in CT and MRI exams with > 1,000 images, 20 sequences

• Hyperlinks easily created by dictating the word “hyperlink”

• Bookmark\(^1\) tables of measurements (automatically generated)

• Additional multimedia elements (can be combined or separate)
  – Graphs representing lesion size changes over time on related\(^2\) lesions
  – Images, graphs or tables included in report or separate tumor report

FINDINGS:

Chest CT:
Lungs, pleurae: Unchanged lung nodules for example
right upper lobe  *(1.9 cm x 1.5 cm) (series 4, image 81)*

- Minimizes crosscheck
- Metadata automatically includes: x,y,z location, who measured, when, relation and designation, name, lesion type
- “Active annotation” is either most recent measured, clicked or “b” shortcut
FINDINGS:

Chest CT:
Mediastinum: Small mediastinal adenopathy for example subcarinal measuring 2.5 cm by 1.4 cm in series 2 image 27. Also, there is a right hilar adenopathy measuring approximately 5 cm on its long diameter. There is another lymph node more inferiorly measuring about 2 cm by 1.8 cm. No pericardial or pleural effusions. Lung window portion of this examination demonstrates Unchanged lung nodules for example right upper lobe measuring 1.2 cm by 1 cm. Heart and great vessels are apparently unremarkable.

Abdomen: Celiac artery and SMA origins are enhanced normally. Pancreas is normal, right kidney and left kidney are seen without apparent abnormalities. Right and left adrenal are normal. Liver parenchyma has a similar hypodensity to the prior study. Retroperitoneal periaortic regions have tiny lymph nodes, non measurable.

Pelvis: Along central pelvis, all structures look normal; whereas, sidewalls show an anterior pelvic mass unchanged on size compared with prior pelvic examination. Osseous structures, spine, body wall, soft tissues: unremarkable

IMPRESSION:
1. Unchanged lung nodules
2. Stable mediastinal and hilar adenopathy/masses
3. Stable anterior pelvic wall mass
4. No new soft tissue mas
… making it difficult for oncology staff to extract tumor measurements, slice and image number of target lesions…
FINDINGS:

Chest CT:
Mediastinum: Small mediastinal adenopathy for example subcarinal measuring 2.5 cm by 1.4 cm in series 2 image 27. Also, there is a right hilar adenopathy measuring approximately 5 cm on its long diameter. There is another lymph node measuring approximately 2 cm by 1.8 cm. No pericardial or pleural effusions. Lung window portion of this examination demonstrates unchanged lung nodules for example right upper lobe (0.8 cm x 0.4 cm) (series 4, image 84)

Mediastinum, heart, great vessels: Unchanged mediastinal adenopathy: subcarinal (2.5 cm x 1.4 cm) (series 2, image 27) and right hilar adenopathy: (5.1 cm x 2.4 cm) (series 2, image 32) and (2.1 cm x 1.4 cm) (series 2, image 25)

Abdomen CT:
Lymph nodes, abdominopelvic vascular: unremarkable
Liver, spleen, biliary, gallbladder:
GU:
GI:
Pelvis: Unchanged anterior pelvic wall mass
Other soft tissues, sidewalls: Unchanged anterior pelvic wall mass
Osseous structures, spine, body wall, soft tissues: unremarkable

IMPRESSION:
1. Unchanged lung nodules
2. Stable mediastinal and hilar adenopathy/masses
3. Stable anterior pelvic wall mass
4. No new soft tissue mass

now measurements and critical items stand out and interact with crucial imaging findings,
FINDINGS:

Chest CT:
Lungs, pleurae: Unchanged lung nodules for example right upper lobe (0.8 cm x 0.4 cm) (series 4, image 84)

Mediastinum, heart, great vessels: Unchanged mediastinal adenopathy for example subcarinal (2.5 cm x 1.4 cm) (series 2, image 27) and right hilar adenopathy for example (5.1 cm x 2.4 cm) (series 2, image 32) and (2.1 cm x 1.4 cm) (series 2, image 25)

Abdomen CT:
Lymph nodes, abdominopelvic vascular: unremarkable
Liver, spleen, biliary, gallbladder, pancreas: unremarkable
GU Kidneys, ureters, adrenal glands: unremarkable
GI Small and large bowel, mesentery, peritoneum: unremarkable

Pelvic CT: Central pelvis, sidewalls: Unchanged anterior pelvic wall mass.
Osseous structures, spine, body wall, soft tissues: unremarkable

IMPRESSION:
1. Unchanged lung nodules
2. Stable mediastinal and hilar adenopathy/masses
3. Unchanged anterior pelvic wall masses
4. No evidence of new soft tissue mass
Hyperlinked Text to Image Annotations

• Hyperlinks to image findings seem to exemplify Clarke’s 3rd law\(^1\)

> “Any sufficiently advanced technology is indistinguishable from magic”

– Thought provoking pre-implementation clinical staff presentations
– Interactive reports result in fewer consultations to help “drive” PACS

• Help radiologists compare priors; jumping directly to key findings
– Enhance readability of unstructured free text narrative reports
– Links combined with standard RadLex templates compound efficiency

• Overwhelming positive feedback supports our survey results\(^2\)

> “...a game changer.”

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1 British science fiction writer Arthur C. Clarke
2 Folio LR. Quantitative Radiology Reporting in Oncology: Survey of Oncologists and Radiologists. AJR. 2015
We subdivided percent exams with bookmarks and percent of reports with hyperlinks by subspecialty.

*Body CT:
94% bookmarks
93% hyperlinks

Highest due to need for consistent measurements in cancer trials

Gaskins C, Folio L. AI Driven Report Value. HIMSS Presentation. March 2018
Physician Clicks from EMR to Thin PACS Viewer

Soon, report “Click Through” analysis should provide a tool to confirm and assess the clinical value of hyperlinks.

Just over 70% of click through from our EMR to our PACS are from four NIH institutes.

Example action: Can help target EMR/ PACS training.
UVA referred patient with multimedia report to NIH
Discussion

• NIH CC is first in the world to implement; UVA 2nd also analyzing
• Widespread adoption supports improved efficiency
  • Radiologists do not adopt technologies or workflows that are not efficient
• Applying advanced hyperlink analytic tools to radiology reports
  • first objective evidence of report value
  • proving clinicians are reading reports; more so interacting with them
• UVA report CTR hyperlink analysis similar to NIH*
• Hyperlinked text connected to image annotation will enhance AI

Gaskins C, Folio L. AI Driven Report Value. HIMSS Presentation. March 2018
Hyperlink-to-Annotation to enhance Machine Learning

• Build on preliminary deep mining report/image data results\(^1\), \(^2\)

• Preliminary work demonstrates value of radiology reports as the basis of labeled training set for deep learning
  • Lesion ID in phantoms with simulated interactive reports

• Radiologists text associated with annotations through links serve as the “supervised” deep learning labeling
  • Enhanced semantic NLP reports provides ideal deep learning training set


Deep Learning Hyperlink Annotation Schema

- **DA**
  - Defined Architecture: cross sectional exams in PACS
  - Radiologist reports with hyperlinks to annotated images

- **SDL**
  - NVIDIA 4x GPU on RHEL (run data locally, not cloud)
  - Apply Supervised Deep Learning (SDL) on labeled data

- **TM**
  - Trained Model (TM) ready for test set of unknown CT exams

- **Test Set**
  - Apply test set of cross sectional exams with unlabeled pathology
  - Analyze results, eventually apply as decision support
Conclusions

• Bookmark & hyperlink adoption by radiologists supports efficiency
  • radiologists would not adopt inefficient workflows
  • we analyzed by radiology subspecialty, institute

• Body radiologists have highest hyperlink use at NIH
  • NCI clicked more links (than all institutes) in our EMR to PACS reports/ images
  • likely due to need for consistent quantification cancer trials

• Can assess report value objectively by referring clinician interaction
  • by analyzing CTR of hyperlinks within our EMR and hyperlinked reports
  • we verify physicians reading our reports; further interacting with them

• Hyperlinked text connected to image annotations will enhance AI
  • radiologists are the “supervision” of supervised deep learning with each report
Thank you for your attention

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References


• Gaskins C, Folio L. AI Driven Report Value. HIMSS Presentation. March 2018