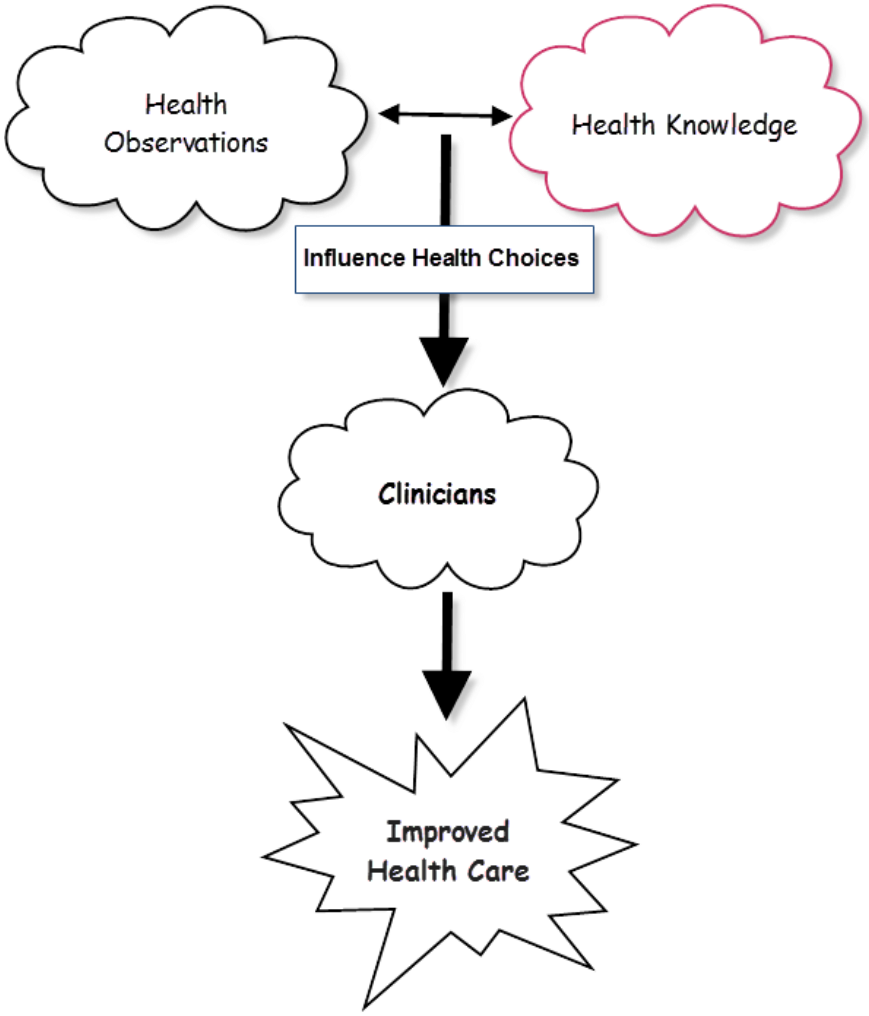
Clinical Decision Support and its Applications in Academic Medical Environments: The Good, the Bad, and the Really Ugly

Internal Medicine Grand Rounds
University of Texas Southwestern Medical Center
Brett Moran, MD

August 16, 2013



This is to acknowledge that Brett Moran has disclosed no financial interests or other relationships with commercial concerns rated directly or indirectly with this program. Dr. Moran will not be discussing off-label uses in his presentation.

Brett Moran, MD
Professor of Internal Medicine
William T. and Gay F. Solomon Division of General Internal Medicine
UT Southwestern Medical Center

Chief Medical Informatics Officer
Parkland Health & Hospital System

Areas of interest: Medical Informatics
Clinical Decision Support
Resident education
Population Management

Purpose and Overview:
Clinical decision support (CDS) is essential to a well-functioning EHR. Its use can facilitate improved and safer care, better outcomes, more timely interventions, and even predicting events and warning of need to intervene. This grand rounds presentation will focus on the basics of what is CDS and how can you use this in your everyday life as practicing clinicians and leaders to make your care of patients better, safer, more timely, and more efficient.

Learning Objectives:
1. Understand the definition of clinical decision support (CDS).
2. Learn the 4 most common ways CDS can be implemented in the common EHR that UTSW, PHHS, and CMC use.
3. Learn qualities of CDS that enable better adoption, acceptance, and outcomes.
4. Learn important characteristics to avoid when implementing CDS.
5. Learn useful methods for incorporating CDS into teaching in the academic environment.
6. Consider ways you can utilize CDS in your practice to improve outcomes.

Biosketch:
Graduating from UT Southwestern Internal Medicine Residency, Brett joined the General Internal Medicine Department in 1997. Now a full professor, he has practiced in a variety of roles including as an associate course director for teaching medical students clinical examination skills, being a part-time HIV physician, practicing privately in an ambulatory practice, performing inpatient consultative medicine for surgical services, being a mentor to medical students, and teaching and attending on the wards. Brett was invited to become the 1st Chief Medical Informatics Officer for Parkland in March of 2009, just 3 months prior to Parkland going "big-bang" live with computerized physician order entry and clinical documentation for nurses and providers. He has been integrally involved with the ultimate transition in Parkland to essentially an all-electronic health institution in this short period of time. His interests include clinical decision support, proficiency analysis of users, education of how to best use and teach within the electronic arena, and engagement of end users for quality and clinical research. He has been involved in creating policies and standards for documenting and attesting in the EHR, student and resident standards, In Basket and EHR "hygiene", copy and paste policy, critical result notification, identification of high risk patients or special needs patients, and standardization of the header. He has led collaborative efforts leveraging similar EHR platforms to mutually share projects for overall improved care for patients, and efficiency for providers both with campus partners as well as local and out of state institutions. Most recently, he has assisted Parkland in creating mostly automated reports of "physician metrics" which are used to effect changes and improvements in items considered important by the physician leadership.

Introduction

Electronic health records (EHRs) have been around for over 30 years but have only become prevalent in the past 5 to 10 years. There has been significant debate about the purpose including:

- Improved efficiency
- Reducing medical errors
- Encouraging best practices and preventive care
- Facilitating population level management
- Information exchange nationwide, more organized unreadable.

Some have compared using the EHR as to driving a car (Holliday, 2008): "Like a car, an EHR may cost $20,000 or more per provider (driver) over 3 to 5 years. And like a car, while specific features and costs are important, they are meaningless if the car is difficult to drive (lacks usability)."

Since the Health Information Technology for Economic and Clinical Health (HITECH) Act, and particularly Meaningful Use (MU), significant electronic accomplishments have occurred. The latest numbers released from the Office of the National Coordinator (ONC) of healthcare (press@cms.hhs.gov, July 17, 2013) have stated that the impact on patients includes more than 190 million electronic prescriptions being sent by Eligible Providers, more than 13 million patient reminders being sent for patients aged 65 or older or 5 years of age or younger about preventive or follow up care, and more than 33 million patients received electronic access to their health records. Regarding impact on providers, more than 458 million test results were entered into the EHR by over 111,000 Eligible Providers. Medication reconciliation was performed on over 40 million patient transitions of care by over 80,000 Eligible Providers, and more than 4.3 million patient transitions of care summaries were generated by more than 24,000 Eligible Providers. Finally, when describing impact on public health, immunization registries have received a least one test data submission from over 69,000 Eligible Providers, and public health agencies received at least one test data submission from 12,298 Eligible Providers.

Despite all of these electronic submissions, there continues to be significant debate in the medical community about whether or not the move to electronic health records has been ultimately beneficial to providers and to patients. Questions continue to be asked, are electronic health records the answer to health care problems, or another problem for providers to tackle?

Along the same lines inquiries abound about whether physicians truly need help. To answer this, one needs only review recent health statistics: Data shows that U.S. adults receive only half of recommended care. The institute of Medicine estimated that up to 98,000 US residents die each year as a result of preventable medical errors. Influenza vaccination rates on average run only in the 40% range for age appropriate adults. Only 50% of hypertension patients have adequate control; and over 25% of primary care patients are not screened for mental health disease--ever. Two percent of hospital admissions experience a preventable adverse drug event, and each error cost $8,750 to

the cost of the hospital stay--impacting the economy an estimated $17-50 billion annually. As one physician lamented, “there’s so much data that we risk doctors becoming lost in it. It is entirely possible that we are in danger of not being able to find our most important clinical signals amongst the noise and clutter of all the data. Worse: Time with patients is disappearing (Fisher, 2012)."

Electronic health records were proposed to improve quality and reduce costs of care, though that has been called into question. We continue to have clinical documentation issues as it has now become mainly tailored to billing, legal or regulatory requirements, whether handwritten or electronic, not to communicating care amongst the treatment team. Ongoing issues of copy and paste (AKA " sloppy and waist"), meaningless templated notes, perpetuated documentation errors, and note bloat muddy the waters of clinical documentation making life more difficult for providers. Computerized physician order entry (CPOE) seems to be reducing the rate of medication errors (Mitchell Adams, 2008) but maybe creating new problems (Kathleen E Walsh, 2006). Nothing has yet been done to dramatically help with diagnostic errors, and we are not sure whether CPOE and clinical documentation help or harm diagnostic thinking. Is there now more reward for checking all the regulatory boxes than outstanding diagnostic prowess? Instead of information paucity we have information overload—with little organization to help discern the important from the mundane. Similar to duty hour restrictions, we have been pushed knee-deep into this issue prior to any true evidence of benefits. What is the real advantage of the EHRs? Does clinical decision support work at all? What is the point?

In the past decade Google hits on the topic of “clinical decision support and the EHR” have skyrocketed, with volumes in the 60-70,000 range per year. Interest in academic medical centers is budding in usability of electronic health records and clinical decision support to achieve more stabilization of care and improved quality and safety metrics. The mantra of the 5 "rights" has become well ingrained into the minds of medical informaticists (Jerome A. Osheroff, 2012): The right *information* to the right *person*, in the right *format* via the right *medium* at the right *time*.

CDS and its broad benefits

So what is clinical decision support? It is defined broadly as clinical system, application or process that helps health professionals may clinical decisions to enhance patient care (CDS 101 Task Force). It provides clinicians are patients with clinical knowledge and intelligently filtered patient information. Another description would be it combines health observations and health knowledge and influences health choices in helping clinicians make improved health care (R Brian Haynes, 1995). So whereas some compare learning to use electronic health records metaphorically with driving a car, this author would likewise associate clinical decision support with traffic signals and signs along the road. Without clinical decision support, one would have extreme difficulty successfully navigating electronic health records. Physicians would frequently encounter wrong turns (missed blood cultures on pneumonia patients), dead ends (giving insulin to patients who were NPO), problems with finding the right road or pathway to caring for their patient (giving nephrotoxic medications to CKD patients) or determining the correct

rate or speed for that medication to be administered (supratherapeutic PTT or INR values). Quite frankly without clinical decision support, patient care in the health system (electronic or otherwise) would be near impossible and fraught with errors and dangerous practices.

The adoption of clinical decision support in the electronic arena has been uneven and filled with difficulties. Users have found it to be distracting and disruptive, overbearing with too many alerts, inadequately planned and resourced, and requiring of continuous quality improvement (CDS 101 Task Force). So why then care about clinical decision support? One must care about clinical decision support because of a variety of governmental and regulatory agencies that mandate or reward based on its use or results of their actions. These include Meaningful Use, PQRS, AHRQ, Core Measures, Accountable Care Organizations, and Patient Centered Medical Homes. One need also care about CDS because it is the tool which facilitates better patient care. The fact is that there is just too much to known and remember when caring for patients that ultimately one will forget something and not perform best practices through errors of omission or commission.

A JAMA study (Amit X. Garg, 2005) in 2005 from the United Kingdom reviewed the effects of clinical decision support on practitioner performance and patient outcomes. They performed a literature review of over 100 studies relating to clinical decision support with focus on "do CDS systems improve practitioner performance or patient outcomes?" and "which study level factors are associated with effective CDS?" They found that CDS improved practitioner performance overall in 64% of the studies:

- 40% for diagnostic
- 62% for disease management
- 66% for drug management
- 76% for reminders

Of the studies reviewed; however, only 13% reported improved outcomes. CDS which automatically prompted users to use support resulted in better outcomes and those in which users had to proactively initiate the CDS (73% vs. 47%; P=0.02).

Another study, published in the British medical journal the same year (Kensaku Kawamoto, 2005), performed a systematic review of randomized controlled trials to identify features of CDS critical for improving clinical practice. In this study, using univariate analysis, they identified 6 features in which the success rate of interventions possessing the feature was significantly greater than that of interventions lacking the feature: 1) when the decision support was provided to clinicians automatically, 2) when the decision support was integrated with the system in which they performed charting or ordering, 3) when the decision support was generated automatically using a computer system, 4) when clinicians were prompted to record a reason when not following the recommended action, 5) when being provided a recommendation as part of the CDS rather than merely an assessment, and 6) when the CDS provided input at the time and location of decision support. Of these 6 features found to be important by univariate

analysis, four were identified as independent predictors by the primary meta-regression analysis:

- CDS provided automatically as part of clinician workflow (OR 112.1; P<0.00001)
- Provision of recommendations rather than just assessments (OR 15.4; P=0.0263)
- Delivery of CDS at the time and location of the decision making (OR 7.1; P=0.0187)
- Computer based CDS (OR 6.3; P=0.0294)

Common Methods of Clinical Decision Support

There are a variety of ways in which clinical decision support can be implemented in an EHR to facilitate patient care and compliance with regulations. The most common ways are through best practice advisory is, order sets, order entry assistance, and documentation decision support. This author will be discussing these individually below. Keep in mind that these decision support modalities, while presented in a very discrete manner, truly have significant overlap and can be found within other areas of decision support. For instance, best practice advisories may be triggered by ordering an order set in the context of order entry. Within the order set, there may be documentation information or hyperlinks to such helping educate the user about best practices for this particular condition. So while this discussion will present the different CDS modalities in a very isolated manner, in the real world, they overlap and interact extensively.

A. Order Sets

Order sets are groups of orders that are aggregated together for convenience. Their benefits include helping organize care contextually, teaching and reminding of best practices and use of evidence based care, ensuring users remember all appropriate orders for situation, standardizing care, and improving efficiency. Our EHR also allows for something called "SmartSets". These are not only groupings of orders but also groupings of note templates, diagnoses, levels of service, patient instructions, and even follow-up scheduling. Functionalities found within an order set that may be beneficial include the ability to compartmentalize sections--having headers and educational bullets at the beginning of each if one so chose. Within a section one can actually create a hard stop for particular group of orders. For instance if one wishes to mandate that a patient require some type of anti-platelet therapy or a documentation of appropriate contraindication, this can be applied within an order set. It cannot be applied with typical standard orders. Order sets can be suggested to users based on discrete patient data. For instance at Parkland, a best practice advisory pops up suggesting a pneumonia order set after any provider admits a patient with the diagnosis of pneumonia in the admission order. Order sets can contain hyperlinks which can take users to internal or external references, manuals, protocols, or guidelines. Users can even save personal preferences personally with than any given order set. And lastly, order sets can also display or hide information based on discrete variables of patients. For instance one can select to hide penicillin antibiotics from order sets of patients who have penicillin allergies.

Despite these ostensible benefits, some have found potential harm from using order sets. A retrospective cohort study out of UCSF reviewed several metrics of patient care before and after implementation of a standard admission order set (Raman Khanna, 2011). They found that this initiative resulted in more patients getting venous thromboembolic prophylaxis (VTEP) ordered (51% vs. 58%, P<0.001). Multivariable models showed that patients who should have been contraindicated for VTEP received prophylaxis more often with initiation of the new admission order set (adjusted odds ratio=1.58; CI 1.12-2.22). This, in turn, resulted in a slightly unadjusted increased risk of in-hospital hemorrhage (0.4% vs. 0.8%; P=0.02); with a significant rise in bleeding events following the order set implementation (AOR-M=1.05; P<0.001). They hypothesize that institutional mandates coinciding with the implementation may have overemphasized use of VTEP, encouraging users to feel this was the default action. With appropriate intervention, including education, the trend quickly returned to baseline.

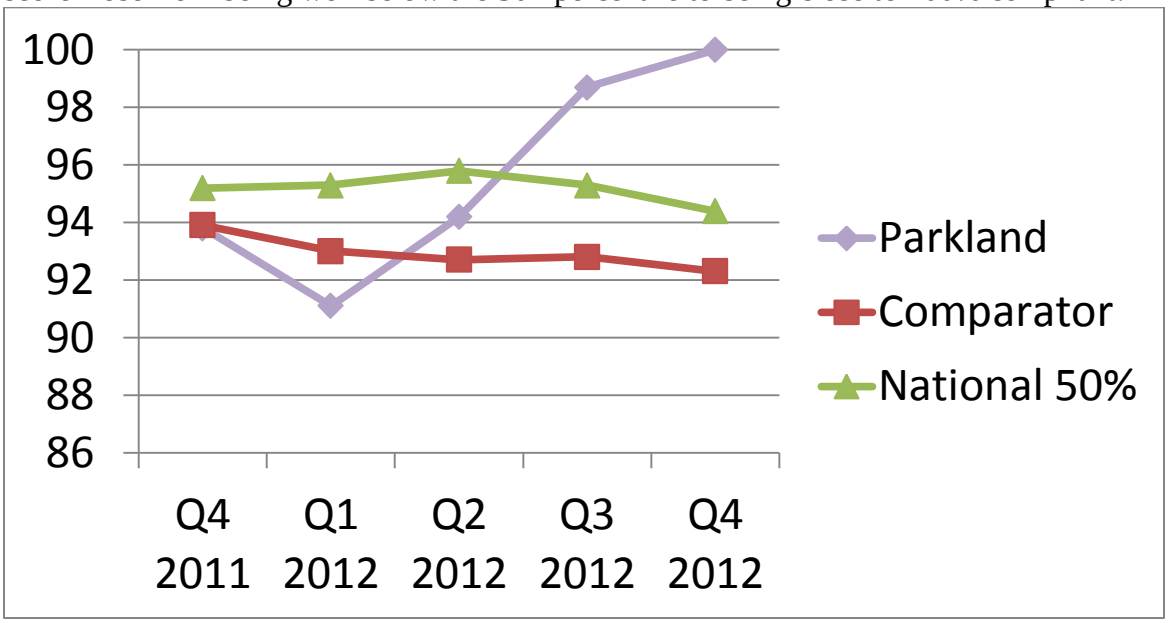
Contrasting with that study, there have been several very successful experiences with use of order sets at Parkland. In the first study, performed by Drs. Don Rockey and Christian Mayorga from the Division of Digestive and Liver Diseases, a prospective analysis of delivery of standard of care therapy in cirrhotics presenting with upper GI bleed was performed. The authors worked with informatics to create a refined order set for management of GI bleeding patients which contained best practices as well as educational bullets and auto-defaulted orders. Its use was tightly regulated by the division who rigorously educated its fellows and monitored use. Patients were randomized in to the use of order set or use of standard practices and followed for outcomes as to time to administration of medications, use of medications, and time to and use of endoscopy.

The authors found that there were no appreciable differences in the use of or time to endoscopy, average length of stay, in-hospital mortality, infection rates, or units of blood transfused. They did however find a significant improvement in time (greater than 4 hours) to octreotide administration in those to use the order set (6:16 vs. 2:11; P=0.004). More notably, they found improved adherence to best practices regarding the use of antibiotics for the cirrhotic GI bleeders when using the order set. Antibiotics were administered in 100% of patients for which the order set was used compared to only 89% of patients in which no order set was used (P=0.01). And similar to the octreotide, time to administration of this antibiotic was markedly shortened by use of the order set by over 7 hours (9:58 vs. 2:49; P=0.002). The authors concluded that using a standardized electronic order set may improve the quality of care in patients with cirrhosis and acute bleeding; that using the order set appeared to improve compliance with best practices and provided this care more rapidly to their patients. They proposed that these patients should be treated similarly to patient's presenting with acute coronary syndrome or stroke.

The second example of excellent use of order sets at Parkland came from the Division of Cardiology care of Drs. Mogabgab, Das, de Lemos, and Jacqui Jones, RN. These individuals, as well as other leadership recognized that Parkland's performance on the Get With The Guidelines (GWTG) ACTION registry of the NCDR (National

Cardiovascular Data Registry) was suboptimal. Parkland was ranked below the 50th percentile on most every metric. This work group, along with some informatics order set experts, created new order sets for all Acute Coronary Syndrome (ACS) scenarios which ensured that all essential management metrics were addressed. The order set contained some educational bullets but most importantly, it included several modules for which an answer was required in order to complete the order set. This way, they guaranteed that patients were receiving best practices or that a contraindication reason was captured. Use of this order set was strictly monitored by the Coronary Care Unit (CCU) fellow on a daily basis and prompt feedback was given to those who failed to utilize it appropriately.

The order sets were implemented in the second quarter of 2012 and almost immediately, the quality of care for ACS patients at Parkland began to rise. The acute MI composite score[1] rose from being well below the 50th percentile to being close to 100% compliant.



The same occurred for virtually all of the GWTG key measures: defect free care[2], STEMI composite[3], NSTEMI composite[4], LV function assessment, cardiac rehabilitation referrals, reductions in heparin overdosing, and $P2Y_{12}$ use for non-PCI NSTEMI patients. Overall, Parkland went from lagging behind even the 50th percentile for ACS quality of

[1] Aspirin at arrival, evaluation of LVSF, reperfusion therapy (STEMI only), time to fibrinolytics if given (STEMI only), time to primary PCI (STEMI Only), aspirin at discharge, beta blocker at discharge, ACE-I or ARB at discharge, statin at discharge, adult smoking cessation advice or counseling, cardiac rehab referral

[2] The proportion of patients that receive "perfect care" based upon their eligibility for each performance measure (see above). If a patient fails to receive even one therapy for which he or she is eligible, that patient fails to meet the "defect-free" criteria and will be removed from the numerator, That patient will still be included in the denominator however.

[3] Aspirin at arrival, Evaluation of LVSF, Reperfusion Therapy (STEMI only), Time to Fibrinolytics if given (STEMI only), Time to Primary PCI (STEMI Only), Aspirin at discharge, Beta Blocker at discharge, ACE-I or ARB at discharge, Statin at discharge, Adult Smoking Cessation Advice or Counseling, Cardiac Rehab Referral.

[4] Aspirin at arrival, Evaluation of LVSF, Aspirin at discharge, Beta Blocker at discharge, ACE-I or ARB at discharge, Statin at discharge, Adult Smoking Cessation Advice or Counseling, Cardiac Rehab Referral.

care to competing with and even leading some of the most elite academic medical institutions around the country. The authors concluded, high quality ACS care is possible in a large urban safety net hospital and leveraging the EHR can improve quality. Physician encouragement is useful if not necessary to ensure consistent use of protocols and soliciting feedback helps improve the work flow.

All in all, order sets are a very powerful tool that can help safeguard standardized care if not best practices. Tips to success include making the order sets fairly straightforward, adding educational bullets, forcing choices where best practices exist, and working with the impacted physicians to ensure they understand the importance of the order set, as well as soliciting feedback on how to improve it for the end users. Try to avoid defaulting behaviors except where truly applicable to all patients for which the order set would be used. Separate into logical groupings of treatment, procedure, and medication orders to be easier for the users to understand and follow the flow of their typical thinking. And finally, these order sets should be reviewed regularly by clinicians to ensure they are meeting current best practices (Institute for Safe Medication Practices, 2010). Those that are not should be retired or modified.

B. Order Entry Alerts

Order entry alerts are decision support modalities presented at the point of selecting and entering orders for a patient. These can occur as information presented within the order (e.g. displaying of latest INR and PTT in a warfarin order, or most recent creatinine in an aminoglycoside order), hyperlinks to resources such as guidelines or institutional procedures (e.g. within the pneumonia order set, include a hyperlink to information about risk factors for drug resistant Streptococcal Pneumoniae and MRSA), or strictly as popup alerts that appear either when initially selecting an order or when signing the order--informing the provider about information pertinent to that specific order in regards to interactions based on discrete data known to the system about the patient.

Order entry alerts have likely the highest potential for benefit and yet are the most poorly implemented in present time. Typically these alerts are of a high safety nature—order this medication or test and potential harm could befall the patient. Due to this high risk, these alerts are typically more intrusive, thus popping up and demanding a click (acknowledgement) of some button before the user can proceed.

Drug-Drug Interaction (DDI) and Drug-Allergy Interaction (DAI) Alerts

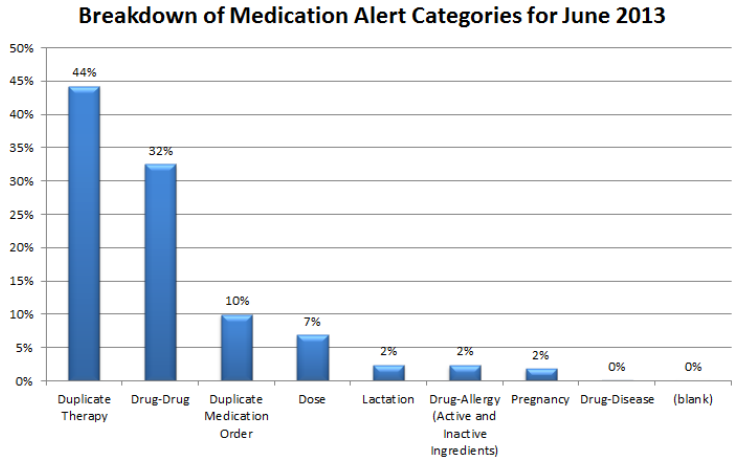
Most electronic health records provide an opportunity to interface with some outside third party product which contains a database of up-to-date drug and allergy interactions. With the EHR that UT Southwestern, Children's Medical Center of Dallas, and Parkland Health and Hospital System all use, there are only 2 companies that provide this content. Fortunately all 3 institutions have chosen the same vendor. Unfortunately, that vendor has chosen to take a very conservative approach to their alerting database. What has resulted is that our campus partners as well as most institutions around the country are dealing with excessive alerting of potential drug-drug interactions and drug-allergy

interactions at a significant rate such that a phenomenon known as "alert fatigue" has become predominant across the nation.

The process by which to use 3rd party vendors provide content is that after a provider enters an order, it is sent through this database. The order is categorized into a particular grouping (e.g. an order for Toradol would fall into the grouping of "Ketorolac/NSAID; Aspirin"), and then that grouping category is compared across the alert database for potential contraindications. The contraindications are separated into different severity levels and are then fed back through the EHR as an alert to the provider based on EHR settings of which severities should be displayed to which groups of end users. The EHRs have the ability to filter out and display only prespecified levels of severity. For instance, with the vendor Parkland uses, there are 5 grades of severity. For providers, we display only the 4th and 5th severity levels and filter out the lower severity grades 1-3, for providers. Keep in mind that vendors may change their severity levels based on ***their*** data at any time, and updates to the database from these vendors occur on a frequent basis. Should any particular institution disagree with the vendor's choices, they can submit an appeal to change the data base for all. In this author's experience, the process typically takes 60 days to get a decision. As to when it is actually incorporated into the database and pushed out to all customers, that is still unknown.

Because these drugs-drug and drug-allergy interaction alerts are facilitated through the electronic health record, they utilize standard functionality for alerting providers. In the past there have been issues with this alert as it appeared quite generic, and distinguishing between a severe interaction and a medium interaction had been difficult to do. Based on feedback from many customers, the EHR made improvements with a later upgrade. Nonetheless these medication warnings do all look quite similar and have added to the risk of end users developing an alert fatigue mentality.

At Parkland hospital we have struggled with our medication alerting. On a typical month we have over 10,000 drug-drug interaction or drug-allergy interaction alerts per day! In the last month, ending June 30th 2013, we placed over 304,000 medication orders. During that same time, our EHR fired over 305,000 medication alert warnings. That averages out to a ratio of medication warning per order of 1.01!



When analyzing these warnings, an astonishing one third of the firings were accounted for by 3 drug-drug interaction alert categories: Narcotic analgesics with non-analgesic

opiates, non-narcotic analgesics with antipyretic, non-salicylate medications, and narcotics with phenothiazine medications.

DESCRIPTION	TYPE	Total Firings
NARCOTIC ANALGESICS- IR (WITH NON-ANALGESIC OPIATES)	Duplicate Therapy	51277
NON-NARCOTIC ANALGESIC/ANTIPYRETIC, NON-SALICYLATE	Duplicate Therapy	30642
NARCOTICS / PHENOTHIAZINES	Drug-Drug	18426
ACE INHIBITORS; ARBS / POTASSIUM PREPARATIONS	Drug-Drug	8850
POTASSIUM	Duplicate Therapy	8697
ANTIDIABETICS / NON-CARDIOSELECTIVE BETA-BLOCKERS	Drug-Drug	8496
ANTIEMETIC	Duplicate Therapy	8081
HYDROCODONE BIT/ACETAMINOPHEN, ORAL, PRN ORDER	Duplicate Medication Orde	7896
SELECTIVE SEROTONIN 5-HT3 ANTAGONISTS	Duplicate Therapy	7141

This highlights the significant issues we are currently experiencing with medication alerts and also the potential easy remediation we can effect by addressing just the top three categories and refining the firing criteria. This work is ongoing and in fact has been slowly occurring for the last several years. For example, in 2011, the top alert firing was for insulin—stating the maximum dose had been exceeded. This was firing thousands of times per month and being overridden more than 95% of the time. When analyzing it, we found that the maximum setting was too low and after changing, the alerts dropped dramatically and became more appropriate when they did fire. Similarly, we had noted alerts firing for duplicate therapy for heparin and enoxaparin. However, inpatient services may be initiating the enoxaparin prior to discontinuing the heparin—appropriate practice. Thus this alert, firing over 200 times per month, was most always inappropriate. We found several other alerts occurring which were felt to be of little clinical value and frequently unnecessary. These included alerts for potassium supplements and inhaled anticholinergics, potassium-sparing diuretics and patients on potassium supplements, and aspirin or NSAIDs in patients who had received ketorolac. Optimizing these alerts helped refine the ratio of appropriate and necessary alerts vs. those felt to be insignificant or clinically appropriate.

Despite these modest interventions, in our current state we continue to have an abundance of medication alerts as above mentioned. We continue to review the statistics of what percentage of these alerts are actually the adhered to or acknowledged appropriately by the providers (i.e. they took a recommendation alert and discontinued or removed the medication). Our data shows that on average 87% of alerts were over-ridden with only 5% of users removing one of the offending drugs from within the alert and another 8% having reviewed the alert and accepted it, though subsequent actions at to the alerted medication were unknown. This data has been fairly reproducible over several reporting periods and numerous alerts. And the issue appears to be that most of the alerts are not clinically relevant or applicable to the patients. We fear also that as a consequence of these voluminous inappropriate alerts, users may be becoming "fatigued" of the alerts and possibly not giving them the attention that they ultimately would warrant. Some users have commented that they now subconsciously move the mouse over to where the override button would be located in an alert after they sign a medication order. This happens just out of habit, some admit.

We continue to work with information technology and the Pharmacy & Therapeutics Committee and sub-committees to review this report and assess for the highest volume

alerts and perform appropriateness reviews and validations. The hope is to strategically display alerts to providers that are clinically useful and actionable, while suppressing those that the vast majority of providers would not want to see or act upon. Thus we hope to improve with our signal to noise ratio such that those alerts acted upon verses those over ridden have a higher percentage. One suggestion, by an advanced academic institution (Peter J. Greco, 2007), was to create a decision pyramid such that the types of alerts displayed to a provider would depend on the alert severity and level of evidence which supports the alert. Thus, for severe alerts, one may display alerts from a wide spectrum of levels of evidence, while for mild or moderate alerts, one may limit displaying alerts to only those with levels of evidence being established or probable. Following these types of strategies one hopes institutions can improve the saliency of alerts and reduce the burden of inappropriate unnecessary or insignificant alerts.

Once the accuracy of alerting is improved, the institution would then be better able to review the reports and address errant providers who may be ignoring truly clinically relevant alerts.

	Severity		
Documentation	Mild	Moderate	Severe
Doubtful/Unknown	<1%	4%	<1%
Suspected	22%	26%	2%
Possible	10%	18%	3%
Probable	2%	8%	2%
Established	<1%	3%	<1%

Other Order Entry Alerts

Besides drug-drug interaction and drug-allergy interaction alerts, there are a variety of other decision support modalities which can be presented to users in order entry. Most notably, best practices advisories can be programmed to fire upon order selection or order firing, when situations of severe importance arrive, such as safety or critical quality initiatives. Several examples of such alerts currently active in the Parkland EHR include the following:

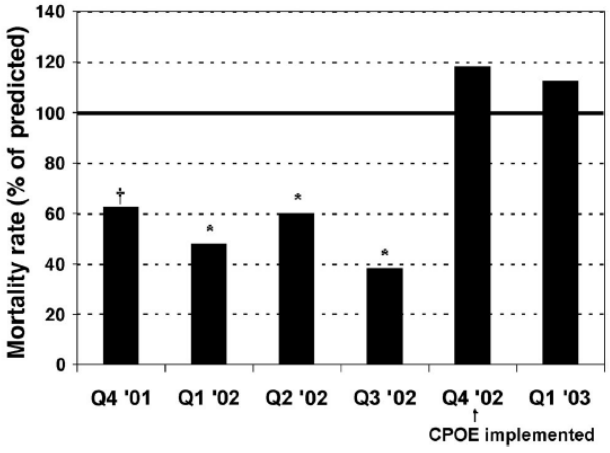
- A BPA to fire if an individual attempts to order Argatroban direct thrombin inhibitor in a patient who has one or more of the following liver failure indicators: AST>120, ALT> 120, total bilirubin>1.5, or any of a grouper of ICD-9 diagnoses for liver failure or hepatitis on the problem list. This has fired a total of 27 times since being enacted.
- An alert to fire if an inpatient has any of a grouper of ICD-9 diagnoses for pneumonia on their problem list, has been admitted less than 24 hours, and has had no blood cultures ordered within the last 48 hours. This alert has fired 2,245 times.
- Two different BPAs to address hypoglycemia in the hospital:
    - One which fires if a patient has an active order for intermediate or long-acting insulin or a sulfonylurea medication and then a provider enters an NPO order. The alert recommends adjusting or at least reviewing the medications in this new context. This alert has fired 12,041 times.

- The second alert identifies patients who have had vomiting documented within the last 8 hours by a nurse and are on an intermediate or long-acting insulin or hypoglycemic agent, prompting both the nurse and provider to review and consider adjusting the regimen. This alert has fired more than 22,000 times since being implemented.

Similarly, a publication from the Massachusetts Technology Collaborative and New England Healthcare Institute in 2008 found benefits from order entry alerts in both reduction of patient harm and cost savings (Mitchell Adams, 2008). In this study of preventable adverse drug event rates with CPOE, they estimated a potential savings of $2.7 million per hospital. If fully implemented in the 63 Massachusetts hospitals that currently had not completed adopting the technology, the number of adverse drug events prevented every year could reach approximately 55,000 and the total cost savings were predicted to be up to $170 million annually.

On the other hand, there have been a few studies showing use of CDS for order entry alerts to adversely impact patients. In one of the more often quoted examples, the United Kingdom National Health Services mistakenly selected "sildenafil" when Zyban was prescribed to smokers (EM Campbell, 2006). This occurred due to a variety of potential issues including a poorly designed interface with auto-completion choosing the wrong item from a pick list, a programming error within the formulary system, and/or poor end-user training and experience. The end result was that over 900 practitioners at over 300 clinics were impacted with unknown numbers of patients affected. Some attribute this study to the beginning of the term "e-iatrogenesis".

The University of Pittsburgh published a retrospective review after going live with computerized physician order entry looking at the mortality and risk factors for death (Yong Y Han, 2005). They respectively reviewed 18 months of data (13 months pre and 5 months post CPOE implementation) to test the hypothesis that CPOE resulted in reduced mortality. What they found instead; however, was that their mortality rate actually was significantly increased after moving to an electronic order entry format.



Of the risks factors independently associated with increased odds of mortality, CPOE was the 2nd highest with an odds ratio of 3.71 ($P<0.001$). This was just below the odds ratio for shock and above that for a Glasgow Coma Score. When reviewing the details, it was noted that as part of their implementation they also restricted the ability to enter orders on critically ill patients in route to the facility. The downstream impact of this on time to administration of critical infusions and medications and timeliness of

critical diagnostic imaging studies was appreciable. Also, for some reason it took "approximately 1 to 2 minutes per single order as compared with seconds previously needed to place the same order by written form." Later comments in the article describe their bandwidth being overwhelmed during peak periods resulting in delays, freezes, and pauses in computerized order entry. Finally at the same time that they went live with computerized physician order entry, they decided to centralize medications and do away with satellite medication dispensers including pressors and antibiotics. Thus, it is obvious that CPOE did not in and of itself cause increased patient harm, but rather multiple concurrent institutional changes in processes as well as technological issues of poor infrastructure planning as to bandwidth demands during peak periods.

When it comes to lessons learned from order and treat alerting, most importantly only fire pop up messages for really important items and make them actionable. Keep in mind the overall prevalence of the problem you're trying to solve and the number needed to treat for benefits. While on alert may sound nice at face value to prevent a minor institutional issue, if it requires significant attention or time by and users the end result may be more adverse than beneficial. Insure that initiatives have owners and support from impacted areas. Merely turning on an alert is seldom effective without infrastructure changes in training, education, or procedures. Continuously monitor alerts and refine the criteria to improve your signal to noise ratio. Because order entry alerts have the highest stake both in impact as well as annoyance, use wisely.

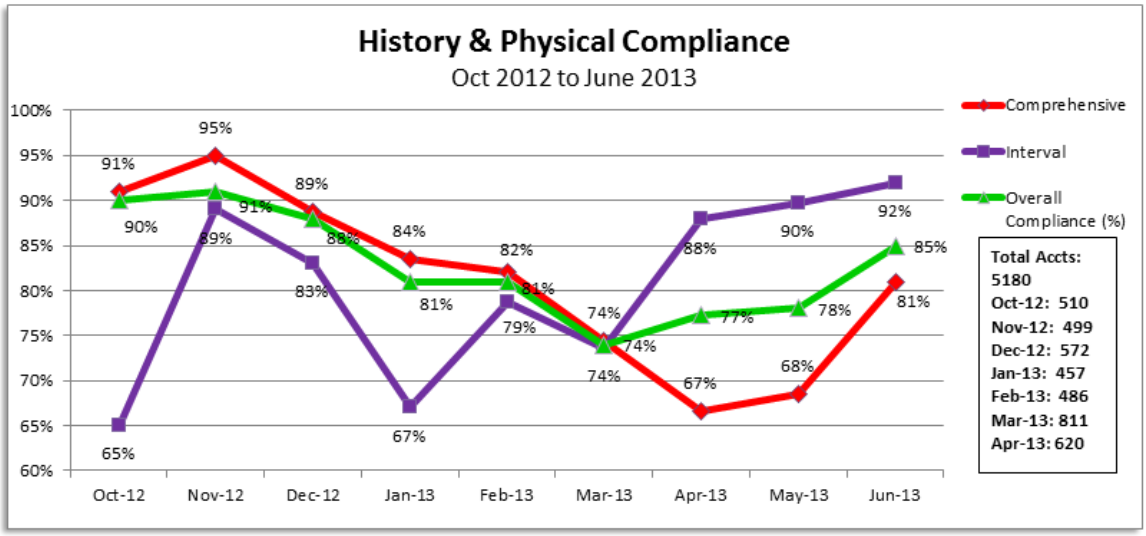
C. Documentation Decision Support

Documentation decision support is a type of decision support in which users are facilitated in helping document those items that are required, mandated, desirable, or overall beneficial for the end user or the institution. Classic examples would be note templates that help facilitate providers in entering content in all of the required fields.

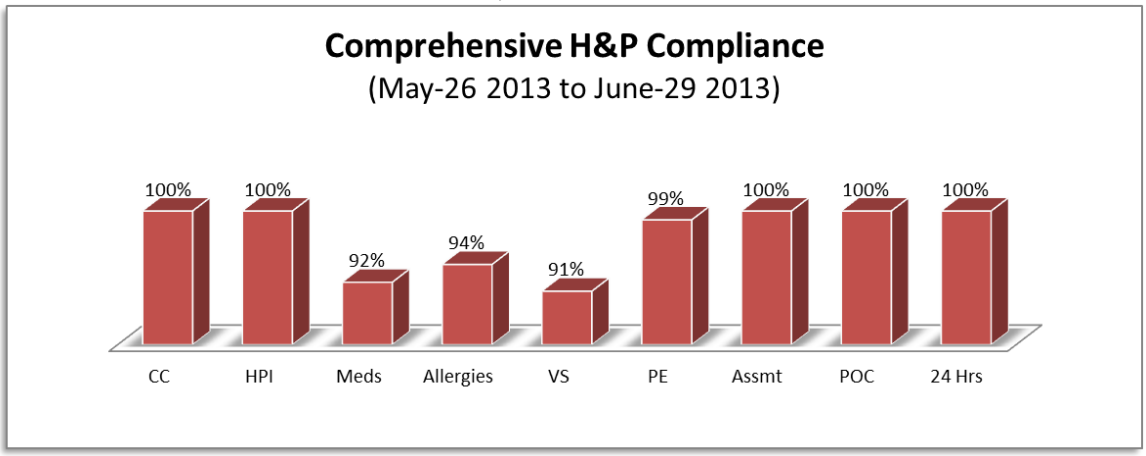
By and large, documentation decision support is a beneficial modality. The only times that it is not efficacious is when users abuse these functionalities to perpetuate inappropriate documentation habits, such as insufficient templates or inappropriate abbreviations. Other common abuses occur when users over-document for the occasion, resulting in bloated and excessively verbose notes. This occurs by way of notes filled with excessive templates or "smart links", in which information is pulled into the note from other areas of the electronic health record (e.g. labs, medication lists, which are not truly necessary or relevant for that note.

A recent initiative for documentation decision support was to improve the compliance of history and physical examinations with meeting those elements as mandated by Parkland Bylaws, CMS, and/or The Joint Commission. A focus group comprised of health information management individuals, internal audit, informaticists, and physician leadership met and formalized the core essential elements required for all history and physical examinations at Parkland to meet requirements. This was then communicated out to the physician body by a memo as well as discussed at the leadership meetings of the Chiefs of Services and the Medical Executive Committee. A SWAT team of HIM

personnel then performed manual reviews of history and physical examinations and provided point of care feedback to errant physicians. The history and physical examination work group met weekly to review progress and discuss trends. One of the informaticists met with department that were not meeting goals and worked with their users to improve and standardize their H&P templates.

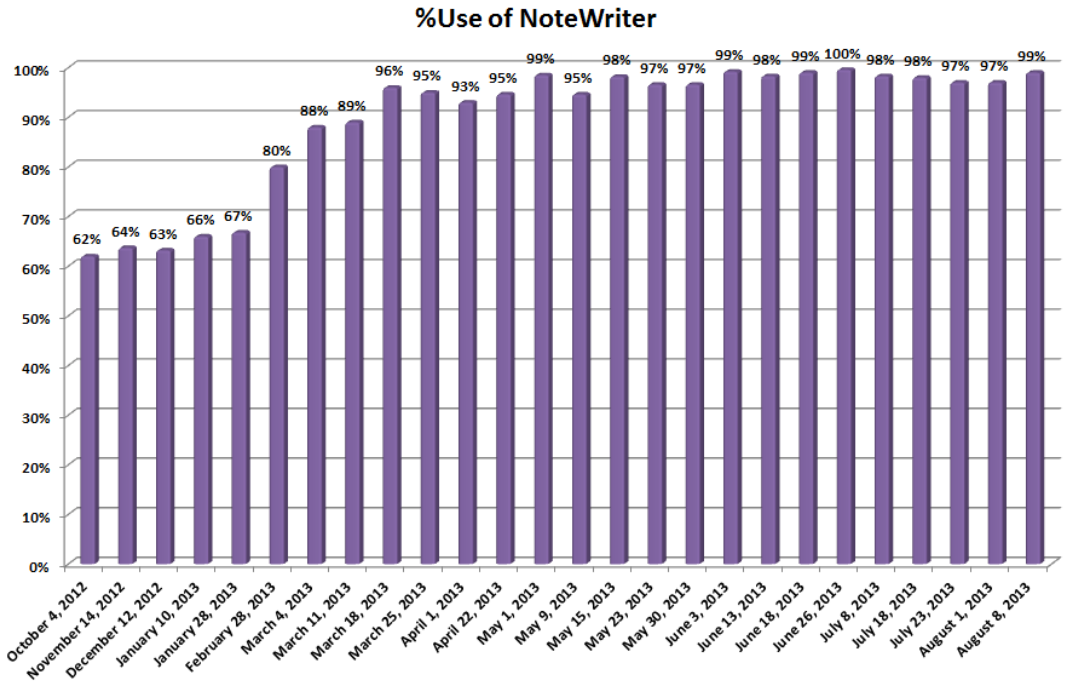


What we found was that despite significant aggressive efforts, there remained a substantial, persistent deficiency rate. Part of this was due to the continued influx of new users every month rotating from other hospitals, and part of this was due to process issues. For instance, the most frequently missed items were documentation of vital signs (missed 9% of the time), medications (missed 8% of the time) and allergies (omitted 6% of the time). When speaking to physicians, it was discovered that many had utilized smart links within their notes for these items; and often would examine the patient and complete their H&P prior to the nurses completing their initial admission assessment on the patient or obtaining a set of vital signs. If the users would merely refresh their smart links or document the items themselves, their deficiencies would be remediated.



And while the overall project had some variability in overwhelming institutional improvement, there were several pockets where the benefits were very significant, thus the project was of some value.

Contrasting the H&P initiative, whereby part of the issue was that there were just too many templates and too difficult to find and correct all of them, Parkland approached enforcing documentation of house officer supervision for procedures in a different manner. As part of an ongoing effort to provide consistent and reliable documentation of Attending oversight and approval and concurrence with Resident procedures for auditing and reporting for compliance with Common Program Requirements, Parkland mandated use of a NoteWriter tool. This NoteWriter note template was mandated for use by house officers whenever they performed a procedure outside of the procedural areas, to ensure appropriate supervision documentation. Similar to the H&P initiative, a work group was convened comprised of physician leaders, the Designated Institutional Officer for the GME, informatics, HIM, and internal audit. The difference here was that only one pathway was acceptable to meet the requirement—use of the specific NoteWriter procedure template, in which was embedded tools to appropriately capture supervision documentation.

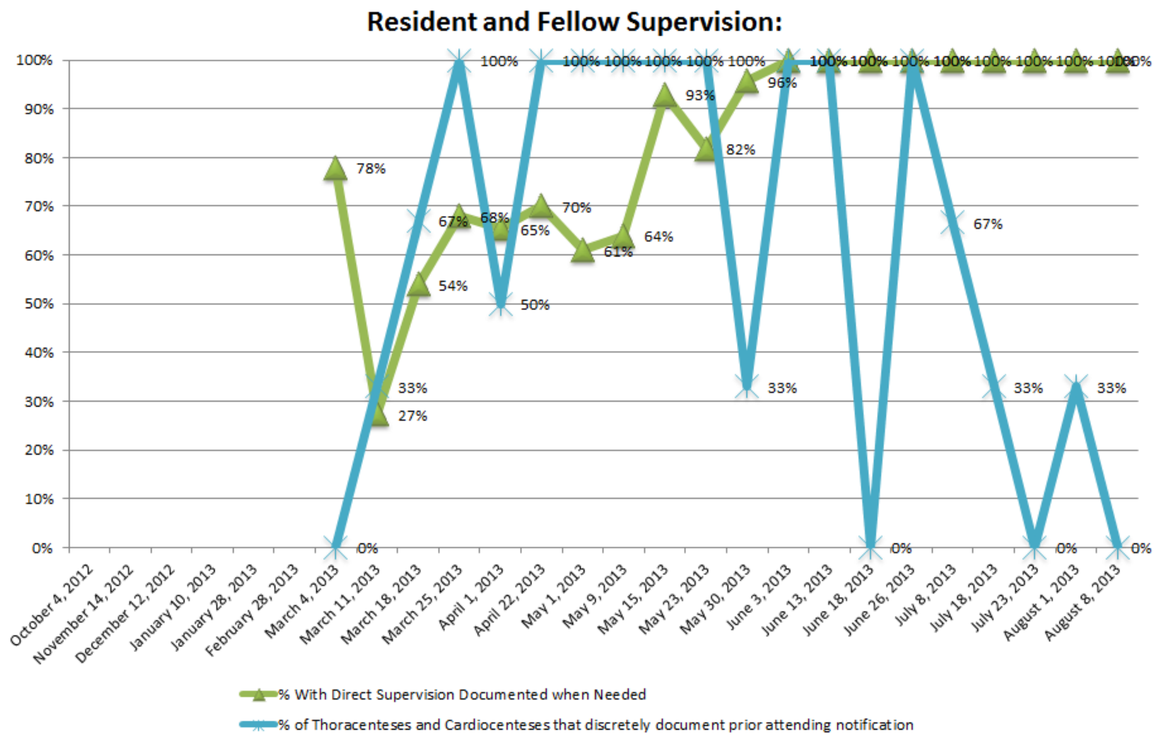


A memo was sent to all house officers and faculty, and some departmental meetings also were held to educate on the new process. An automated report was created which captured all inpatient events[5]. There were also manual audits of a sampling of charts by Internal Audit to ensure accuracy of the report and look for any instances of non-procedural procedure notes (i.e. using a progress note to document a procedure). The work group met weekly to review the trends and perform some manual validations of those found delinquent by the report. These weekly meetings also serve to further optimize the tool based on trends found within the report. After about 3 months, the work group felt enough education had occurred and decided to begin sending feedback to end users found noncompliant with the new mandates. The Designated Institutional Officer begin sending templated letters to house officers on a weekly basis should they

[5] Ambulatory could not initially go live until a new EHR upgrade occurred to allow for use of this tool

have been found to have used a non-NoteWriter templates for their procedure note. Almost overnight compliance with use of this tool skyrocketed. Within one week the percent compliance had increased by 20%. Within 2 months compliance was consistently in the mid to upper 90% range, and since May 15th, the weekly compliance has not dropped below 97%.

Similarly, this tool allowed for better capturing of documentation of direct supervision when direct supervision was needed. Since the tool was modified to capture this in March of 2013, compliance has dramatically improved to being consistently 100% since June of this year. Thus this tool has allowed for the institution to better capture and document the supervision of house officers and fellows that has been occurring but may not have been so readily captured. The fact that the tool allows for discrete capturing of these fields as well as the entire procedure note allows for other uses including validating procedure case logs of physicians.



In summary, documentation decision support can be beneficial in many ways. It can help ensure that users enter the correct information as required by the hospital policies, or state and national laws. It allows for discretely capturing of information that can later be reported upon for a variety of institutional metrics. However, to be effective, it should be applied only when necessary, so as not to dilute all notes into meaningless hypertrophied documents. And when it is really important, restriction of choices may be necessary to truly guarantee compliance with the mandate.

D. Best Practice Advisories

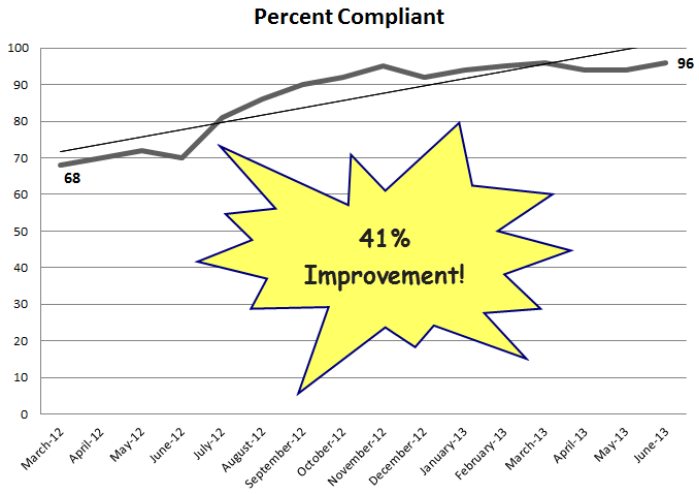
Best Practice Advisories (BPAs) are alerts that trigger based on a set of prespecified discrete conditions being met. They can be merely informational or facilitate actions by containing choices of orders or order sets to enact from within the alert, or hyperlinks to take a user to a particular part of the EHR to perform another actions (e.g. the immunization historical registry, or the health maintenance navigator). BPAs can popup for users at different locations within the EHR or they can be passive (i.e. found by going to the BPA section of a navigation area). They can fire immediately when criteria are met or be set to fire asynchronously some period of time after criteria are met (e.g. fire a BPA to remind providers to remove a central line 5 days after it has been placed if it is still active for a patient). One can also include "exception" buttons within a BPA so that if a particular suggested action is declined by a provider, they can select one of the exception buttons to document whey they did not follow a particular proscribed care pathway, for example.

There have been several studies looking at best practice advisories and their impact on patient care. One notable study looked at the issue of wrong-patient electronic orders (JS Adelman, 2012). This study created a "retract-and-reorder" measurement tool in which they identified orders entered on one patient, retracted, and then re-entered on another patient by the same provider within 10 minutes of retraction. Their hypothesis was that these represented near misses with wrong-patient orders. They validated this by interviewing 223 providers where this occurred and found a positive predictive value of 76.2% with this method. They then attempted a few interventions to try to reduce the number of true wrong-patient orders as well as the number of retract-and-reorder instances. The most notable intervention was to fire a BPA every time a provider attempted to access the order entry screen of a patient, blocking access to the order screen until they correctly reenter the patient's initials, gender, and age. The authors found that this reduced the retract-and-reorder rates by a significant 41% (OR=0.60, CI 0.50-0.71; P<0.001); however, there is little data to estimate how many real wrong-patient orders were prevented of these numbers of potential near-misses. And while even the very aggressive ID-reentry challenge only required an average of 6.6 seconds per challenge, that when aggregated, cost the institution an additional approximate 3,300 hours per year more of extra data entry work. The Pharmacopeia voluntary reporting system estimates that 9 errors would have occurred in the time span of this study and while this may underestimate the volume, it is unlikely that the number of extra hours of data entry would be compensated for the numbers of cases prevented. So, while the idea of using CDS to reduce wrong-patient orders is noble, the general application across a wide-ranging institution to affect every order entry session is likely too broad of an application and perhaps more innovative, focused interventions would be more efficient and maintain the effectiveness.

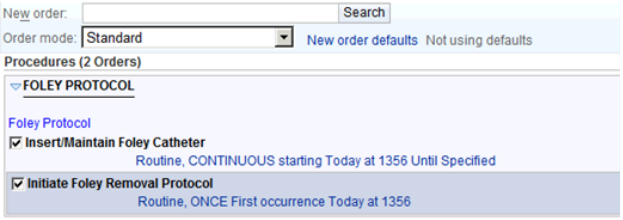
Internally we have struggled at times with effective use of and acceptance of BPAs. A prominent example was a BPA for reminding providers if admission medication reconciliation had not been completed (i.e. 100% of PTA medications had not been reconciled). This alert, while honorable in purpose, had some programming and systematic issues, including firing even after initial full medication reconciliation had occurred. Investigation found that nurses were entering additional PTA medications

when the patients arrived to the floors and families would bring in bags of home medications. This was remediated partially by modifying the look-back time for firing the BPA, and to educate the nurses to notify the providers if they entered new medications so that they could determine if they needed to order them on the patient while in the hospital. Then it was noted that the alert would fire on patients who had expired—prompting physicians to perform medication reconciliation as they entered a death note! This highlighted the importance of anticipating all scenarios when programming BPA logic.

Despite these setbacks, the medication reconciliation efforts went forward and at least partly due to this BPA and some additional decision support related to medication reconciliation, the institution now has 100% of admitted patient's PTA medications reviewed by a provider within 24 hours of admission more than 95% of the time.

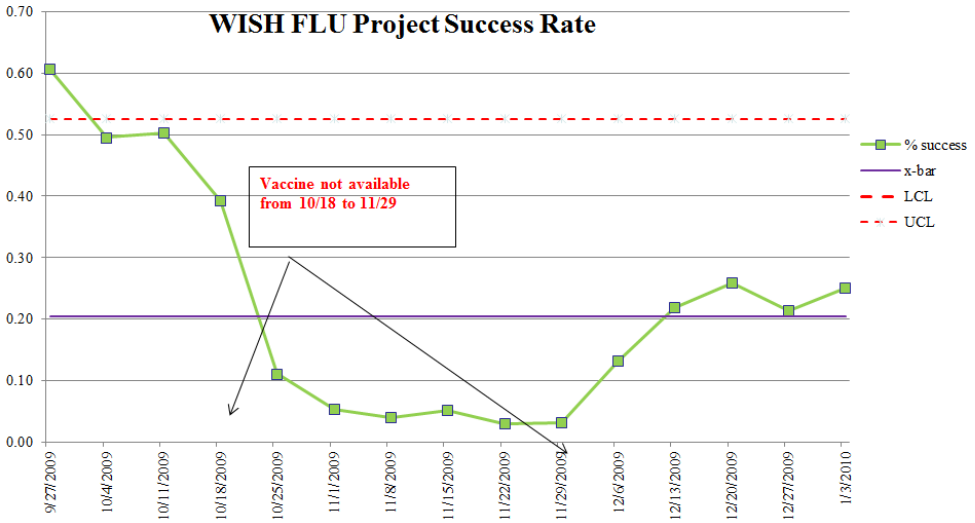


On the other hand, a BPA to reduce catheter associated urinary tract infections (CAUTIs) proved disappointing in lack of impact. The project combined the Foley catheter order with a "Foley removal protocol" order, which would then give nurses latitude (as well as additional alerts) to remove any and all Foley catheters in patients that did not meet strict criteria per the protocol (validated by urology and surgical specialists).



Despite all these efforts, the CAUTI rates in the hospital remained unchanged. Deeper dives revealed that nursing was overwhelmed with significant other hospital endeavors and were not fully educated or engaged in this campaign. It was also determined that there were additional systematic issues contributing to the rates outside of the actual Foley days.

A success was seen with use of the BPA for alerting providers and nurses when patients were due for their influenza immunization. In fact, the Department of



Obstetrics at Parkland won a Health IT Innovation Award in 2010 for their project on creating a methodical process for utilizing the EHR as well as concerted efforts of the department to increase vaccination rates in their high-risk population, even despite vaccine shortages (Stevens, 2010). In this example, the Obstetrics department increased baseline rates of vaccination to levels well above the national average, and at times to rates never before seen in the OB population anywhere in the nation[6].

Lastly, and also successfully, Parkland collaborated with both Divisions of General Internal Medicine at UT Southwestern and Northwestern (Stephen D. Persell, 2010) to implement BPAs in the ambulatory environment with the goal of improving management of selected chronic diseases through CDS and with exception reporting within the alert. In this project, over 20 different BPAs were created encompassing chronic care initiatives, often linked with National Committee for Quality Assurance (NCQA) Health Effectiveness Data and Information Set (HEDIS) metrics, such as checking an LDL on a diabetic patient every 12 months, or treating abnormal nephropathy screening with an ACEI or ARB.

Heart Failure:	% Meeting Quality Measure			Modeled post-pre Difference in Rate of Change	
Quality Measure	2010	2011 Pre	2012 Post	% per year	P
Beta Blocker in LV Systolic Dysfunction	72.5	70.7	76.0	6.2	<0.001
Anticoagulation for Afib in CHF	68.2	66.1	72.1	5.3	0.004
ACEI/ARB in LV Systolic Dysfunction	70.3	69.0	72.5	2.5	0.056

With this project[7], there was significant collaboration between the physician leaders for all 3 areas. There was rigorous communication between the leaders and their divisions and education with information technology support during the go-lives. At Parkland, the BPAs were implemented in a case-control prospective manner with 4 primary care locations going live in June of 2012 and then the other 5 in January of 2013. Unfortunately, Parkland data is not yet fully available for presentation. The UT data, however, has revealed small but significant, steady improvements in most all metrics.

Moreover, the inclusion of exception buttons allowed physicians to document appropriate exceptions for patients who would otherwise file to their delinquency list. By removing them from the "clinical" report, physician satisfaction improved because they were able to focus on just those patients where they truly were missing a particular metric.

[6] C/o Dr. James Alexander, Linda Licata, Jane Kosarek, and Paula Turicchi, SVP WISH

[7] C/o Dr. Ethan Halm, Dr. Jason Fish, Dr. Temple Howell-Stampley, Dr. Lynne Kirk, Dr. Blake Barker, Dr. Michael Bowen, Deepa Bhat, ME, Kim Batchelor, Val Henriquez, Heather Schneider

Health Maintenance:	% Meeting Quality Measure			Modeled post-pre Difference in Rate of Change	
Quality Measure	2010	2011 Pre	2012 Post	% per year	P
Breast Cancer	68.2	69.2	74.8	4.2	<0.001
Pneumococcal Vaccine	64.4	67.3	81.5	7.4	0.012†
Colorectal cancer	46.6	53.7	70.1	4.3	0.002†
Osteoporosis	66.5	67.1	75.4	7.4	<0.001†
Cervical Cancer	52.1	52.5	61.7	7.3	<0.001

Heart Disease:	% Meeting Quality Measure			Modeled post-pre Difference in Rate of Change	
Quality Measure	2010	2011 Pre	2012 Post	% per year	P
LDL Measured	74.2	76.8	81.4	4.1	<0.001
LDL <100	56.1	57.3	59.4	2.6	<0.001
Beta Blocker in MI	72.7	70.0	76.8	11.4	<0.001
ACEI/ARB in CHD with DM	79.7	79.0	81.8	2.0	0.054
Antiplatelet therapy	77.8	79.4	81.7	-0.4	0.284†

†Modeled rate of change adjusting for autoregressive errors

The hope at Parkland is that by engaging physician leadership to build the logic for the CDS and to allow for exceptions to be captured, the level of engagement and satisfaction will improve, along with the patient care.

The most important lessons learned from BPAs is to ideally make them actionable as they are most heeded by physicians in these circumstances (our BPA suggesting use of the pneumonia order set for pneumonia admissions is accepted 40% of the time). Ensure the specificity of the alert is such that the alert only fires for those individuals who can truly act on the alert. Allow an "out" with exception buttons which turn off the alert rather than pester providers about items repeatedly and encourage alert fatigue. Ensure you have departmental and leadership buy-in with any initiatives as their support and feedback on reporting data will be essential. And lastly, try to keep the message succinct and simple. Documents that are wordy will quickly lose an audience.

E. Teaching in the electronic arena

Teaching with order sets

There has been significant debate about the benefits versus hazards of using CDS in academic medical institutions, most notably use of order sets. Detractors (Murphy, 2013) will contend that order sets act as a crutch for learners and prevent them from needing or desiring to learn the true content contained within the sets. They will argue that these facilitate 'cookbook' medicine (Dean F Sittig, 2011), "where the drive to eliminate all preventable errors runs over the art of creative medical problem solving (Performance

Clinical Systems, 2010)", thus decreasing critical thinking. Other common disadvantages described include lack of physician autonomy, treating all patients the same, displaying too many options and resulting in unnecessary orders, and causing apathy due to burnout from lack of ability to think outside the box. Finally, opponents will argue that order sets require extensive investments in time and money to create, maintain, and monitor content. There has become an entire industry of 3rd party vendors tailoring to assist with this aspect.

Proponents tout the benefits of order sets, including:

- Teaching evidence based best practices
- Putting the care team members all on the same page (provider, nurse, pharmacist, etc…) so everyone knows what will be ordered on a patient
- Increasing adherence with guidelines and reduced variability
- Increased speed of ordering and reduced errors
- Allowing more centralized control and rapid modification based on evidence based practice changes
- Helping teach learners how to think through problems by presenting the content in an organized manner with educational bullets and hyperlinks to references with further information
- Acting as a reminder list so that providers don't forget to order what is needed or recommended

They advocate that not only can users learn from these but educators can readily teach from them, challenging why a resident chose the particular orders he or she chose. Educators can pose differing scenarios for exceptions for use of particular parts of an order set—for instance, how do you approach treating community-acquired pneumonia in a patient with a penicillin allergy? What if the patient has stage 5 chronic kidney disease? Has no viable intravenous access? Etc… If the learner did not use the order set, challenge them to defend why their practice is better than the standard care pathway.

Teaching with Best Practice Advisories

Similar practices can be utilized for best practice advisories as well. What many educators do not know is that in the EHR used by Parkland, UTSW, and Children's Medical Center, they can pull up a report on BPAs for any given admitted patient. There is capability to generate a report detailing all the BPAs that have fired for that particular patient, listing the date, user it fired for, and action taken, which can be accessed readily by any attending in seconds.

Educators can challenge their learners to explain the basis for the alert—what best practice is this trying to achieve and what is the evidence to support it? What would be some appropriate exceptions to following that recommendation? How should they respond to the alert? How should they try to incorporate this into their clinical practice in an ongoing basis?

Many order entry alerts are also BPAs and would display under this same report. Challenging learners to describe their actions with the alert and encouraging them to incorporate better habits of reviewing alerts and acting upon them is a useful endeavor.

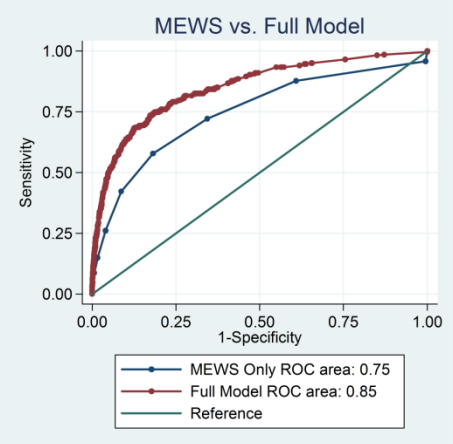
Teaching with Documentation Decision Support

Lastly, documentation decision support facilitates providers in performing complete documentation of history and physical examinations, procedures, discharge summaries, and operative notes. Should an educator find a learner's notes missing of essential information, they should broach a conversation about what practices the provider uses for composing notes. Educators should review learner's notes for originality of documentation—particularly in the HPI and assessment and plan sections, where templates have little value. It is in these sections where description of critical thinking should be encouraged. Discuss the importance of readability in notes and compare and contrast with priorities to efficiency versus meaningfulness of a note: what is the purpose of the note? What would the person(s) the note is written for want to see in the note?

F. Future directions for clinical decision support

The future is bright for CDS and mostly includes opportunities to effect more intelligent and timely alerting. Many institutions have already taken lead in linking peripheral data warehouses with some data analytics application to perform predictive analysis and push conclusions into the EHR. From there, decision support can work as it has always, alerting users via a variety of modalities but now with new information coming from a warehouse that hosts data from multiple applications (EHR, lab, financial, care management, perhaps even local and state registries). The "peripheral brain" of the analytics engine can allow for more complicated assessments and calculations than the typical commercial EHR can provide. It can also contain natural language processing to better infer what providers' notes describe. This can then all be used to predict trends and outcomes, and alert the correct members of the institution's care team for appropriate attention or action.

An example of this type of advance analytics comes from the Parkland Center for Clinical Innovation (PCCI), led by Dr. Ruben Amarasingham. This team, under the leadership of Carlos Alvarez, Pharm.D., M.Sc., looked at using CDS to predict resuscitative events and deaths in patients out of the ICU (Carlos A Alvarez, 2013). They derived and validated an automated, electronic clinical predictive model for patients at high risk of cardiopulmonary arrest and unexpected death and then compared this with that of the Rapid Response Teams (RRTs) and with the Modified Early Warning Score (MEWS) predictive



model. They found that their model was more sensitive (51.5% vs. 42.2%) and specific (94.3% vs. 91.3%) than the MEWS model, and when comparing to the RAT timeliness, the automated system identified patients on average 5.7 hours earlier (P=0.003). This model nearly doubled the positive predictive value (10% vs. 5.6%) of the MEWS while maintaining the same negative predictive value (99.4% vs. 99.2%). It is this kind of predictive analytics that we hope to start incorporating into the EHR to drive CDS and help alert the care team members of potential risks, at an earlier point in the patient's care, such that proactive management may prevent or reduce adverse events and improve outcomes.

G. Conclusions

Clinical decision support is the traffic control that allows users to navigate the EHR. It is essential to a well-functioning EHR as it is the glue which holds it together. Without it, users have little support, assistance, or feedback and consequential outcomes of inefficiency, heterogeneity of practices, and outright errors may occur. CDS facilitates safer ordering with documented reductions in adverse medication errors. It prompts more standardized care for specific disease states with proven improvements in consistency of best practices, more timely care, and overall improved quality of care for the patients. It can help us do the right thing but can also be fraught with poor programming that creates indiscriminant firing resulting in alert fatigue. It can, in extreme and poorly thought out cases, push providers to actually do the wrong thing for their patients. And if implemented without institutional support and engagement, may fail to have any impact whatsoever. In the ideal scenario, it helps the care team remember to do the right thing at the right time for the right patient in the right context via the right medium in a unobtrusive way—only displaying when we have had the opportunity to do the right thing but have failed.

The future is bright for clinical decision support as enhancements within the electronic health records as well as within third party applications are allowing for more intuitive, sophisticated programming and predictive analytics. And while there is significant, ongoing work needed to improve the signal to noise ratio for alerts, we are quickly learning what works and what doesn't for effecting positive actions. Informatics leaders are learning the importance of engaging clinical leaders and content experts when creating CDS, trying to ensure it is following the five rights and being presented automatically to end users at the time and location of decision making, with recommendations that are actionable.

Bibliography

Amit X. Garg, N. K.-A. (2005). Effects of computerized clinical decision support systems on practitioner performance and patient outcomes--A systematic review. *JAMA*, 1223-1238.

Carlos A Alvarez, C. C. (2013, February 27). Predicting out of intensive care unit cardiopulmonary arrest or death using electronic medical record data. *BMC Medical Informatics and Decision Making, 13*(1), 1-11.

CDS 101 Task Force. (n.d.). *CDS 101*. Retrieved August 8, 2013, from HIMSS: http://www.himss.org/library/clinical-decision-support?navItemNumber=16563

Dean F Sittig, J. S. (2011). *Clinical informatino systems: overcoming adverse consequences.* Jones & Bartlett Publishers, LLC.

EM Campbell, D. S. (2006). Typers of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc.*, 547-56.

Fisher, D. W. (2012, March 19). Doctors are drowning in too much data, not enough appropriate information. *Med City News*.

Holliday, M. (2008, June 3). Electronic health record usability--do you really need an "embraceable" EHR? *EHR Scope, Spring 2008*(5).

Institute for Safe Medication Practices. (2010). *ISMP's Guidelines for Standard Order Sets*. Retrieved from ISMP: http://www.ismp.org/tools/guidelines/standardordersets.pdf

Jerome A. Osheroff, J. M. (2012). *Improving outcomes with clinical decision support: an implementer's guide, second edition.* Scottsdale Institute, AMIA, AMDIS, and SHM.

JS Adelman, G. K. (2012). Understanding and preventing wrong-patient electronic orders: a randomized controlled trial. *J Am Med Inform Assoc, 20*(2), 305-310.

Kathleen E Walsh, W. G. (2006, November 1). Medication erros related to computerized order entry for children. *Pediatrics, 118*(5), 1872-1879.

Kensaku Kawamoto, C. A. (2005, March 14). Improving clinical practice using clincial decision support systems: a systematic review of trials to identify features critical to success. *BMJ*.

Mitchell Adams, D. B. (2008). *Saving lives, saving money: the imperative for computerized physician order entry in Massachusetts hospitals.* Boston: Westborough, MA: Massachusetts Technology Collaborative; Cambridge, MA.

Murphy, K. (2013, July 8). How is COPE more than cookbook medicine in teh EMR? *EHR Intelligence*.

National Cardiovascular Data Registry. (n.d.). Retrieved August 7, 2013, from American College of Cardiology: https://www.ncdr.com/webncdr/action/

Performance Clinical Systems. (2010). *The Clinical Impact of Advanced Order Set Management.*

Peter J. Greco, G. N. (2007). Fixing the interactions checker. *Epic Physician Advisory Council, Fall Council.* Verona, WI.

press@cms.hhs.gov. (July 17, 2013). *Data show electronic health records empowers patients and equip doctors.* Baltimore: Centers for Medicare & Medicaid Services.

R Brian Haynes, R. S. (1995, Nov/Dec). Bridges between health care research evidence and clinical practice. *J Am Med Inform Assoc, 2*(6), 342-350.

Raman Khanna, E. V. (2011). Unintended consequences of a standard admission order set on venous thromboembolism prophylaxis and patient outcomes. *J Gen Intern Med, 27*(3), 318-24.

Stephen D. Persell, N. C. (2010). Frequency of inappropriate medical exceptions to quality measures. *Annals of Internal Medicine, 152*, 225-231.

Stevens, M. (2010, September). Health IT Innovation Awards: 5 Health IT projects that improved care. *CMIO*, pp. 5-9.

Yong Y Han, J. A. (2005, December 11). Unexpected increased mortality after implementationof a commmercially sold computerized physician order entry system. *PEDIATRICS, 116*(6), 1506-1512.