Risk Reduction and Systematic Error Management: Standardization of the Pediatric Chemotherapy Process

Beverly Ann David, PhD; Ana Rodriguez, PharmD; Stanley W. Marks, MD

Abstract

There is an urgent need to make the administration of chemotherapy to hospitalized children a less intricate, lower risk process. Children have a distinct physiology and an immature ability to metabolize drugs. Combined with complex chemotherapeutic regimens and narrow therapeutic indices, the probability and severity of adverse drug events in a vulnerable population like children are high. Given this need, near-miss chemotherapy ordering errors, and research that identifies the prescribing/ordering step as a significant source of pediatric chemotherapy errors, Memorial Healthcare System (MHS) has been working to integrate and decrease variability in the pediatric chemotherapy process. This paper describes MHS's ongoing program of standardization and integration of pediatric chemotherapy process components using information technology to promote a culture of safe practices and continued automation implementation in a complex health care delivery system.

Introduction

Chemotherapy administration to hospitalized children is an intricate, high-risk process that is prone to error at multiple points. Children, especially small infants, have a unique physiology and an immature ability to metabolize drugs. In addition, children with cancer receive diagnosis-specific chemotherapeutic agents that have narrow therapeutic indices and require complex protocol administration regimens.[1, 2] Furthermore, weight-based dosing and toxicities inherent in the investigational drugs that are sometimes used present further challenges to the safe administration of chemotherapy to hospitalized children.[3, 4, 5]

There is a consensus that most general medication errors, and pediatric chemotherapy errors in particular, occur at the prescribing/ordering step.[6, 7, 8, 9] However, overall, studies demonstrate that medication process errors can occur during ordering, dispensing, and/or administration stages. Prescribing errors occur far upstream in the medication management process and are more likely to be mitigated if intercepted early. If prescribing/ordering errors are not interrupted early, their effects may be propagated and often exacerbated at subsequent steps.[1, 7] These risks, combined with potential protocol disruption (secondary to the labile physiologic state of the patients and their disease processes), generate a relatively high probability of significant error. The potential exists for results that represent far worse patient outcomes in an already vulnerable population.[4, 5]

There are few tools to safely integrate the distinct and complex variables of the pediatric oncology process into inpatient and ambulatory clinical workflows. Many leading pediatric oncology centers are struggling to minimize variability in the multiple stages of the chemotherapy process.[3, 4, 5, 9, 10] More precisely, protocol-specific care plans, standardized order sets, medication administration records, and pharmacy medication profiles that consistently and clearly articulate the patient's treatment criteria are sporadically instituted. As a result, complex elements of pediatric chemotherapy protocols are double-checked by multiple clinicians at distinct points in the prescribing, dispensing, and administration processes. Nevertheless, a deficiency of tools for standardizing and connecting the multifaceted elements of pediatric chemotherapy into a clinician's workflow can result in a significant propensity for error.

Opportunity for error reduction at strategic process points, combined with a number of identified near-miss pediatric chemotherapy ordering errors, motivated the Memorial Healthcare System (MHS), including Joe DiMaggio Children's Hospital (JDCH), Hollywood, FL, into action. The innovative components of the MHS efforts have involved:

- Linked/integrated Children's Oncology Group (COG) protocol-specific, standardized order sets. (COG is the world's largest childhood cancer research organization[11] and is a pioneer in new treatments and cures for pediatric oncology patients.)
- Associated multiday medication administration records (MARs).
- Pharmacy profiles that clearly articulate the entire plan of care to all care providers, decrease the possibility of transcription errors, and reduce processing time from order to administration.

The protocol-driven order sets, associated multiday MARs, and pharmacy profiles developed by JDCH are unique in that they provide clinicians with standardized, integrated tools to follow complex COG protocols more efficiently and more safely. Since COG protocols are standardized across the cooperative research group, the innovative JDCH-developed tools could potentially have widespread implementation potential and thus enhance the patient safety arsenal of pediatric oncology centers nationwide.

Improvement Development: The Context

Prior to the development of the MHS error-reduction system, it had been noted that JDCH oncology nurses were spending an inordinate amount of time verifying physician's handwritten orders against complex COG protocols and roadmaps. In addition, the computer-generated MARs provided by the pharmacy system were failing to group patients' treatment criteria in a chronologic format, making the MAR/original order reconciliation process extremely difficult and labor intensive and, consequently, increasing the risk of error. Despite adhering to strict double-check policies, near-miss errors were often being caught during the order and MAR reconciliation process (Figure 1).

Oncology nurse-clinician verification of the discrepancies provided baseline measures of variability in the accuracy of the JDCH pediatric chemotherapy prescribing process. It was noted that from January through November 2005, 79 percent of chemotherapy orders were written correctly, but 58 problematic individual patient order sessions had chemotherapy errors. Flawed

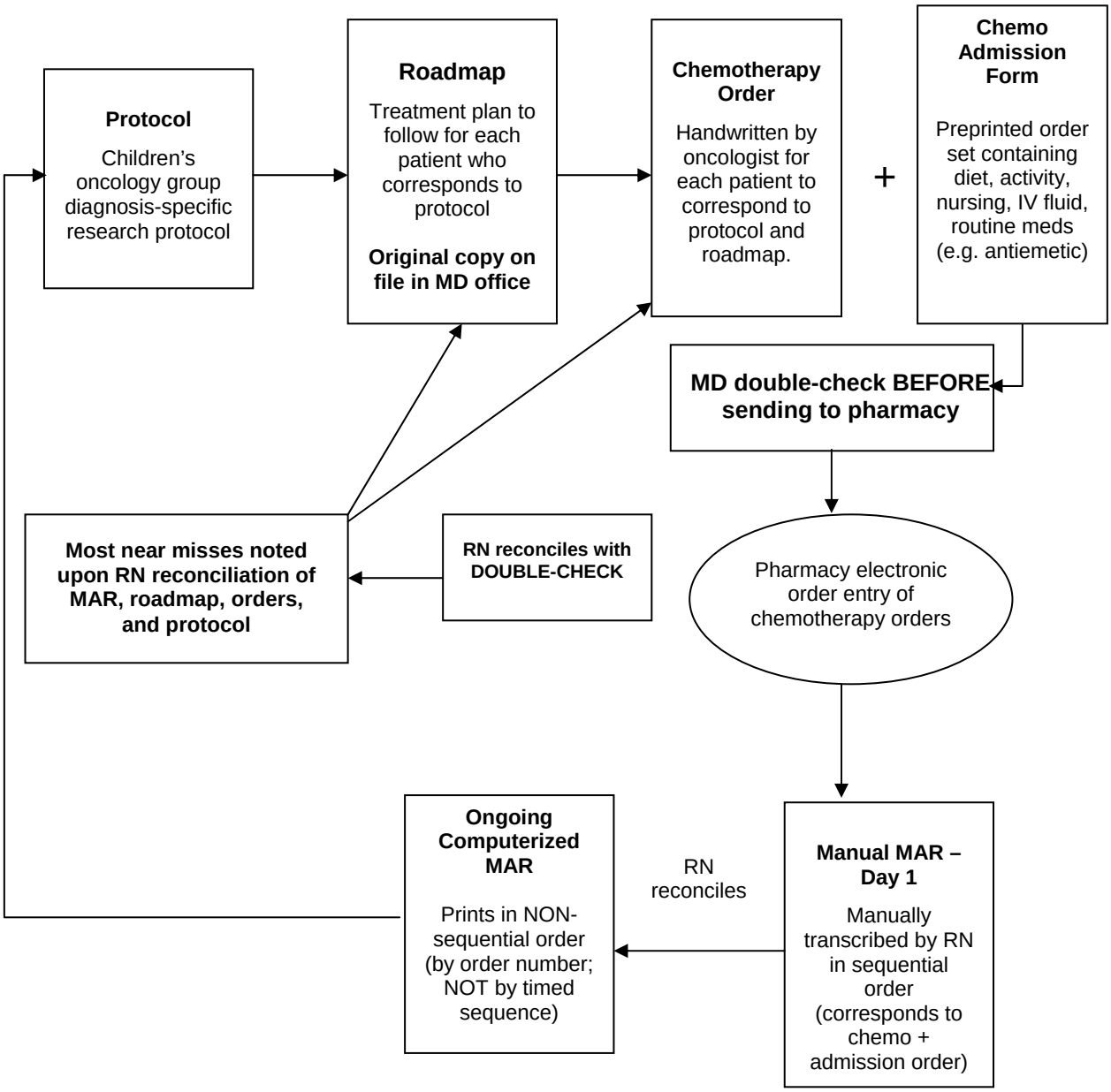

Figure 1. Joe DiMaggio Children's Hospital chemotherapy order process

chemotherapy orders included incorrect protocols, faulty calculations, inaccurate scheduling and weight/body surface area calculations, and missing dates, as well as legibility issues. For a vulnerable population of patients, such near-miss prescribing errors had the potential to cause serious harm had they not been caught and remedied.

With the growth of the pediatric oncology practice at JDCH, protocols increased in complexity. Recognizing the safety issues involved, JDCH nurses and oncology clinicians saw the need to improve the efficiency and safety of this process. Networking with peers at other pediatric oncology centers revealed that many centers were struggling with similar issues and that no

automated solution existed. Having identified the problem, MHS leadership empowered JDCH nurses to find a solution.

Standardization of the Pediatric Chemotherapy Process

With an awareness that nationwide centers were concerned about pediatric chemotherapy safety,[3, 4, 8, 9, 10] that the pediatric chemotherapy system was excessively prone to errors, and that a systemwide initiative was needed to improve patient safety, a multidisciplinary team was formed to improve pediatric oncology patients' outcomes. The team consisted of two pediatric oncology physicians (employed by MHS), a nursing director of pediatrics, the JDCH chief nursing officer, three JDCH oncology clinicians, a JDCH oncology pharmacist, and three clinical informatics pharmacists. Team members were chosen for their particular clinical or process expertise, their willingness to work toward a solution, and their ability to make and enforce administrative decisions.

The team's intent was to streamline the pediatric chemotherapy process and implement standardized order sets and medication administration templates that would correlate with COG pediatric chemotherapy treatment protocols**.** The group's hypotheses were that: one, use of COG protocol-specific standard order sets and multiday MARs would decrease the number of chemotherapy order errors; and two, decreasing the number of individual patient order sessions with problematic chemotherapy orders would improve patient safety.

Although significant obstacles were not encountered in designing the new system, the team struggled with a number of decisions, including creating an effective and efficient forms-review process; facilitating ongoing forms maintenance; and implementing an alternative process for access to forms (to ensure that clinicians always had the most current version). The forms access issue was resolved by the group's decision to post the forms on the MHS physician portal site, which is accessible to any authorized MHS employee or medical staff member, either in-house or remotely.

The forms review/approval process was established as follows:

1. A protocol specialist develops order forms and MARs for an arm of the protocol.
2. Once the draft of these order forms is completed, a subset of the team members reviews that protocol arm.
3. The review process for each arm is assigned to a rotating group that includes two individuals from each discipline (i.e., physician, nurse, and pharmacist).
4. These individuals have 2 weeks to assess the protocol for accuracy and appropriateness, after which they share any feedback and/or necessary changes with the rest of the team at one of the scheduled monthly meetings. The approval process is usually completed within 2 weeks.
5. After changes are made, the team members perform their final review and then sign off using a sheet maintained by the protocol specialist.
6. Once finalized, the forms are converted to PDF format and attached to the intranet menu, where they can be accessed and printed as needed by pediatric oncology physicians or their designees.

The process for pharmacy orders was also changed. Previously, one pharmacy satellite entered orders for a patient's non-chemotherapeutic medications, while another entered only chemotherapeutic agents. However, with the new protocol standardization and implementation, a single pharmacist would enter all protocol medications, regardless of whether they were considered chemotherapeutic or non-chemotherapeutic agents. Lastly, a decision was made to adopt the standardized order forms and MARs, whether the patient was being treated as an inpatient, in an outpatient clinic, or in a physician's office.

Standardization of the Chemotherapy Process: Prescribing

Handwritten order sets are associated with significantly greater risk, compared with standardized, preprinted order sets.[3, 12, 13] Incorrect, incomplete, or illegible chemotherapy orders require nurses and/or pharmacists to make assumptions that may be erroneous, thus putting the patient's health at risk.[1] In contrast, standardized, complete order sets are an inexpensive and readily available method that substantially reduces the need for clarification and the number of changes required during order verification and processing.[14, 15]

MHS made a commitment to create standardized preprinted order sets for all oncology protocols. Since more than 90 percent of pediatric oncology patients are treated based on open or closed protocols,[16] the team agreed to begin with open protocol order-set creation for the most common pediatric malignancies. Figure 2 shows the AALL0331 protocol, the first such standardized order set we developed, for acute lymphoblastic leukemia (ALL), the most common malignancy of children.[17]

The AALL0331 protocol consists of 13 treatment arms (induction, consolidation, maintenance), for which 67 order sets/multiday MARs were drafted and validated by the multidisciplinary design group through the articulated iterative process. Once the first group of documents was completed for ALL, the group conducted a "parallel go-live" by using the forms in parallel with the existing process. The feedback from the clinicians for the new protocol was so favorable that the forms were immediately implemented. Two additional protocols were developed to study patients with pre-B type of leukemia. Pre-B type pediatric oncology patients may be either on the "low risk" (AALL0331) or "high risk" (AALL0232) protocol.

Once feedback from the first diagnosis-specific protocol was completed, the task force presented their findings to MHS executives and leaders for review. This resulted in the hiring within a year of a full-time protocol specialist to design, create, maintain, and manage the approval and ongoing education process for full implementation of all COG-specific order sets and MARs. To date, 238 order sets/MARs for four pediatric COG diagnoses have been implemented at JDCH. There are 10 new and eight existing patients on the AALL0331 and AALL0232 protocols, respectively, and two on the AREN0532 protocol. A fifth order set/MAR for Wilm's tumor is in the final stages of approval. Our goal is an order set/MAR for 100 percent of all COG protocols.

Redundant, manual, multidisciplinary checks of chemotherapy orders are a proactive approach to error management.[16] Thus, as an additional safety measure, two-physician verification and cosignature of all chemotherapy orders was implemented in December 2005. Oncology nurse-clinician assessment of both handwritten and template order sessions for chemotherapy order

CHEMOTHERAPY ORDER: PRE-B ALL STANDARD INDUCTION

PROTOCOL No. AALL0331 (STANDARD INDUCTION) **DAY:** _____

Protocol Starting Criteria: NONE

Diagnosis: ACUTE LYMPHOBLASTIC LEUKEMIA **On Study (circle one): YES / NO**

Allergies: _____

Height: _____ (cm) **Weight:** _____ (kg) **BSA:** _____ (m^2) **DOB:** _____ **Age:** _____

Medication Dose Calculation:

					Adjustment Factor	Final Dose
Med 1	Cytarabine IT	(age-based dosing refer to chart below)				
Med 2	Vincristine IV	1.5 mg/m^2/dose	X	_____m^2 X	_____% =	_____mg/dose
Med 3	Dexamethasone PO	6 mg/m^2/day	X	_____m^2 X	_____% =	_____mg/day (divided BID)
Med 4	PEG Asparaginase IM	2,500 units/m^2/dose	X	_____m^2 X	_____% =	_____units/dose
Med 5	Methotrexate IT	(age-based dosing refer to chart below)				

* For Down Syndrome patients please see Physician regarding Leucovorin *

Reason for dose adjustment, if applicable: _____

DAY/DATE	CHEMOTHERAPY MEDICATION ORDERS
1_____	**Intrathecal Cytarabine** (note age-based dosing) Dose by Age: 1 - 1.99 yrs = 30mg; 2 - 2.99 yrs = 50mg; 3 yrs & above = 70mg = _____mg in _____mL of STERILE PRESERVATIVE FREE NS ONETIME. **INTRATHECAL**
1 _____ 8 _____ 15 _____ 22_____	**Vincristine (VCR)** 1.5mg/m^2/dose (maximum 2mg) = _____mg **IV** PUSH ONETIME.
Days 1 - 28	**Dexamethasone (DEX)** 6mg/m^2/day = _____mg daily divided BID = _____ mg **PO** BID for 28 days (DO NOT TAPER)
4 **or** 5 **or** 6 Date:_____	**PEG Asparaginase (PEG)** 2,500 units/m^2/dose = _____units **IM** ONETIME on day 4 **or** 5 **or** 6 **(circle day)**
8_____ *15_____ *22_____ 29_____	**on days 8, 29 *(CNS3 also days 15 & 22)** **CNS Status:** _____ **Intrathecal Methotrexate** (note age-based dosing) Dose by Age: 1 - 1.99 yrs = 8mg; 2 - 2.99 yrs = 10mg; 3 - 8.99 yrs = 12mg; 9yrs & above = 15mg = _____ mg in _____ mL of STERILE PRESERVATIVE FREE NS ONETIME. **INTRATHECAL** **NOTE**: Down Syndrome patients require Leucovorin rescue. Please check with Physician.

Please communicate with physician prior to initiation of chemotherapy (with exception of dexamethasone)

1ST PHYSICIAN'S SIGNATURE/ID #	DATE/TIME	
2ND PHYSICIAN'S SIGNATURE/ID # (Required PRIOR to transmission to Pharmacy)	DATE/TIME	
1ST NURSE'S SIGNATURE/ID #	DATE/TIME	**Patient Label**
2ND NURSE'S SIGNATURE/ID #	DATE/TIME	

Joe DiMaggio Children's Hospital AT MEMORIAL

Chemotherapy Order Form

revised: 7/01/2007

Figure 2. Standardized Pre-B ALL Standard Induction order form

errors continues. These efforts appear to be paying off, as evidenced by a decline in chemotherapy order errors from 58 in January to November 2005 (prior to standardization and integration of the pediatric chemotherapy process components) to 6 such errors for the same time period in 2007. No chemotherapy order errors have so far occurred using the four standardized chemotherapy order sets/MARs. The significant decrease in chemotherapy order errors in handwritten order sessions is believed to be a function of increasing physician familiarity and utilization of the standardized order method and incorporation of the standardized structure and content into the handwritten order session process.

To promote ease of access and consistency of use, MHS placed the current standardized leukemia chemotherapy order sets on the MHS intranet page (Figure 3), making them accessible to any authorized MHS employee or medical staff member, either in-house or remotely. Clicking on the link opens the actual order document in PDF format, so that it can be printed, completed, verified, cosigned, and used to initiate chemotherapy administration. This MAR is then reconciled with another nurse against the protocol-driven roadmap and individual patient chemotherapy order.

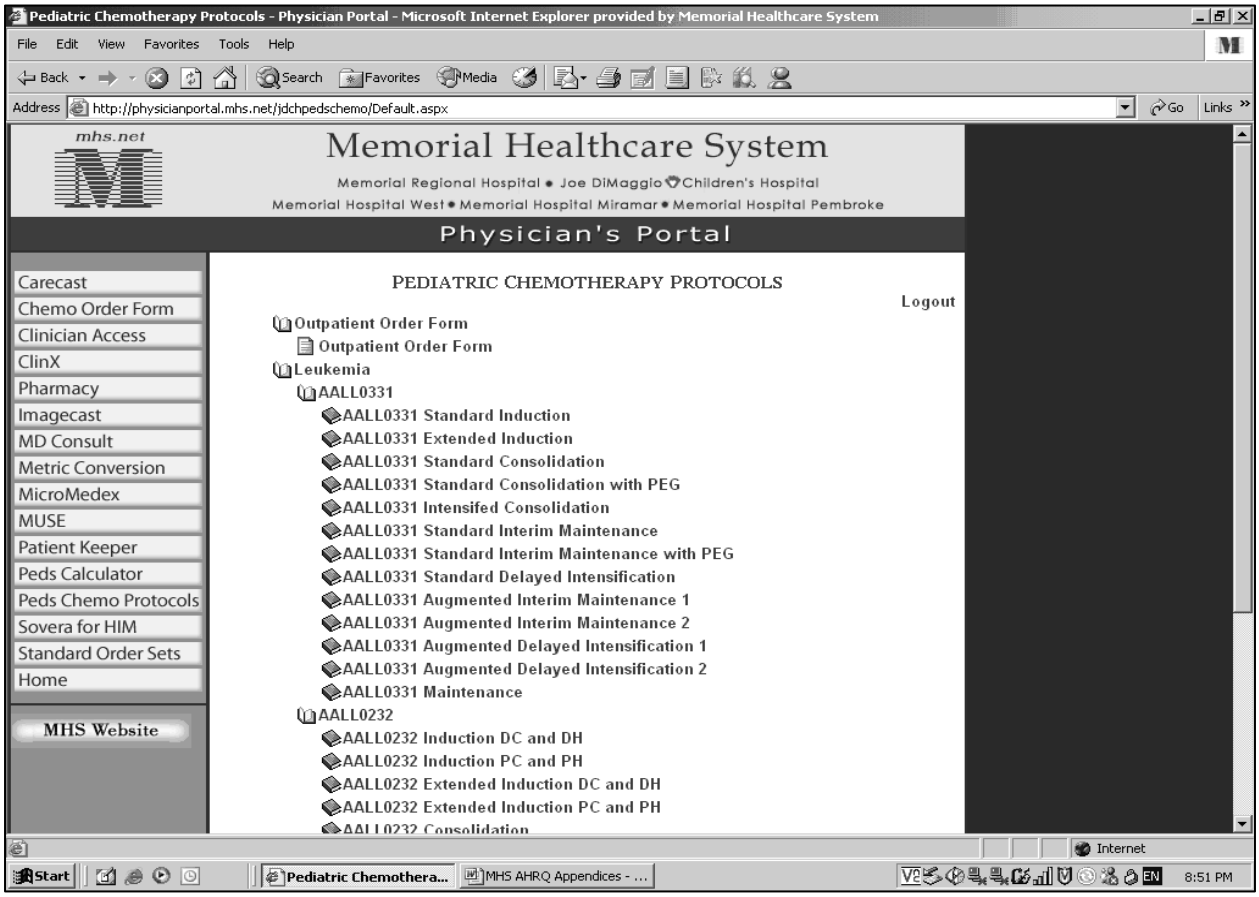

Figure 3. Online standardized pediatric chemotherapy order sets

Standardization of the Chemotherapy Process: Dispensing

Once the standardized chemotherapy form is completed, verified, and cosigned by two physicians, it is sent to the chemotherapy-dedicated pharmacy, where a pharmacy triple-check process is initiated (Figure 4). MHS's pharmacy triple-check process was instituted to mitigate modeled probability dispensing error rates of 2 to 3 percent.[18] (Note: Probability dispensing error rates are a quantifiable statistical relationship between a measure of workload [e.g., number of prescriptions dispensed by individual pharmacy staff during a single workday] and the risk of committing at least one dispensing error during that same workday period.)

AALL 0331 STANDARD INDUCTION - PHARMACY TRIPLE CHECK

Patient Name: _____ **MR#** _____ **Sex:** _____ **Age:** _____ **Course/Week:** _____

Allergies: _____ **Port ? Yes** _____ **No** _____ **Physician:** _____

Diagnosis: **ACUTE LYMPHOBLASTIC LEUKEMIA** Ht: _____ Wgt: _____ BSA: _____ Notes: _____

Calculation:

Med 1	Cytarabine IT	*age based dosing refer to chart on order*		**Adjustment Factor**			**FINAL DOSE**	**VOLUME**
Med 2	Vincristine	1.5mg/m^2/dose	X	_____ m^2	X _____ %	=	_____ mg	
Med 3	PEG Asparaginase	2,500 units/m^2/dose	X	_____ m^2	X _____ %	=	_____ units	
Med 4	Methotrexate IT	*age based dosing refer to chart on order*						

Note: Three initials required signifying: (1) Correct patient, chemo drug and calculated dose against label, (2) Correct chemo drug and calculated syringe volume checked against label and (3) labeled medication and calculated dose checked against order.

Date	MEDICATION ORDER	Day 1 Initials:	Day 2 Initials:	Day 3 Initials:	Day 4 Initials:	Day 5 Initials:	Day 6 Initials:	Day 7 Initials:
	Intrathecal Cytarabine (IT AraC) = _____mg in _____ mL SPFNS (age-based dosing) Total Volume = _____mL	____/____/____ Date: _____						
	Vincristine 1.5mg/m^2 = _____ mg IV PUSH ONETIME on days (1st dose) 1, 8, 15, 22 (maximum 2mg)	____/____/____ Date: _____						
	PEG Asparaginase (PEG) 2,500 units/m^2= _____ units IM ONETIME *on Day 4 OR 5 OR 6 (Total Dose maybe dispensed in two syringes) Syringe # 1 = _____units Syringe # 2 = _____units (If Applicable)				(SYR #1) ____/____/____ (SYR #2) ____/____/____ Date: _____	(SYR #1) ____/____/____ (SYR #2) ____/____/____ Date: _____ *Do not dispense if given on Day 4	(SYR #1) ____/____/____ (SYR #2) ____/____/____ Date: _____ *Do not dispense if given on Day 4 or 5	
		Day 8		**Day 15**		**Day 22**		**Day 29**
	Intrathecal Methotrexate (IT MTX) = _____ mg in _____mL SPFNS (age-based dosing) Total Volume = _____mL	____/____/____ Date: _____		____/____/____ Date: _____ *if CNS3 only per protocol		____/____/____ Date: _____ *if CNS3 only per protocol		____/____/____ Date: _____
	Vincristine 1.5mg/m^2 IV PUSH ONETIME on days 8, 15, 22 **Indicate dose dispensed** (maximum 2mg)	**Dose: _____mg ____/____/____ Date: _____		**Dose: _____mg ____/____/____ Date: _____		**Dose: _____mg ____/____/____ Date: _____		

Figure 4. Pharmacy pediatric chemotherapy order triple check

The MHS pharmacy's triple-check process ensures accuracy in interpreting and entering the chemotherapy order, as well as in compounding and dispensing the medication. Although the pharmacy triple-check process is an industry benchmark practice, the MHS triple-check profile is unique in that it corresponds with the COG-specific protocol. This protocol-specific triple-check profile provides the pharmacist with the entire standardized plan of care, thus decreasing the possibility of transcription errors and improving order process efficiency. Pharmacist review of the chemotherapy order, verification of the order with the chemotherapy protocol, and redundant checks of entering and dispensing chemotherapy orders are recommendations of the failure

modes and effects analysis (FMEA) for safe order interpretation, compounding, and dispensing of chemotherapy medications to hospitalized children.[3]

Standardization of the Chemotherapy Process: Administration

Chemotherapy administration is the chemotherapy subprocess with one of the highest risks for errors.[3] Every step in the standardized process—from prescribing to dispensing with redundant checks by physicians, pharmacists, and nurses against the protocol, roadmap, and individual order—could be performed, but if the nurse administers the wrong medication to the wrong patient, the entire process is a failure with potentially devastating consequences.

When caring for pediatric patients, health care organizations must have effective processes to ensure that their staff is competent in the use of devices, equipment, and drug administration.[19, 20, 21] MHS's culture of safety is proactively focused on safety promotion vs. reactive error management. All personnel who administer chemotherapy must have completed the Oncology Nursing Society's chemotherapy provider course "Get Certified"[22] and be able to demonstrate clinical competency with the clinical nurse specialist. All staff members are required to be competent in terms of drug therapy knowledge, ability to function safely in the medication administration system by adhering to policies and procedures, ability to foster communication and teamwork, and use of decision-support tools.

Upon receipt of the chemotherapy from the pharmacy, two certified chemotherapy provider nurses review the original chemotherapy order, the patient's protocol-based roadmap for appropriate dosage, and the administration schedule with the dispensed, labeled chemotherapy bag. The patient's absolute neutrophil count (ANC) is calculated from the most recent CBC, and relevant lab results, and specific tests are reviewed, verified, and documented. Inappropriate lab and test results are reported to the physician in a timely manner.

Immediately prior to chemotherapy administration, two certified chemotherapy provider nurses perform a critical check at the point of delivery. A critical check includes verification of the patient's name and medical record number and of the chemotherapy agent, dose, route, volume, and infusion time. The critical check is documented on the patient's MAR. To ensure safe administration of chemotherapy to hospitalized children, FMEA recommendations include redundant, two-RN verification of the chemotherapy order, the patient's individualized protocol-based roadmap, and administration dose, times, and bedside patient identification.[3]

Technologic Advances

The Institute of Medicine's (IOM) groundbreaking report, "To Err is Human," documented as many as 98,000 deaths per year from avoidable medical errors. It also identified information technology as an important tool for decreasing adverse medical outcomes.[23] In the aftermath of the IOM report, hospitals have prioritized patient safety and investigated new methods for improving the delivery of health care. Motivated by an awareness that current health care delivery practices are not as efficient or effective as they need to be, MHS has embraced technology to assist physicians and staff in providing more efficient, effective, and safe patient care**.**

Standardization of pediatric chemotherapy order sets and a more efficient order verification process are foundational process improvement steps toward implementation of computerized physician order entry (CPOE) and bar code medication administration (BCMA) in this complex setting. CPOE is one technologic process of medical management that provides a well-organized, electronic strategy to enhance efficiency, improve the quality of patient care, and decrease adverse medical outcomes.[24]

MHS has developed and is testing the CPOE order set for Protocol AALL0331-Standard Induction Arm (Figure 5). MHS is already in the initial stages of CPOE. The pediatric and adult emergency departments (EDs) at three of the six facilities are "live on CPOE" with plans for two additional ED facilities to "go-live" in 2008. In addition, nursing computer-based clinical documentation and BCMA have been implemented at several facilities. These initiatives offer exciting opportunities to fuse quality and best practices at the point of care.

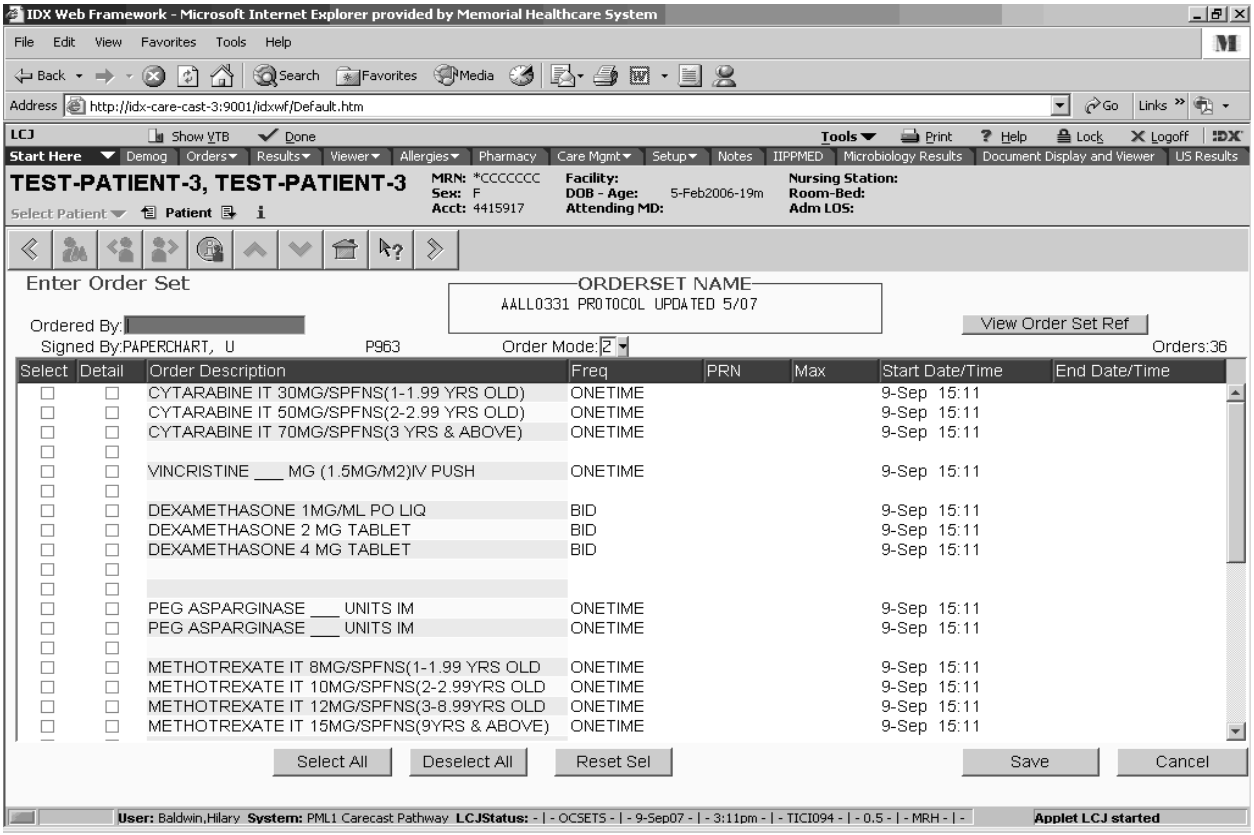

Figure 5. CPOE test order set – Protocol AALL0331 Standard Induction Arm

Conclusion

Medicine is a knowledge- and information-intensive domain, where timely patient care decisionmaking must be effective, efficient, and accurate. Development of protocol-specific standardized order sets and medication administration templates—with a complex system of double-checks for physicians, pharmacists, and nurses—promotes dialogue among disciplines,

minimizing the possibility of serious error in ordering, dispensing, and administering chemotherapy in this high-risk area. Anticipated outcomes of this process include:

- Improved efficacy and accuracy in writing, checking, interpreting, and entering chemotherapy orders.
- Decreased pharmacy chemotherapy preparation turnaround times.
- Increased nursing chemotherapy administration efficiency.
- Shortened length of stay/throughput times for pediatric patients and their families.

Online access to protocol-specific order sets and medication administration templates, as well as future CPOE implementation, will integrate numerous safety processes into the culture of medication management. MHS is proud to be a part of the imperative for change, adapting technology for the delivery of safe, effective, quality health care.

Author Affiliations

Memorial Healthcare System, Hollywood, FL.

Address correspondence to: Beverly David, PhD, Memorial Healthcare System, 3051 N. Commerce Parkway, Miramar, FL 33025; telephone: 954-275-4073; fax: 954-276-5387; e-mail: bdavid@mhs.net.

References

1. Leonard M, Cimino M, Shaha S, et al. Risk reduction for adverse drug events through sequential implementation of patient safety initiatives in a children's hospital. Pediatrics 2006; 118: 1124-1129.
2. Baranowicki P, O'Neill J, Dwyer J, et al. Improving complex medication systems: An interdisciplinary approach. J Nurs Admin 2003; 33: 199-200.
3. Robinson D, Heigham M, Clark, J. Using failure mode and effects analysis for safe administration of chemotherapy to hospitalized children with cancer. Jt Comm J Qual Patient Saf 2006; 32: 161-166.
4. Kim G, Chen A, Arceci R, et al. Error reduction in pediatric chemotherapy. Arch Pediatr Adolesc Med 2006;160: 495-498.
5. Taylor R, Bailey C, Robinson K, et al. Results of a randomized study of preradiation chemotherapy versus radiotherapy alone for nonmetastatic medulloblastoma: The International Society of Paediatric Oncology/United Kingdom Children's Cancer Study Group PNET-3 Study. J Clin Oncol 2003; 21: 1581-1591.
6. Barber N, Rawlins M, Dean Franklin B. Reducing prescribing error: Competence, control and culture. Qual Saf Health Care 2003: 12(suppl 1): i29-i32.
7. Bates D, Cullen D, Laird N, et al. Incidence of adverse drug events and potential adverse drug events. Implications for prevention. ADE Prevention Study Group. JAMA 1995; 274: 29-34.
8. Gandhi T, Bartel S, Shulman L. Medication safety in the ambulatory chemotherapy setting. Cancer 2005; 104: 2478-2483.
9. Dinning C, Branowicki P, O'Neill J, et al. Chemotherapy error reduction: A multidisciplinary approach to create templated order sets. J Pediatr Oncol Nurs 2005; 22: 20-30.
10. Opfer N, Wirtz D, Farley K. A chemotherapy standard order form: Preventing errors. Oncol Nurs Forum 1999; 26: 123-128.
11. National Childhood Cancer Foundation. Children's Oncology Group. Available at: http://www.curesearch.org/. Accessed February 3, 2008.

12. Pape TM, Geurra DM, Muzquiz M, et al. Innovative approaches to reducing nurses' distractions during medication administration. J Contin Educ Nurs 2005; 36: 108-116.

13. Ash JS, Gorman PN, Seshadri V, et al. Computerized physician order entry in U.S. hospitals: Results of a 2002 survey. J Am Med Inform Assoc 2004; 11: 95-99.

14. Fishbane S, Niederman MS, Daly C, et al. The impact of standardized order sets and intensive clinical case management on outcomes in community-acquired pneumonia. Arch Intern Med 2007; 167: 1664-1669.

15. Stuckey ER. Prevention of medication errors in the pediatric inpatient setting. Pediatrics 2003; 112: 431-436.

16. Müller R, Sergl M, Nauerth U, et al. THEMPO: A knowledge-based system for therapy planning in pediatric oncology. Comput Biol Med 1997; 27: 177-200.

17. CureSearch. National Childhood Cancer Foundation. Acute lymphoblastic leukemia – practicing science every day in patient care. Available at: www.curesearch.org/support_curesearch/eblast.aspx?id=4456. Accessed February 4, 2008.

18. Carnahan BJ, Maghsoodloo S, Flynn EA, et al. Geometric probability distribution for modeling of error risk during prescription dispensing. Am J Health Syst Pharm 2006; 63: 1056-1061.

19. American Academy of Pediatrics Committee on Drugs and Committee on Hospital Care. Prevention of medication errors in the pediatric inpatient setting. Pediatrics 2003; 112: 431-436.

20. The Institute for Safe Medication Practices. ISMP Medication Safety Self Assessment® for Hospitals. Available at: www.ismp.org/selfassessments/Hospital/Intro.asp. Accessed February 5, 2008.

21. Lesar TS, Mitchell A, Sommo P. Medication safety in critically ill children. Clin Ped Emerg Med 2006; 7: 215-225.

22. Oncology Nursing Certification Corporation. Get certified. Available at www.oncc.org/getcertified. Accessed March 19, 2008.

23. Institute of Medicine. To err is human: Building a safer health system. Committee on Quality of Health Care in America. Washington, DC: National Academies Press; 2000.

24. Levick D, Lukens H, Stillman P. You've led the horse to water, now how do you get him to drink: Managing change and increasing utilization of computerized provider order entry. J Healthc Inf Manag 2005; 19: 70-75.