RESEARCH ARTICLE

A Comparison of Musculoskeletal Exam Documentation in Two Electronic Health Record Systems

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`Abstract

Introduction
Electronic Health Record (EHR) systems have changed the way physicians record their exams. Several studies have reviewed the quality of these transcribed exams; some of which have found with regard to arthritic and musculoskeletal conditions significant omissions in the recorded exam.

Methods
Inpatients charts for patients receiving rheumatology consultations at 2 different Indiana hospital systems, both employing unique EHRs, were reviewed. Notes were evaluated for the presence of four major musculoskeletal criteria: axial skeleton, upper extremity, lower extremity, and muscular exams. Exam completeness was assessed by evaluating more specific examination documentation within these major groups. Simple two sided Pearson Chi Square tests were used to assess all other individual patient and management dependent variables for the significance of the effect on exam documentation.

Results
44 study patient cases were reviewed. Of the management dependent variables, the most significant one in affecting the likelihood of a thorough MSK examination being recorded was the location of the patient ($p=0.017$). Patients admitted through the Emergency room compared to direct admits or ICU transfers were more likely to have an MSK exam recorded. The more detailed exams were recorded by the neurology services and rheumatology fellows. In comparing the two different EHR systems, more detailed examinations were found with users who free typed examinations versus those who used templated exams.

Conclusions`
This study demonstrated the need for optimization of EHR practices with regard to managing patients with arthritic and musculoskeletal conditions. Several patient cases where joint conditions were key components of the patient care had marked omissions of MSK exam documentation. This may likely reflect a disconnect between what occurs during the examination and what is actually transcribed. Various factors may foster these oversights including use of templated notes, copy and paste features, and click fatigue.

Keywords: Electronic health record, musculoskeletal documentation

1. Background: A brief history of medical documentation

Over the centuries, documentation within the practice of medicine have evolved just as the science itself. From early medical records dating back to papyrus in 1600 BC Egypt, to Hippocrates' case records during the 5th Century BC, to physician case books, daybooks, and diaries of the 18th and 19th centuries—the methodology of how physicians record medical exams has reinvented itself many times over.[1-6]

The intent of patient record keeping has taken on a broader scope over time. In the 20th century medical records were an important part of education; patient cases were used for didactic and archival purposes with some records being bound and stored in libraries for teaching.[7,8] With time the role of research with medical records was actualized and by the 1880s the medical record became recognized as a legal document.[9,10]

Prior to the 20th century, much of the record keeping was unorganized, often lacking in depth pieces of information. This began to change in 1907 Henry S. Plummer (1874-1937) developed models at St. Mary's Hospital and the Mayo Clinic which called for each patient to be assigned a clinic number and for all data to be maintained for each patient within this single record.[11] The idea of what is often termed now as a medical record number or MRN was born. The practice of record keeping gained further momentum by a bolstering from the American College of Surgeons (ACS). In 1914 the ACS went about setting standards for prospective members, requiring applicants to submit 100 case abstracts; the submissions however were scant and inadequate to judge the providers' capabilities.[12] This led the ACS to launch a reform program setting standards for hospital competency through documentation.[12] The ACS called for hospitals to keep a repository of records on all hospitalized patients which included a summary of each patient's care and outcomes of therapies.[12,13] Most of the 20th century saw these records stored in one master copy written on paper, filed into sub sectioned folders.[14]

The 1960's revolutionized American healthcare. In 1965 President Lyndon B. Johnson's historic Social Security Act, which included provisions for Medicare and Medicaid, was passed.[15] The Amendments to the Social Security Act contained several hospital requirements—included among them was the maintenance of clinical records.[16] At this same time in the 1960's came the advent of computer technology which opened new possibilities for the practice of medicine under these newer standards set forth.[17,18]

1.1 Medical documentation with electronic health records

The computer age brought forth the birth of the electronic health record (EHR). Initial versions were developed by academic medical institutions.[19-28] The aim of these programs varied with some centered on hospital billing and scheduling while others were focused on clinical systems to improve medical care and research. [21,29-31] By the 1980s and 1990s the size and costs of computers dropped, making the feasibility of widespread adoption of an EHR a closer reality.[32-34] In 2009, passage of President

Barack Obama's Meaningful Use Act further spurred the implementation of EHRs as it called for use of certified EHR systems.[14,35]

The adoption EHRs has led to some clear benefits such as elimination of problems with legibility that were prevalent with handwritten notes, increased availability of clinical documents for research and quality improvement initiatives.[36-40] However EHRs are not without fault and many unforeseen consequences have surfaced since their institution. For some users it may take longer to type a note on an electronic system as compared to a writing a paper note. This increased time has led to input errors and also common use of short cut features such as "cut and paste" or "copy forward".[41,42] While the shortcut features are designed to ease use, overreliance on them may lead to some errors in documentation.[41-45]

1.2 Musculoskeletal exam documentation in electronic health records

The musculoskeletal system is a critical exam portion for evaluation and monitoring of arthritic and other rheumatologic conditions. Critical evaluations of the documentation of musculoskeletal physical examinations has only been studied in a limited capacity. The results of more modern studies were not too dissimilar from what the ACS found in 1914 on reviewing surgical case documentation. In patients complaining of acute shoulder or knee pain, an abysmal 28% ± 17 % of patients had shoulder or knee physical exams even documented.[46] Amongst inpatients with active musculoskeletal (MSK) complaints only 49% had documentation of an MSK history and only 22% had an MSK exam on admission notes.[47] Review of inpatient pediatric records found only 4% contained an MSK exam.[48] With regard to provider types, orthopedic surgeons outperformed internists and rheumatologists in charting more historical and physical examination items.[46] These deficiencies prompted this study to explore potential causes that may contribute to insufficient MSK exam documentation in the era of EHRs.

2. Study methods

Patients receiving inpatient rheumatology consultations at two Indiana University affiliated hospitals from were included in this study. These hospitals included Wishard Hospital (now Eskenazi Hospital), which is a large county hospital, as well as University Hospital, which is an academic tertiary referral center. Forty four patients met this criteria and were included. The study was approved by the Indiana University Purdue University Institute's IRB committee.

Each chart was reviewed by an individual investigator who evaluated all admission history and physicals, daily notes by all primary service medical students, nurse practitioners, residents, and staff on the day of admission and 24 hours preceding the rheumatology consult. All initial rheumatology fellow and staff notes were also evaluated. Exams were evaluated for the presence of four major musculoskeletal criteria: axial skeleton, upper extremity, lower extremity, and muscular exams. Admitting practitioner exams were evaluated for the presence of what was an adequate musculoskeletal exam. This was defined as having at least 2 or more major areas identified in the documented exam.

This was chosen as an exam standard as an appropriate evaluation of a joint or area of the axial skeleton would include an associated muscular exam thereby achieving at least 2 major MSK exam areas. In addition, by requiring 2 major areas, exams that may have minimal documentation where it is difficult to assess the quality of the exam were able to be excluded.

Table 1. Musculoskeletal Exam Documentation Areas

Major Areas	**Specific Areas**
Axial skeletal	Cervical
	Thoracic
	Lumbosacral
	Sacroiliac
	Tender points
	Nonspecific Spine
Upper Extremity	Shoulder
	Elbow
	Wrist
	Hand
	Grip
	Nonspecific Upper Extremity
Lower Extremity	Hip
	Knee
	Ankle
	Foot
	Nonspecific Lower Extremity
Muscular	Proximal Upper Extremity
	Distal Upper Extremity
	Proximal Lower Extremity
	Distal Lower Extremity
	"normal motor"
	Nonspecific motor exam

Note: Each exam was scored 1 point for each specific area that was recorded.

Exam completeness was assessed by evaluating more specific examination documentation within these major groups. A total of 23 possible individual areas were noted which included individual joints, proximal/distal strength, tender points, axial spinal divisions, as well as nonspecific examination qualifiers (e.g. no focal

deficits). The complete list is included in Table 1. There was a distinction made between a "normal motor exam" that appeared to use a preselected template choice and a general comment pertaining to a nonspecific exam such as no focal deficits. In addition, there needed to be an account for general statements such as "no focal deficits" or "no joint deformities". The statement"no focal deficits" was assigned one point for a generic muscular exam. The statement "no joint deformities" was given 2 points (1 for the upper and 1 for the lower extremity nonspecific exams).

Proposed variables that may affect documentation were extracted from the chart review. Variables were divided into two major categories: patient dependent variables and management dependent variables. Patient dependent variables included patient age, cognitive ability, if they had a joint complaint, if they were intubated. Management dependent variables included whom the primary service was (e.g. general surgery, medicine, neurology), where the patient was located (e.g. intensive care unit, floor), if the patient was a transfer from an outside medical facility, the level of training of the examiner (e.g. medical student, resident), and the EHR system used.

Both institutions have EHRs. Wishard utilized an EHR called Gopher which was created over 30 years ago and offers an option of utilizing a template which has a dropdown type menu option for the musculoskeletal exam versus free typing an exam. Gopher is keyboard driven with limited mouse features. University Hospital uses the Cerner EHR which offers a point a click option versus free typing. As part the investigation it was noted if users clearly used the dropdown or point and click options versus free typing. Of note since the completion of the study, University Hospital has altered their EHR documentation formats by offering a greater number of point and click choices within the musculoskeletal exam portion of the medical record. Also Eskenazi has adopted a new EHR system, EPIC.

Simple statistical analyses were performed by the primary investigators using SPSS software. A 1 sample t-test was used to evaluate age demographic data and effect on documentation of the musculoskeletal exam. Simple two sided Pearson Chi Square tests were used to assess all other individual patient and management dependent variables for the significance of the effect on exam documentation. Standard means were calculated for evaluation for completeness of MSK exam and template use. All statistics were carried out by a single investigator.

3. Study results: Documented admission exam

42 patients met inclusion criteria. One patient was seen in the emergency room but still received a consult from the inpatient rheumatology service. This patient was included in the study. In addition one of the patients received two separate rheumatology consults during the study period and therefore each consult was maintained as a separate study patient case, bringing the total number of study patient cases (n) to 44. Baseline demographic information is provided in Table 2.

Table 2. Demographics

Patient Characteristics	
Total (n)	44
Female Sex (%)	61.4
Age (M ±SD)	51.3 (15.0)
Race (%)	
African American	34.1
Caucasian	61.4
Hispanic	4.5

Admitting practitioner exams were evaluated for the presence of an adequate musculoskeletal exam defined as 2 or more major areas identified in the documented exam. Exams documenting a "supple neck" were given credit for an axial skeleton exam, however there is some uncertainty if this is considered a true musculoskeletal exam or at least a complete one. 7 of the 44 patients were in this category with regard to this specific example. In addition, there needed to be an account for general statements such as "no focal deficits" or "no joint deformities". The statement of "no focal deficits" was assigned one point for a generic muscular exam. The statement of "no joint deformities" was given 2 points (1 for the upper and 1 for the lower extremity nonspecific exams). Using this model, both patient and management dependent variables were analyzed to assess the impact on the presence of exam documentation as shown in Table 3.

Table 3. Musculoskeletal exam documentation on admitting exam

Variables	**≥ 2 Major Areas**	**P value**
Patient Dependent Variables		
Age (M ± SD)	50.9 (14.0)	0.29
Race (%)		0.11
AA	86.7	
Caucasian	55.6	
Hispanic	50	
Joints a complaint (%)		0.068
yes	48.2	
no	20	
Cognition Impaired (%)		0.061
yes	10.3	
no	33.3	

Intubated (%)		0.013
yes	70.7	
no	0	
Management Dependent Variables		
Hospital (%)		0.15
Wishard, County Hospital	58.6	
University, Tertiary Referral Center	80	
Primary Admitting Service (%)		0.063
Emergency Medicine (n =1)	100	
Hospitalist (n= 12)	85.7	
Medicine Teaching Service (n= 23)	69.6	
Neurology (n= 4)	50	
Surgery (n=1)	0	
Transplant Surgery (n=3)	0	
Location of Admission (%)		0.017
Clinic (n=5)	20	
Emergency Department (n=27)	81.5	
Hospital Ward (n=11)	54.5	
ICU (n=1)	0	
Hospital Transfer (%)		0.95
Yes	66.7	
No	65.7	
Level of Training of Exam Author		0.18
Emergency Medicine Staff (1)	100	
Hospitalist (14)	85.7	
Medical Student (3)	66.7	
Medicine Resident (18)	61.1	
Surgery Resident (2)	0	
Medicine Fellow (1)	0	
Medicine Staff (1)	100	
Neurology Resident (3)	33.3	
Neurology Staff (1)	100	

Notes were reviewed 24 hours preceding the rheumatology consult along with initial rheumatology fellow and rheumatology attending staff notes. Means exam scores out of 23 points were calculated and are shown in Table 4. The most detailed exams were recorded by rheumatology fellows. Among non-rheumatology specialties neurology had the next most detailed exams.

Table 4. Musculoskeletal exam scores within 24 hours of rheumatology consultation

Management Dependent Variables	**Exam Score**
Service	
Emergency Medicine	3
Hospitalist	3.83
Medicine Teaching Service	3.17
Surgery	2
Transplant Surgery	1.67
Neurology	4.5
Level of Training of Examiner	
Medical Student	3.67
Resident	3
Fellow	0
Staff	3.94
Rheumatology Fellow	5.86
Rheumatology Staff	3.03

3.2 Assessment of template usage

Additional review was done to evaluate apparent use of EHR software. Evaluations of how EHRs were utilized are included in Figures 1 and 2. While it was not possible with software versions available to clearly distinguish when an exam was documented exclusively by a template format versus free typed, there were cases where the MSK exam appeared only to have template syntax. In these instances these cases were considered to have been recorded with a template. What is notable is the Hospitalist services have higher template usage compared to trainees. In addition Gopher users almost exclusively free texted their notes.

Figure 1: Template use on a Cerner Electronic Health Record system

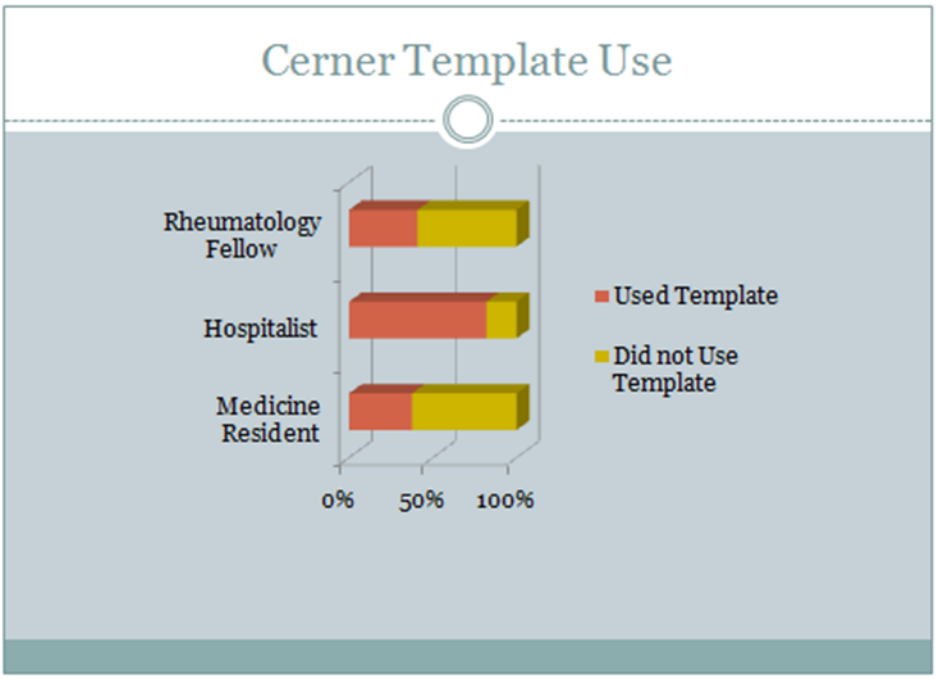
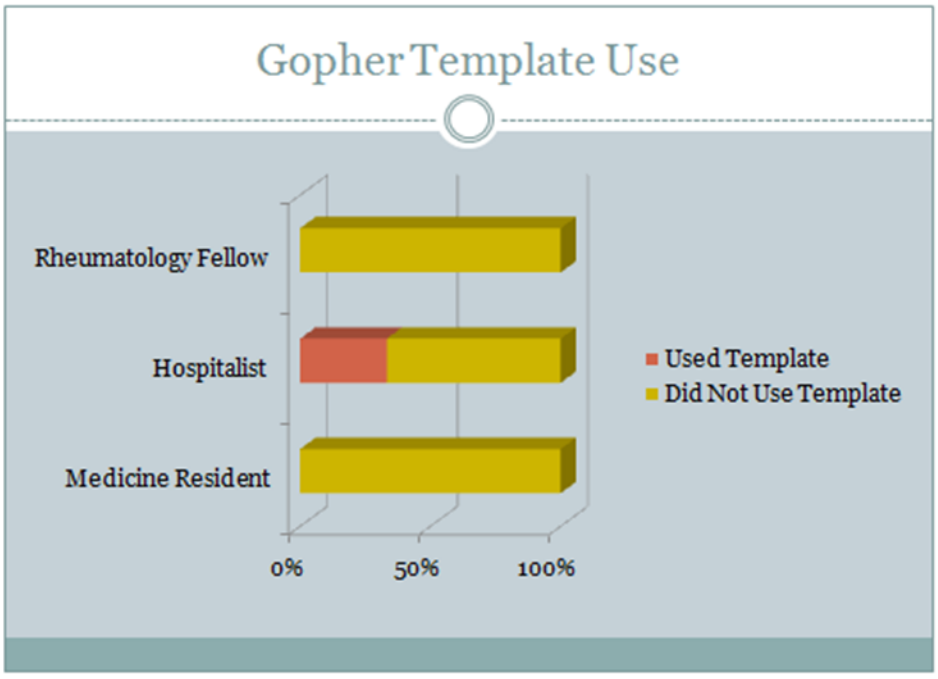


Figure 2: Template use on Gopher Electronic Health Record System



4. Discussion: Deficits in exam documentation

This initial review of MSK documentation on rheumatology patients has revealed some interesting findings that may lead to further hypothesis generation and future investigations. As expected certain variables affect the likelihood of whether an MSK exam will be documented, however what is perhaps more noteworthy is what variables were not as likely to influence this documentation, such as whether or not a patient complained of a joint on admission. Even in patients who mentioned joint symptoms an MSK exam with at least 2 major exam areas was only present 48% of the time. This is of major concern as many rheumatologic diseases often presenting on inpatient services such as septic arthritis or gout for example have an evolving course whose diagnosis may be limited when joint signs are not recorded early.

10 patients in the study received rheumatology consults specifically for an arthrocentesis. In this subset 30% had no joint exam recorded on admission by any admitting practitioner including a supervising attending or 24 hours prior to consult by any member of the primary service. While these findings are somewhat disappointing, they fare better than previous studies. In one study 78% of inpatients with MSK complaints did not have documented exams[47], in another study 72% had no corresponding MSK exam to the joint the patient was complaining of.[46]

There are a few possible explanations for this astounding lack of documentation. One explanation is the copy forward features. On admission exams some practitioners may have a standard exam whether it be templated or free texted likely focusing on what are generally viewed as more critical parts of a hospital admission exam, e.g. cardiac and pulmonary. Anecdotally, MSK exams are often lacking on admission physical exams. So if on admission the MSK exam is not included, these deficits in documentation may often be carried out throughout a patient's admission even in cases where the primary team recognizes a joint problem requiring procedural intervention, as in our study. EHR features, such as cut and paste, which is present on both the Cerner and Gopher systems, may further perpetuate these recurrent exam deficits.[42-45]

In other situations, a patient may have a joint complaint, but the actual cause of the joint pain may not be musculoskeletal in nature. For example, a patient may note left shoulder pain, but an evaluation may reveal this is referred pain from the heart. While an MSK exam may be done, the focus of the evaluation may quickly be directed towards the suspected condition and could be why documentation of an MSK exam is not included. This is not to say that the documentation of an MSK exam is justly omitted.

In addition, a common practice noted in our study was for attending physicians to write a generic statement agreeing with a resident exam which may be lacking in a complete musculoskeletal exam. Of the 3 patients consulted for arthrocentesis without a documented joint exam, 2 were admitted and followed by residents; in both cases staff agreed to notes without any joint exam. In

hospitals where medical students, residents, and staff are rotating throughout the month, it is critical to have accurate and complete documentation to help any practitioner evaluate a disease process. In many instances these patients are intubated or cognitively impaired, rendering the exam a key historical marker of disease evolution, thus making exam documentation crucial. Beyond patient care, thorough documentation is necessary for billing. In academic training centers, residents' ability to document an exam is paramount to their financial viability.[49]

4.1 Variances in documentation with undifferentiated patients

Of the management dependent variables, the most significant one in affecting the likelihood of a thorough MSK examination being recorded was the location of the patient ($p=0.017$). Patients admitted through the Emergency room (ER) compared to direct admits or intensive care unit (ICU) transfers were more likely to have an MSK exam recorded. There could be several factors as to why location matters in exam documentation. One key reason may be implicit bias with an already diagnosed patient.

An ER patient is generally an undifferentiated patient. ER patients have not been transferred from another facility where another team of doctors may have already diagnosed the patient, such as in ICU transfers or direct admissions. If a patient is being transferred already with a chest imaging showing pneumonia, sputum cultures growing out a respiratory pathogen, an elevated white blood cell count, and fever, and other extensive testing being normal, the admitting physician may be more likely to document a more focused exam and not comment on other areas of the body that may less likely be directly related to the clear diagnosis.

However in an ER, while an ER doctor may have a working diagnosis, some testing may not be completed at the time of admission, leaving the patient in the ER still in the process of a workup and possibly without a confirmed diagnosis. An admitting provider may be more likely to perform and complete a more thorough exam with an undifferentiated patient as the diagnosis may still be unconfirmed. In the example above, the provider may be looking for other causes of shortness of breath and fever such as sarcoid, vasculitis, or connective tissue disease, and thus expand their exam to look for signs of other conditions in the differential.

Another factor may have to do with intubation status. Several of the ER admissions were intubated and when looking at the patient dependent variables on admission, those patients that were intubated were more likely to have an MSK exam ($p=0.013$). It may be that with an undifferentiated patient who is unable to provide a history due to being intubated, the physical exam may be even more critical. This hypothesis is further supported when considering that a patient complaining of a joint was not a statistically significant factor in contributing to whether a thorough MSK exam was documented on admission. Perhaps when there is limited history to document providers may focus more on detailing the examination.

4.2 Variances in documentation based on provider type

Previous studies have assessed how documentation varies among specialties. In one study documentation between internal medicine providers, rheumatologists, and orthopedic surgeons was compared. Of the 3 provider types, orthopedists documented more physical exam findings with regard to shoulders and knees specifically (p=0.001); with regard to degree of details in the documented exams, orthopedists also recorded more specific exams.[46]

This was further reviewed in our study, however due to small sample size it is difficult to draw complete conclusions, but general trends may be noted. There is a clear difference between the surgical and non-surgical services. Within the non-surgical groups, the neurology service demonstrated a greater degree of detail in their exams with an average of 4.5 areas documented. This may reflect a more thorough muscular exam, typically found in standard neurology examinations. What is more is that perhaps it may be indicative of the weight of the importance of the clinical exam amongst neurologists, which perhaps may be deemphasized amongst other specialties. This may serve as a leading point for further studies in medical education.

4.3 Variances in documentation based on training level

Beyond provider services, the study identified completeness amongst examiners at different levels of training. Not only do residents document less detail than hospitalist staff, they are also less likely to even have an MSK exam documented. Medical residents specifically had a 61.1% rate of documentation on admission of 2 or more major areas as compared with 85.7% of hospitalist staff. One problem with this minimal documentation by medical residents is that staff often agree with an incomplete exam without documenting a thorough one of their own. 7 patients were admitted by a resident who failed to document an MSK exam; 6 of them had medicine staff agree with the resident note without documenting an additional exam of their own. This group of 7 undocumented patients includes 2 who specifically noted joint complaints on admission.

In this study the rheumatology staff appear to have less detailed exams than what may be expected, this however reflects the limitation with this set of analysis as it does not take into account how often the staff agreed with a previous fellow exam. Instead each rheumatology staff note was reviewed for a uniquely documented exam for the patient. Therefore in instances where a staff not only agreed with a fellow note but also expounded upon the previous record with their own exam, appear in the data only as though the additional exam is the only exam of record. Of the 44 cases, 32 rheumatology staff agreed with the rheumatology fellow exam, of these 32 cases, 22 rheumatology staff wrote an additional exam of their own. Unlike the medicine resident admission notes discussed above, the rheumatology staff are not only agreeing to more detailed exams but are often expanding upon the exam record.

4.4 Variances in documentation between electronic health record systems

This study suggested differences in documentation between different EHR systems. Both Cerner and Gopher have starkly different user features for documentation. Anecdotally, many that work with both systems find the point and click features more user friendly. This appears evident in at least a cursory review of how examiners utilized the EHRs. Virtually no one recorded their exams with the drop down Gopher template that was available through by using the tab button to navigate through the template options. Only 1 of 3 hospitalists appeared to utilize this template feature whereas no residents or rheumatology fellows opted to. This is in striking contrast to the point and click menus of Cerner where 82% of hospitalist, 37.5 % of medicine residents, and 41% of rheumatology fellows appeared to utilize the Cerner template. These differences between the two systems may represent the ease of user formats or a preference to a point and click feature when documenting an MSK exam. This user preference would be of interest to study further to review how practitioners utilize EHRs.

Template usage may save time for some, but may be at the expense of examination details. Free text entry on Gopher seemed to account for greater detail in exam documentation versus the templated options on Cerner. In this small study there was greater MSK exam documentation with free texted exams. Using the criteria of an adequate MSK exam containing at least 2 major areas, Gopher had 80% of exams meeting this criteria versus Cerner with 58.6% (p=0.15). The degree of detail also was greater with the Gopher system with an average of 3.9 areas on a 23 point scale versus 3.1 areas with Cerner. It may be that a provider may complete a template without going further to add a greater degree of detail that they otherwise may be more likely to when free texting a note. The point and click features may also have overgeneralized limits and may lead to click fatigue where users only click a few boxes to confirm an exam was done and then move on.[50] It would be of interest for further investigations to evaluate if template use leads to less prevalent and less specific documentation.

4.5 Patient records beyond the musculoskeletal exam

While this study focused on the MSK exam documentation, other studies have evaluated additional key components of documentation and what role EHRs play in them. Several studies have reviewed the impacts of patient based tools with inputting components of their medical history such as past medical history, social history, and family history (FH) into a web based patient portal for inclusion in the medical record. Allowing patients to input their medical history gathered 20% more discrete information that was deemed new and meaningful.[51] One study looking specifically at quality of FH collected via a web-based platform demonstrated high quality data in 99.8% of cases, as investigators found over half of the patients in the study reached out to relatives to gather specific information regarding FH to enter into the platform.[52]

With regard to the complete physical exam, inclusive of an MSK exam, several studies have also investigated the impact of EHRs on documentation. One study found that in

comparing paper charts to EHR records, there were more inaccuracies in the EHR documented exams (24%) compared to the paper exams (4.4%); examples of these were documentation of a regular heart rhythm when the patient was known to have permanent atrial fibrillation or mentioning normal speech when the patient was intubated.[53] The study did find more omissions however in paper charts (41.2%) compared to EHR charts (17.6%); examples of these were no mention of cardiac exam in a patient with permanent atrial fibrillation or no mention of an endotracheal tube when a patient was intubated.[53] While our study did not specifically review other areas of the medical chart, similar omissions and inaccuracies have anecdotally been seen at our institutions and were noted during chart review in data collection for the study.

These other studies demonstrate that the MSK exam is certainly one piece of the exam record, and the impacts of the EHR on documenting not only the exam but the history are worthy of further investigation.

5. Study conclusions

The widespread adoption of EHRs has allowed for more streamlined review of documentation practices. Several studies, this one included, have demonstrated a lack of MSK examination documentation even in patients with an MSK complaint. This omission may likely reflect a disconnect between what occurs during the examination and what is actually transcribed. EHRs may foster these oversights. One mechanism may have to do with the limitations in templates. Additionally the copy and paste features also prevalent in many EHRs may carry over previous exam notes without updates to new signs developing in patients over time. Interestingly, this study demonstrated that notes that were free typed led to greater detail.

Review of the documentation in EHRs for patients with MSK complaints is an area of interest as hospital systems and private companies develop new software for optimizing EHRs. It also highlights the need for greater medical education in documentation for trainees and also for ongoing education for staff physicians.

References

1. Al-Awqati Q. How to write a case report: lessons from 1600 B.C. Kidney Int 2006;69(12):2113-2114.
2. Reiser SJ. The clinical record in medicine. Part 1: learning from cases. Ann Intern Med 1991;114(10):902-907.
3. Hess V. Formalizing observation: the emergence of the modern patient record exemplified by Berlin and Paris medicine, 1725-1830. Medizinhist J 2010;45(3-4):293-340.
4. Wulff HR, Jungersen KA. Danish provincial physician and his patients; the patient records from the practice of Christopher Detlev Hahn in Aarhus around 1800. Medizinhist J 2005;40(3-4):321-345.
5. Fraser S, Ayres C. The doctor's casebook—a process of discovery. Scott Med J 2009;54(3):36-41.
6. Shephard D. The casebook, the daybook, and the diary as sources in medical historiography. Can Bull Med Hist 2000;17(1-2):245-255.
7. Engle Jr, RL. The evolution, uses, and present problems of the patient's medical record as exemplified by the records of the New York Hospital from 1793 to the present. Trans Am Clin Climatol Assoc 1991;102:182-189 discussion 189–192.
8. Siegler EL. The evolving medical record Ann Intern Med 2010;153(10):671-677.
9. Gillum RF. From papyrus to the electronic tablet: A brief history of the clinical medical record with lessons for the digital age. The American Journal of Medicine 2013;126(10):853-857.
10. Siegler EL. The evolving medical record Ann Intern Med 2010;153(10):671-677.
11. Camp CL, Smoot RL, Kolettis TN, et. Al. Patient records at Mayo Clinic: lessons learned from the first 100 patients in Dr Henry S. Plummer's dossier model. Mayo Clin Proc 2008;83(12):1396-1399.
12. Reiser SJ. The clinical record in medicine. Part 2: reforming content and purpose. Ann Intern Med 1991;114(11):980-985.
13. American College of Surgeons. Hospital Standardization Series: General Hospitals of 100 or more Beds. Bulletin of the American College of Surgeons. 1919;4:5 Evans RS. Electronic health records: Then, now, and in the future. Yearb Med Inform 2016;(Suppl 1):S48–S61.
14. Berkowitz E. Medicare and medicaid: The past as prologue. Health Care Financ Rev 2005 Winter; 27(2):11–23.
15. Institute of Medicine (US) Committee to Design a Strategy for Quality Review and Assurance in Medicare; Lohr KN, editor. Medicare: A Strategy for Quality Assurance: VOLUME II Sources and Methods. Washington (DC): National Academies Press (US); 1990.7, Medicare Conditions of Participation and Accreditation for Hospitals. Available from: https://www.ncbi.nlm.nih.gov/books/NBK235473/ [Accessed March 7, 2020].
16. Luce JM, Bindman AB, Lee PR. A brief history of health care quality assessment and improvement in the

United States. West J Med 1994;160:263–8.
17. Ambinder EP. A History of the shift towards full computerization of medicine. J Oncol Pract 2005;1(2):54–56.
18. Weed LL. The problem oriented record as a basic tool in medical education, patient care and clinical research. Ann Clin Res 1971;3(3):131-4.
19. McDonald CJ, Murray R, Jeris D, Bhargava B, et al. A computer-based record and clinical monitoring system for ambulatory care. Am J Public Health 1977 March;67(3):240-5.
20. Pryor TA, Gardner RM, Clayton PD, et al. J Med Syst 1983;7(2):87-102
21. Stead WW, Hammond WE, Straube MJ. A chartless record--is it adequate? J Med Syst 1983;7(2):103-9.
22. Clayton PD, Anderson RK, Hill C, McCormack M. An initial assessment of the cost and utilization of the Integrated Academic Information System (IAIMS) at Columbia Presbyterian Medical Center. Proc Annu Symp Comput Appl Med Care 1991:109-13..
23. Davis LS, Collen MF, Rubin L, et al. Computer-stored medical record. Comput Biomed Res 1968;1(5):452-69.
24. Blum BI. Understanding computer basics. MD Comput 1984;1(1):59-65.
25. Barnett GO. The application of computer-based medical-record systems in ambulatory practice. New Engl J M 1984;310(25):1643-50.
26. Walker HK. Grady Memorial's integrated database improves speed, accuracy and cost containment. Comput Healthc 1989. March;10(3):36-7, 40, 2.
27. Ornstein SM, Garr DR, Jenkins RG. A comprehensive microcomputer-based medical records system with sophisticated preventive services features for the family physician. The J Am Board Fam Pract 1993;6(1):55-60.
28. Barnett GO. Computer-stored ambulatory record (COSTAR). Rockville, MD; U.S. Dept. of Health, Education, and Welfare, Public Health Service, Health Resources Administration, National Center for Health Services Research; 1976.
29. Schultz JR, Cantrill SV, Morgan KG. An initial operational problem oriented medical record system—for storage, manipulation and retrieval of medical data. AFIPS—Conference Proceedings. 1971;38:239-264.
30. Stead WW, Hammond WE. Computer-based medical records: the centerpiece of TMR. MD Comput 1988;5(5):48-62.
31. Salenius SA, Margolese-Malin L, Tepper JE, et al. An electronic medical record system with direct data-entry and research capabilities. Int J Radiat Oncol, Biol, Phys 1992;24(2):369-76.
32. Wormuth DW. SCUT: clinical data organization for physicians using pen computers. Proc Annu Symp Comput Appl Med Care 1992:845-6.
33. Specthrie L, Berg W, Fishman S, et al. Power to the portables. Healthc Inform 1992;9(8):22-30.
34. Henricks WH, "Meaningful use" of electronic health records and its relevance to laboratories and pathologists. J Pathol Inform 2011;2:7.

35. Hammond WE, Stead WW, Straub MJ, et al. Functional characteristics of a computerized medical record. Methods Inf Med 1980;19157–62.
36. Schriger DL, Baraff LJ, Rogers WH, et al. Implementation of clinical guidelines using a computer charting system. Effect on the initial care of health care workers exposed to body fluids. JAMA 1997;278:1585–90.
37. Schriger DL, Baraff LJ, Rogers, Buller K et al. Implementation of clinical guidelines via a computer charting system: effect on the care of febrile children less than three years of age. J Am Med Inform Assoc 2000;7:186–95.
38. Johnson KB, Serwint JR, Fagan LM, et al. Computer-based documentation: effect on parent and physician satisfaction during a pediatric health maintenance encounter. Arch Pediatr Adolesc Med 2005;159:250–4.
39. Brown SH, Hardenbrook S, Herrick L, et al. Usability evaluation of the progress note construction set. Proc AMIA Symp 2001:76–80.
40. Stetson PD, Morrison FP, Bakken S, et al. Preliminary development of the physician documentation quality instrument. J Am Med Inform Assoc 2008;15:534–41.
41. Poissant L, Pereira J, Tamblyn R, Kawasumi Y. The impact of electronic health records on time efficiency of physicians and nurses: A systematic review. J Am Med Inform Assoc 2005;12:505–16.
42. Weir CR, Hurdle JF, Felgar MA, et al. Direct text entry in electronic progress notes. An evaluation of input errors. Methods Inf Med 2003;42:61–7.
43. Hammond KW, Helbig ST, Benson CC, et al. Are electronic medical records trustworthy? Observations on copying, pasting and duplication. AMIA Annu Symp Proc 2003:269–73.
44. Hirschtick RE. A piece of my mind. Copy-and-paste. JAMA 2006;295:2335– 6.
45. Thielke S, Hammond K, Helbig S. Copying and pasting of examinations within the electronic medical record. Int J Med Inform. 2007;76 Suppl 1:S122-8. Epub 2006 Aug 8.
46. Solomon DH, Schaffer JL, Katz JN, et al. Can history and physical examination be used as markers of quality? An analysis of the initial visit note in musculoskeletal care. Med Care 2000;38(4):383-91.
47. Lillicrap MS, Byrne E and Speed CA. Musculoskeletal assessment of general medical in-patients—joints still crying out for attention. Rheumatology *2003; 42(8):951-954.*
48. Myers A, McDonagh JE, Gupta K, et al. More ‘cries from the joints’: assessment of the musculoskeletal system is poorly documented in routine paediatric clerking. Rheumatology 2004;43(8):1045-1049.
49. Miller DD, Getsey CL. Impact of a compliance program for billing on internal medicine faculty's documentation practices and productivity. Acad Med 2001;76:266–272.
50. Collier R, Rethinking EHR interfaces to reduce click fatigue and physician

burnout. CMAJ 2018; 190(33):E994–E995.

51. Arsoniadis E.G., Tambyraja R., Khairat S., et al: Characterizing patient-generated clinical data and associated implications for electronic health records. Stud Health Technol Inform 2015; 216: pp. 158-162.
52. Wu, R.R., Himmel, T.L., Buchanan, A.H., et al. Quality of family history collection with use of a patient facing family history assessment tool. BMC Fam Pract 2014 (15): 31.
53. Yadav S, Kanzanji N, Paudel S, et al. Comparison of accuracy of physical examination findings in initial progress notes between paper charts and a newly implemented electronic health record. J Am Med Inform Assoc. 2017 (1):140-144.

