Title of Case Study: Reduce medication errors with closed-loop medication administration system

Organization: North York General Hospital
4001 Leslie St.
Toronto, ON M2K 1E1, Canada

Primary Point of Contact: Dr. Jeremy Theal, MD
Chief Medical Info Officer
jeremy.theal@nygh.on.ca

Secondary Point of Contact: Linna Yang, RN, MHI
Manager Clinical Informatics
Linna.yang@nygh.on.ca

Executive Summary

Since 1968, North York General Hospital (NYGH) has served the culturally diverse communities of North Toronto with the best possible care experience. As one of Canada’s leading community academic hospitals, we offer a wide range of acute, ambulatory and long-term care services across our three sites (inclusive of 618 inpatient beds) covering the south central region of Ontario, centered on Toronto (Figures 1 & 2). Our dedicated team of 5,000+ staff, physicians and volunteers are proud to serve our growing population of over 400,000 people. Our Patients Come First in Everything We Do.

NYGH has a history of adopting innovative technology to promote the ideal patient experience. Beginning in 2007, we embarked on a multi-year clinical transformation project to bring our electronic health record system (EHR) into the future, from HIMSS Stage 2 to a goal of HIMSS Stage 7. This project, called eCare, has a primary focus of improving the quality and safety of care that we provide to our patients every day. One of eCare’s most significant achievements to date is how NYGH established a culture of evidence-based care to measurably improve the number of lives saved. In fact, over the past 6 years, the NYGH eCare project has won seven national awards for improving quality and safety of patient care.
One of our first eCare initiatives was to redesign our medication administration process. Prior to eCare, the medication process consisted of handwritten physician orders, duplicative manual transcription and shared med carts. This system left a lot of room for error, with 39 percent of errors occurring with medication prescribing and 38 percent occurring with medication administration.

After examining the local problem and designing a new workflow to solve that problem, NYGH implemented closed-loop medication administration (CLMA). By leveraging information technology at every step in the process, CLMA eliminates manual entry and fires an alert if a medication about to be administered does not match the drug, dose, route, timing and/or intended patient indicated in the active orders on the electronic chart. From 2010-2015, NYGH has prevented more than 11,000 medication errors using CLMA.

Local Problem

As outlined in the 2014 Ontario Hospital Association report “Let’s Talk Solutions”, Ontario hospitals have the lowest standardized hospitalization rates in the country and the lowest hospital expenditure per capita.

“At 6.4 days, Ontario has the lowest average duration of a hospital stay in acute care of all the provinces, when adjusting for differences in age and sex,” the report states.

At the same time, Ontario hospitals are running the same volume of inpatient beds, caring for an aging population and admitting more acute conditions with shorter hospital lengths of stay.\(^1\)

Over the past five years, the inpatient volume at NYGH has increased 10.2%, but the hospital’s staffing only increased by 0.7%. In 2015, NYGH administered more than 1.6 million medications, a 15% increase since 2011. This kind of surge in workload can increase the chances of nurses being interrupted or distracted during medication administration, making it more likely for errors to occur.\(^2\)

Adverse events from medication errors have been an alarming problem in North Toronto and across Canada for decades. In 2004, the Canadian Adverse Events Study (CAES)\(^3\) reviewed 3,745 inpatient cases from acute care hospitals across the country and found that 7.5% of those had an adverse event that harmed patients. By extrapolating that percentage across the entire country, the study suggests about 185,000 hospital admissions likely had an adverse event. The study also reports that of those adverse events, 45% (83,250) were related to medication services.

Before implementing eCare in 2010, NYGH had about 28,000 admissions a year. Based on the CAES conclusions, NYGH had approximately 2,100 (7.5% of 28,000) admissions with harmful adverse events with approximately 945 (45% of 2,100) relating to medication services.

\(^1\) Visser, M., Dale, A. (2014). “Let’s Talk Solutions – Advancing the conversation about health system priorities.” Ontario Hospital Association. 5


Many of these adverse events were a result of the previous (pre-eCare) medication administration process. Several steps required manual entry, which left a lot of room for error.

**Previous Medication Order and Administration Processes**

1. Physician hand writes medication orders, or uses pre-printed paper order sets
2. Nurse manually transcribes orders into paper Medication Administration Record (MAR)
3. Physician order sheet is sent to pharmacy
4. Pharmacist manually transcribes orders into Pharmacy system
5. Pharmacy dispenses medication to nursing unit
6. Nurse uses shared paper MAR to select medications from shared medication cart
7. Nurse manually documents what was administered into paper MAR

Medication errors can occur at various steps in the process from prescribing, to transcribing, to dispensing, and finally administration. A study by Agarwal\(^4\) evaluated the error rates at the various stages of this process and further identified relevant technologies that can be implemented to mitigate the potential errors (Figure 3).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Error rate, %</th>
<th>Intercept rate, %</th>
<th>True error rate, %</th>
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Figure 3

From the risk management perspective, information gathered from medication error reporting systems can be analyzed to detect system issues, identify staff education opportunities, and improve patient safety. With a paper system, medication errors are often significantly underreported.\(^5\) This poses challenges for quality improvement initiatives at acute care organizations such as NYGH. By comparison, a significant advantage of CLMA is that it helps to quantify the number and types of errors prevented by such technology, and the information provided allows risk management personnel to analyze the root cause of such errors and develop mitigating strategies.

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Design and Implementation

A key element that made NYGH’s CLMA design and implementation successful is the organization retooled the medication administration workflow before selecting any technology. Using this approach, the organization made sure equipment and devices effectively met nursing needs and supported workflow — instead of tailoring the process to fit the technology on the back end. This not only led to strong clinician adoption of the technology, but also ensured that NYGH had standardized processes for medication management that met the unique needs of the organization. By designing the workflow first, NYGH was able to establish best practices and then incorporate technology to sustain those best practices.

To redesign the medication administration workflow, NYGH leveraged LEAN methodology tools to map current and future state. The project team also implemented a Failure Modes and Effects Analysis in order to gain trust from clinicians, ensure we had thoroughly thought through all design considerations, and ensure that future processes supported clinicians to safely and effectively deliver care.

As part of this process, NYGH created a team which included representatives from all levels of nursing, pharmacy and clinical informatics. The group started by mapping the current state of their medication administration process. Then they identified a “Target State” by separating needs through the voice of the patient, staff and organization (Figure 4).

![Figure 4](image)

After comparing these needs against the current state through a gap analysis, the group then discussed and documented the future state, including how computerized medication carts and handheld devices could effectively support workflow by documenting medication administration at the patient bedside.

Once the new workflow was established, the Project Team visited organizations who had previously implemented a closed-loop medication administration process. By seeing the systems in action in other facilities, we began to learn how the technology could be used to eliminate medication errors. We gained confidence in the technology, but also became more aware of the importance of system design, clinician engagement, as well as integration of technology into clinical workflow (rather than vice versa).

To accurately develop the future state process, NYGH brought in samples of various computerized medication carts and medication administration devices for simulation and stakeholder feedback. The
organization converted an actual patient room on a nursing unit into a simulation room, allowing nurses
to practice using the different equipment in a realistic setting.

As the team tested the different technologies, they were able to identify potential points of failure in
both the workflow and the technology. Once the team pinpointed and ranked these potential failures,
the team then developed a plan to resolve or mitigate each one. For example, one issue identified was
the inability to display the entire electronic Medication Administration Record (eMAR) on the computer
monitor housed on the medication cart. The size of the monitor forced staff to scroll to view the
complete patient record. This introduced risk if the nurse forgot to scroll across, and inadvertently
missed seeing the complete medication administration history. NYGH responded to the potential failure
by switching to a 22-inch widescreen monitor, which minimized the need to scroll across and decreased
the chance that pending medication administrations would be missed.

Another problem involved how pharmacy dispensed medications to nursing units. Representatives from
pharmacy expressed concern about having nurses swap out medications from the cart. They didn’t want
nurses removing and replacing medications piecemeal, as this could result in dropped medications,
medications inadvertently stored for the wrong patient, and other negative situations. To address
pharmacy concerns, NYGH incorporated a transfer cabinet into its medication administration workflow.
Now, each day at a set time, pharmacy dispenses 24 hours of medications for each patient, which are
stored in the transfer cabinet. Nurses can swap out each patient’s medications, drawer for drawer, at
their convenience. This ensures the right medications are available for administration, limiting the
possibility for error.

In order to implement CLMA with barcode scanning technology, all medications need to be barcoded
and pre-packaged at the unit-dose level. Barcoding of medication is a complicated process that requires
significant pharmacy space, time and effort. Based on NYGH barcode strategy, if the product comes with
its own unit-dose static Universal Product Code (UPC) barcode from the manufacturer, this UPC will be
entered into the medication drug file for barcode scanning. However, if the product does not have its
own static unit-dose UPC barcode, NYGH will utilize various barcoding systems in the inpatient
pharmacy to barcode products. The type of product will determine which barcoding system will be used
to barcode the product. (Figure 5.1)
In 2012, the Institute for Safe Medication Practices Canada (ISMP) and the Canadian Patient Safety Institute (CPSI) released the publication Medication Bar Code System Implementation Planning: A Resource Guide. This resource has strong support from GS1 Canada who advocates for the standard use of Global Trade Identification numbers (GTIN) as a standard for barcoding. The Canadian Society of Hospital Pharmacies (CSHP) has defined their 2015 strategic objectives to include:

- 75% of hospitals will use machine-readable coding to verify medications before dispensing.
- 75% of hospitals will use machine-readable coding to verify all medications before administration to a patient.

These initiatives speak to the challenges faced in Canada in having drug manufacturers adopt GS1 barcoding standards.

Currently only 3.4% of Canadian healthcare organization have implemented closed loop barcoded administration (Figure 5.2) which explains the lack of demand to have manufacturer’s package unit dose medications with standard barcodes.

The combination of national groups advocating for this standard and more Canadian hospitals embarking on closed loop medication administration projects will level set the availability of standardized global unit dose barcoded medication availability which will make it easier to organizations to adopt this best practice to reduce medication errors.
How Health IT Was Utilized

The new NYGH medication administration process utilizes information technology within the eMAR at every step, creating a closed loop. eMAR and CareMobile™ barcode scanning technologies are utilized in all NYGH inpatient units to ensure the eight rights are addressed during medication administration. eMAR is generated by CPOE, and built-in logic in eMAR ensures information scanned from the medication barcode matches the patient medication profile at patient the bedside. If discrepancies are identified, CareMobile™ will issue warnings to the clinicians. Once the medication administration is completed, CareMobile™ also allows clinicians to complete the necessary documentation at the point-of-care. As illustrated in Figure 6, during the medication administration process, clinicians must perform each step sequentially.
New Closed Loop Medication Administration Process

1. Physician enters orders online using CPOE and evidence based order sets
2. Medications populate in the eMAR in real-time
3. Orders are routed to automated dispensing cabinets for cart fill and first dose dispensing
4. Nurse views medications on eMAR and obtains medications that are due for the patient
5. Nurse signs into CareMobile™ using his/her barcoded ID badge
6. Nurse uses CareMobile™ to scan pre-packaged unit-dosed medication(s)
7. Nurse scans patient armband
8. Nurse reviews and resolves any alerts, administers medications to the patient and signs off the administration on CareMobile™

Discrepancies/alerts detected at any of the above stages require clinician intervention in order to proceed to the next stage. Therefore, CLMA technologies have been viewed as the last defense against medication errors at the sharp end of care.
At NYGH’s inpatient pharmacy, barcode scanning is used for dispensing initial/missing/IV fill list doses using Cerner’s WorkFlowMonitor™ module (Figure 7). Each medication order in Cerner’s PharmNet™ solution that has been verified by the pharmacist is assigned a workflow sequence. During the dispensing process, a pharmacy technician launches the WorkFlowMonitor, scans the patient label to pull up the workflow sequence, and then scans the corresponding product barcode. This ensures the correct product is dispensed. It also eliminates the need for a second check by another pharmacy technician, as the dispensed product is validated by the scan.

Legend
- Start/End
- Process
- Decision

New orders received in PharmNet
Pharmacist verifies medication orders
Pharmacy technician launches WorkFlowMonitor
Pharmacy technician scans patient’s label to pull up the workflow sequence
Pharmacy technician scans medication barcode

Is it the correct medication?
Yes
Dispense the scanned medication
No
Ensure to pick the correct medication and reason

Figure 7
Value Derived

CLMA was implemented throughout the organization in phases, and with each implementation phase the clinical process and patient outcomes further improved. From 2010-2015, scanning compliance among the clinical staff grew from 73% to over 95%. The new CLMA process shortened the STAT medication turnaround time by 83%, which means patients are now getting their STAT medications more than 4 hours faster. Additionally, through new reporting capabilities built into the eMAR, NYGH has been able to track more than 11,000 avoided medication errors.

Errors happening during medication administration can be categorized as: dose administered significantly earlier than scheduled time; no corresponding order in patient EMR; wrong dose (higher or lower); wrong drug form; and wrong patient. At NYGH, with the implementation of CLMA technology, medication administration tasks are generated one hour prior to the scheduled administration time based on the patient’s medication order profile. If the medication is scanned prior to this, a “Task not found” alert will be triggered. The same alert will also pop-up if there is no corresponding order found in the patient medication order profile. All above potential errors could lead to serious adverse drug events and cause harm to patients.

The CareMobile Scanning Compliance chart (Figure 8) shows the continued growth in clinical adoption. The periodic drops represent when a new department went live.

Implementation Timeline:
- 2010: All medical & surgical inpatient units
- 2013: Maternal & perioperative units
- 2014: Mental health inpatient units
- 2015: NICU
The previous (pre-eCare) workflow allowed room for errors at multiple stages in the medication process, with the majority occurring when the medication was prescribed or administered (Figure 9). With CLMA, the entire process occurs within the eMAR, which has reduced the risk of errors at each step (Figure 10).

When a clinician scans the medications and scans the patient’s armband, if the two don’t match a “Patient Mismatch” alert is triggered. Figure 11.1 shows the growing number of mismatches identified. As more units went live with CLMA, the number of errors avoided continued to climb. NYGH identified more than **11,000 patient mismatches** from 2010-2015.
Medication scanning at NYGH has become the new standard of practice for medication administration which is supported by the organizational policy; Medication Administration II-226. As a practice standard, compliance with medication scanning is incorporated into annual nursing staff performance evaluations. Compliance data is presented to various levels of leadership in various forms:

- Senior Leadership – QIP Corporate performance dashboard
- Directors – Program level dashboards
- Manager – Monthly unit scanning reports
- Clinical Nurse Educators – Ad hoc reports can be run by unit or nurse variable by time

This top-down and bottom-up accountability model holds every staff member accountable to ensure compliance to CLMA best practice standard.

During implementation while validation of system build for all products was in process, NYGH built an issue reporting tool to make it easy for clinicians to report non-urgent system issues. The issue reporting application resided in the start-up icon section of every device. When launched, it automatically captures a snapshot of the opened screen which includes user details, time stamp and clinical details of the issue being reported (Figure 11.2). This makes it easy for clinicians to report concerns. This tool came in very handy when nurses could not interpret or understand the rationale for medication scan errors. They would simply highlight the medication on the eMAR that they were trying to scan and submit an issue report if they did not understand the alert. These issue reports were automatically routed to the clinical informatics support team. In the report, the informatics resource is presented with all the information required to troubleshoot the scanning concern. The majority of the reported issues were related to education and as a result, the reporting tool served as an education opportunity to teach about scanning alerts and in turn fostered trust in the system as near misses were caught.
NYGH uses this online feedback tool and regular monthly meetings to encourage transparency and interactive communication about nursing and pharmacy concerns related to medication administration; these have helped to improve continuous education and training. With these reports, the informatics team could run auditing tools to see what medications were scanned and the cause of the scanning error. The nurses often thought these scanning errors were “glitches” in the system; however, they were often true medication errors. The immediate explanation of the error in near real time allowed the nurse to understand the error messages and gain confidence in the technology. This not only strengthens organizational processes, but it also bolsters continual staff buy-in and enthusiasm for the technology and workflow.

**Lessons Learned**

NYGH continues to review its medication administration efforts to foster ongoing best practice workflow compliance. For example, one year after the initial Failure Effects Mode Analysis, the organization revisited its processes and technology. Since staff members had lived the workflow and used the equipment for a year, they had a better appreciation of what tweaks were necessary. Based on staff input, the organization added accessories to the medication carts to further streamline medication administration workflow, including a sharps container, garbage basket and medicine cup holder.

In the first few weeks after implementation, scanning compliance was not growing at the desired pace. To boost adoption, NYGH started sending monthly scanning compliance reports to each unit. These reports identified top performers and those who were struggling. Often times, the unit managers posted the reports on a public bulletin board to create a friendly competition within the staff. More importantly, the reports were used to make sure those who were struggling received the necessary training and education. Also, the compliance reports identified drugs that clinicians were having trouble scanning. The medications that continued to have scanning issues were set aside to be re-barcoded.

To further encourage staff adoption and scanning compliance, NYGH included each nurse’s scanning compliance metrics in his or her annual performance review. Nurse managers were holding each nurse
accountable for his or her performance. This incentivized nurses to adopt best practice not only because it would help avoid errors, but also because it would impact their review.

Another challenge impacting the nurses’ workflow was that the CareMobile devices were frequently running out of battery power in the middle of a nursing shift. When the CLMA system was first implemented, the device charging stations were at the nurses’ stations. This forced nurses to return to the nurses’ station each time they needed to charge their device. With nurses moving from room to room, returning to the nurses’ station was an inconvenience. Often times, nurses would fail to charge the device, and the nurse on the following shift would be stuck with a dead device.

Battery usage reports were sent out daily to identify which devices needed to be recharged. This identified the problem, but did not solve it. Six months after implementation, NYGH added charging stations to every work station on wheels (WOWs). This allowed nurses to charge their device as they moved from room to room. Since making the change, low batteries are no longer a problem, and the only reason why battery usage reports are still sent out is to identify devices that require replacement batteries.

**Financial Considerations**

**Initial capital costs**
- *eCare* Project costs: $12.8 million
- Hardware/Infrastructure: $1.1 million
- **Total: $13.9 million**

**On-going operational costs (per year)**
- Software/Hardware: $1.9 million
- IT and CI Staff: $2.7 million
- **5-year total: $23 million**

**Total eCare investment from 2010-2015: $36.9 million**
The Canadian Patient Safety Institute (CPSI) estimates the attributable costs of adverse events range from US$2,162 (CAN$4,028) to AU$11,846 (CAN$12,648). CPSI estimates that medication errors have an attributable cost of US$334 (CAN$402) to AU$525 (CAN$632)\(^6\). Multiplying the average cost of a medication error (CAN$517) by NYGH’s annual number of patient mismatches (11,000) produces a significant cost avoidance. Figure 13 shows the calculated savings for each year.

From 2010-2015, NYGH saved more than **$5.7 million** from avoided patient mismatch errors alone.

NYGH has also prevented other types of medication errors such as wrong dose, wrong administration time and wrong delivery method, but those errors are difficult to track accurately in our electronic health record. For example, a “Task Not Found” alert is triggered under the following circumstances:

- Scanned wrong medication
- Scanned wrong dose
- Scanned time is one hour earlier than the scheduled administration time; this is often valid, as medication administration time may be adjusted accordingly for other clinical interventions
- During emergency situations in which medication(s) need to be administered prior to entering orders in the electronic health record

All of these situations trigger the same “Task Not Found” alert, which in retrospective reporting is not linked to a specific order. Instead, the error links with a user and medication information. Therefore, it

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is difficult to determine whether a given alert represents a true medication administration error, or was due to valid variation in clinical workflow. As a result, any potential savings from medication errors averted from “Task Not Found” alerts are not factored into this cost analysis. If we were able to accurately track all types of medication errors prevented, the potential savings would be significantly higher. Figure 14 shows the number of “Task Not Found” alerts each year.
Figure 14
In addition to reducing costs by preventing medication errors, the eCare project has realized substantial savings by preventing several other common and costly inpatient adverse events. Examples of these cost savings are outlined in our other three case studies. A comprehensive framework of the total eCare return on investment (ROI) is detailed in the Financial Considerations section of our case study that focuses on reduction of preventable inpatient deaths. Please refer to that case study for more details.

Moving forward, North York General Hospital will continue to use eCare to design and iteratively improve IT-enabled, patient centered solutions that achieve the best clinical and financial outcomes for our patients, families, community and health care system. We will also continue to share our lessons learned with other organizations, so that they can achieve similar benefits.