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Medication errors, handoff processes and information quality

A community hospital case study

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Abstract

Purpose – The purpose of this paper is to examine how clinical handoffs affect clinical information quality (IQ) and medication administration quality.

Design/methodology/approach – A case study was conducted in a US hospital. The authors applied a business process management (BPM) perspective to analyze an end-to-end medication administration process and related handoffs, and accounting control theory (ACT) to examine the impact of handoffs on IQ and medication errors.

Findings – The study reveals how handoffs can lead to medication errors (by passing information that is not complete, accurate, timely or valid) and can help reduce errors (by preventing, detecting and correcting information quality flaws or prior clinical mistakes).

Research limitations/implications – The paper reports on one case study on one hospital unit. Future studies can investigate the impact of clinical IQ on patient safety across the multitude of health information technologies (e.g. computerized provider order entry (CPOE), electronic medication administration records (EMAR), and barcode medication administration systems (BCMA)) and approaches to process design and support (e.g. use of clinical pathways and checklists).

Practical implications – The findings can contribute to more successful design, implementation and evaluation of medication administration and other clinical processes, ultimately improving patient safety.

Originality/value – The paper's main contribution is the use of accounting control theory to systematically focus on IQ to evaluate and improve end-to-end medical administration processes.

Keywords Accounting control theory (ACT), Business process management (BPM), Case study, Information quality (IQ), Handoffs, Health care, United States of America

Paper type Case study

Nomenclature

ACT	= accounting control theory	IQ	= information quality
BCMA	= barcode medication administration	MAR	= medication administration record
BPM	= business process management	MO	= Medication order
CPOE	= computerized provider order entry	PA	= physician assistant
CH	= community hospital	PML	= patient medication list
EMAR	= electronic medication administration records	PS	= pharmacy system
ICU	= intensive care unit	SIPOC	= suppliers, inputs, process, outputs, customers

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1. Introduction: medication errors and handoffs

Many studies (Kohn *et al.*, 1999; Barker *et al.*, 2002; Aspden *et al.*, 2007; Landrigan *et al.*, 2010) report that medication errors are common, and contribute to adverse events (patient discomfort or harm). About 400,000 preventable medication-related injuries occur each year in US hospitals (Aspden *et al.*, 2007). To prevent errors, nurses are trained to verify order information (Smith *et al.*, 2008), question a doctor's order if they suspect it contains incorrect information, and attend to the "five rights" (right patient, drug, time, dose, and route of administration) (Cohen and Hilligoss, 2010). However, errors may occur due to miscommunication among clinicians (doctors, nurses, physician assistants (PAs)), between clinicians and patients, and clinicians and pharmacists. About 40 percent of medication errors (20 percent of which cause harm) occur due to inadequate medication reconciliation – the process of obtaining a complete list of a patient's current medications and comparing it to medication orders (MOs) when a patient is admitted to a hospital, transferred within a facility, or discharged (5 Million Lives Campaign, 2008; Barnsteiner, 2008).

Medication reconciliation, ordering, dispensing and administration involve information handoffs. A clinical handoff is "a contemporaneous, interactive process of passing patient-specific information from one caregiver to another for the purpose of ensuring the continuity and safety of patient care" (Wayne *et al.*, 2008). In hospitals, handoffs happen when a patient is admitted, moved from one unit to another or discharged, when clinicians change shifts, attending physicians consult with specialists, MOs are sent to the pharmacy, and at any other time when patient care responsibility shifts between clinicians. Handoffs involve interactions among clinicians, patients and their families (as when the patient is very young, incapacitated, or suffers cognitive impairment), pharmacists, laboratory technicians, and information systems such as the pharmacy system (PS) or the medical record system. Handoffs convey data, information and judgments (hereafter, "information" for simplicity) via speech, paper, and electronically – often by way of more than one medium simultaneously.

This case study examined how handoffs both contribute to and reduce medication errors through their impacts on information quality (IQ) during hospitalization. We interviewed multiple informants in a US Community Hospital (CH). The study is part of a larger multi-year project on healthcare processes and systems which also includes an extensive literature review of handoffs and IQ[1]. As others have shown, important insights can be gained from applying a process management lens to healthcare case studies (Snyder *et al.*, 2005; Helfert, 2009; Cinquini *et al.*, 2009; Bertolini *et al.*, 2011). Here, we combine the process perspective with accounting control theory (ACT) to address several questions:

- What IQ flaws impact medication administration?
- How do ineffective handoffs contribute to medication errors?
- How do effective handoffs detect, prevent or correct medication administration errors?
- How does institutional context affect medication administration IQ and safety?

2. Business process management and ACT

Business process management (BPM), a set of methodologies and tools for "managing, improving and controlling processes" with roots in the total quality management,

six sigma, and process improvement/reengineering traditions (Laguna and Marklund, 2004), has been successfully used to analyze healthcare processes, their improvement (Snyder *et al.*, 2005; Helfert, 2009; Bertolini *et al.*, 2011), and performance (Cinquini *et al.*, 2009). This perspective takes an end-to-end, cross-functional view of an entire clinical process – which is needed to identify the causes of medication errors (Cain and Haque, 2008) and to design potential remedies. Unlike other studies that apply specific process improvement methodologies such as Six Sigma, Lean, and failure modes and effects analysis (FMEA) to analyze single clinical handoffs (Bayley *et al.*, 2005; Mistry *et al.*, 2008; Steinberger *et al.*, 2009), BPM attempts to avoid sub-optimization (McFetridge *et al.*, 2007) by providing a clearer view of a cross-functional care process that involves many handoffs among multiple participants. To support this, BPM provides modeling tools, such as SIPOC diagrams (Conger, 2010) that depict end-to-end process activities and their "suppliers", "inputs", "customers" and "outputs", as well as internal interfaces and external boundaries – all of which are required for meaningful clinical process improvements (Boyer and Pronovost, 2010). BPM analysis also classifies activities as value added, non-value-added, and control, with the aim to eliminate activities that do not add value.

While previous studies applied various aspects of BPM to healthcare processes, they focused primarily on efficiency improvements – modeling, simulating and analyzing processes in detail in order to reduce cost, time and resources (Snyder *et al.*, 2005; Cinquini *et al.*, 2009; Bertolini *et al.*, 2011). However, important, efficiency goals need to be complemented by an understanding of the effectiveness/quality of clinical process outputs; this is especially true in processes such as medication administration, in which low-quality outputs (medication errors) can lead to patient harm. SIPOC analysis is a valuable tool for process effectiveness analysis since it can pinpoint the source of output errors as one of the following: output handoffs, flawed process activities, flawed input handoffs, or flawed input information that is propagated from a previous process step. This in turn enables more focused improvement efforts.

We contend that ACT techniques (ISACA, 1998; Kaplan *et al.*, 1998) can fruitfully augment BPM analysis by revealing specific IQ flaws in a medication administration process and by guiding the selection of appropriate controls. ACT underlies auditors' techniques for analyzing IQ issues in financial transactions and related systems and processes (Walker *et al.*, 2001; Dunn *et al.*, 2003; Kiger and Rose, 2004). It is the transaction focus of ACT that makes it particularly suited to the current study (i.e. we view each step in an end-to-end medication administration process –reconciliation, ordering, dispensing and administering drugs – to be a clinical transaction. Management information systems (MIS) researchers also study IQ, which has developed largely independently from ACT. We next briefly review prior IQ research based in MIS and computer science, then explain our choice of ACT for the current study.

Prior studies (Strong *et al.*, 1997; Redman, 1998), reveal that poor IQ can adversely affect business processes and outcomes and can even have life-and-death consequences, such as when IQ deficiencies contributed to the space shuttle Challenger disaster and the tragic accidental downing of an Iranian Airbus (Fisher and Kingma, 2001). Many IQ studies (reviewed in Madnick *et al.*, 2009) focused on identifying IQ traits. Cappiello *et al.* (2004) examined how deficiencies of information accuracy and currency can propagate in poorly integrated financial information systems. Several studies, viewing information as a "product," applied tools from total quality management (Ballou *et al.*, 1998). Others propose that information that is merely transferred in or across processes can

be automated, whereas information that is transformed (through summarization, translation, or itemization) "would require a closer look at the content of that information when engaging in process improvement" (Berente *et al.*, 2009, p. 138). Many studies have examined how IQ affects decision making. For example, Ahituv *et al.* (1998) reported that under time pressure, experts digest additional/more complete information more effectively than less-experienced people. Another stream of research tested the effectiveness of providing users with meta-data (data that indicates whether information is of high or low quality). For example, Biros *et al.* (2002) report that while warnings about possible false information may lead some users to be more effective at spotting deception, these warnings may produce too many false alarms and thus be ineffective from a cost-benefit perspective. Fisher *et al.* (2003) report that meta-data describing IQ is helpful for managers who lack domain-specific experience but may be unnecessary for expert users, and Lee and Strong (2003/2004) report that knowledge about data (especially knowing-why) is more useful for people in data collection roles and less important for data custodians. Lee (2003/2004) further demonstrates how users' interaction with data is highly context-dependent.

While IQ research in MIS and computer science has addressed a wide range of perspectives and goals, ACT focuses more narrowly on financial transactions and related systems and processes. It is this long-standing and systematic transaction focus, which we find promising as a complement to the end-to-end BPM perspective. Accounting controls aim to ensure that information adheres to the traits of validity (describes an authorized event which actually occurred), accuracy (correctly describes relevant aspects of the event), completeness (a record is captured for every relevant event), and timeliness (available when needed) (AICPA, 1980). Note that while validity is an IQ attribute that is not mentioned in the MIS stream of IQ research, the other three traits are widely used by MIS IQ researchers, employing similar definitions (Lee and Strong, 2003/2004; Nelson *et al.*, 2005). Table I compares examples of trait violations for financial processes and medication administration processes.

3. Research methodology

A case study was conducted at "CH", which offers a full range of medical and surgical care, mental health, and rehabilitation services. The researchers toured a medical/surgical unit, examined various CH documents, and interviewed 16 individuals: chief executive officer, executive vice president, chief operating officer, chief information officer, a project leader in clinical informatics, pharmacy director, a pharmacist, VP of medical affairs, hospitalist program medical director, division of geriatrics chief,

Table I.
Violations of IQ traits in financial and medication administration processes

IQ trait violated	Financial process examples	Medication administration examples
Validity	Record of a false or duplicate invoice or payment to a fictitious recipient	Order for an incompatible or redundant medication
Accuracy	Transaction indicates unit price of \$89 instead of real price of \$98	Incorrectly recorded dosage information (100 mg instead of 10.0 mg)
Completeness	A properly authorized (valid) transaction is not recorded	Drug was administered, but not recorded
Timeliness	Transaction information is not available when needed	Delay in administering a dose of drugs

chief nursing officer (CNO), two other nurse managers (director, outcomes; senior director, risk management), two floor nurses, and a PA. Interviewees described CH's medication administration processes and efforts to improve patient safety. Interviews of 30-60 min in length were recorded and professionally transcribed. The research team also prepared a repository of key documents, including hospital reports and other information provided on the hospital's web site and in news accounts.

The interview transcript segments were coded as follows:

- Factual coding captured descriptive data about interviewees (e.g. background, role), CH and its medication administration policies and procedures.
- Comparative coding classified interview segments into a priori themes identified in prior research (e.g. strategic, regulatory and organizational challenges) and themes related to broader information and process quality issues and medication errors in healthcare.
- Open coding identified new themes (such as types of handoffs and medication administration errors and their outcomes).

Each coding step was performed by different researchers. Factual and comparative coding resulted in classifying 93 percent of the interview segments into 20 themes, while open coding resulted in classifying 100 percent of the interview segments into more than 50 themes. After individual coding, factual, comparative, and open codes were compared across researchers and interviewees and triangulated against information from other sources, such as hospital planning documents and quality reports. Lastly, through a process of interpretation (Stake, 1995) we explored relationships among themes.

To help understand IQ issues in medication administration in the broader context and to show the role of handoffs in medication administration errors, we analyzed the data as follows:

- We identified the main medication administration activities in an end-to-end hospitalization process and organized these into three sub-processes: patient admission, hospitalization, and discharge (Bayley *et al.*, 2005; Carayon *et al.*, 2006).
- We constructed a SIPOC diagram to depict information flows through these activities and identify suppliers and customers of information and resources involved in each activity.
- For each activity we summarized process quality risks (potential for medication errors), identified their sources (input handoff, process or output handoff flaws) and corresponding impacts on the IQ traits of validity, accuracy, completeness and timeliness.
- We identified activities that serve as preventive, detective, or corrective controls.

This approach is similar to other empirical case studies that document and explain healthcare processes (Cinquini *et al.*, 2009; Goh *et al.*, 2011).

4. Case findings

Based on interviews, observations, and examination of hospital documents, we discuss our findings in light of a common clinical scenario involving a patient hospitalized for a planned surgery. Figure 1, a SIPOC diagram, shows the main process activities. While the diagram is linear for simplicity, the scenario can involve multiple iterations for

Input Handoff Supplier ←→ Resource			Output Handoff Resource ←→ Customer	
Supplier (s)	**Input (s)**	**Process Steps [Resource (s)]**	**Output (s)**	**Customer (s)**
		Admission		
Patient	Patient history with meds list	A1. Obtain patient history, prepare chart [Admissions nurse or clerk]	Chart (w. patient history, updated PML)	MD
		Hospitalization		
Patient, MD	Chart, Patient info, Vital signs/symptoms, MD judgment	H1. Create orders [MD].	MO, Other orders	PA
Patient, MD, PA	PML, MO, Formulary, PA judgment	H2. Reconcile PML, formulary, MO [PA]	Reconciled MO (w. current PML, patient info)	Unit secretary *or Nurse*
PA	Reconciled MO	H3. Fax to pharmacy [Unit secretary *or Nurse*, Fax]	Reconciled MO	Pharmacist
Fax, Clinical data repository, *Provider*	Reconciled MO, Formulary, Basic patient info, *Additional patient* info	H4a. Review all;may *requestadditional patient info from provider*; enterreviewed MO into PS [Pharmacist]	Reviewed MO	PS
PS, Pharmacist	Warnings, Pharmacist judgments	H4b. Respond to system generated warnings, resolve issues, create final MO [Pharmacist]	Final MO (PS record)	PS
PS	Final MO	H5a. Send final MO to OMC [PS]	Final MO (OMC record)	OMC
PS	Final MO	H5b. Send printed paper final MO/MAR form to offline nurse cabinet [Printer, Runner]	MO/MAR printout	Nurse cabinet
Nurse	Nurse schedule	H6a Retrieve MO/MAR from nurse cabinet [Nurse]	MO/MAR	Nurse
Nurse, *OMC*	*Nurse ID, Patient ID,* MO/MAR info	H6b. *Enter IDs for OMC comparison and access, compare MO/MAR meds info with OMC display,* remove meds, record withdrawal [Nurse]	Valid meds	Nurse
OMC	OMC sensor data	H6c. Update PS re withdrawn meds [OMC]	Updated PS	PS
Nurse, Patient	MO/MAR info, Valid meds, Patient info	H6d. Verify 5 Rights, administer meds. [Nurse]	Authorization, Meds admin data	Patient, Nurse
Nurse	Meds admin data	H6e. Record meds admin time, dose, other details on MO/MAR form (now MAR) [Nurse]	Updated MAR	Nurse, MD
Outgoing nurse, *Patient*	Treatment info, Patient info	H6f. Bedside reporting at change-of-shift [Outgoing and Incoming nurses]	Treatment info, Patient info	Incoming nurse
		Discharge		
MD	Chart, MAR, MD judgment	D1. Create discharge orders (with MO) [MD]	Discharge orders	Nurse
Nurse	Discharge MO, Other orders or forms	D2. Review discharge orders (with MO) with patient and hand-deliver paper orders and helpful documents to patient [Nurse]	Discharge orders copy, Other documents	Patient
Nurse	Discharge orders	D3. Send discharge orders (with MO) to follow-up provider [Unit secretary]	Discharge orders copy	Follow-up provider

MD: Attending Physician
PS:Pharmacy System
PML: Patient Medication List
MAR: Medication Administration Record

Key:
PA: Physician Assistant
OMC: Online Medications Cabinet
MO:Medication Order
MO/MAR: MO with MAR information; becomes MAR once drugs administered

Figure 1.
SIPOC diagram: end-to-end medication administration process on the medical/surgical unit

verification or clarification, and repetition of steps whenever meds orders change. Interacting processes, such as medical procedures or billing, are not represented.

Before admission the surgeon tells the patient how to prepare for hospitalization. Some meds (e.g. antibiotics) may be started. At admission, a nurse or clerk inquires about allergies, existing medications, prior surgeries and other matters. Responses, along with patient weight and vital signs, are recorded on a patient medication list (PML) (process step A1). The patient and this PML are given to an attending physician, who examines the patient, repeats some questions, and orders meds needed for surgery (Handoff 1, denoted

as H1 in Figure 1). During hospitalization, a record of the patient's care is kept on a paper chart; demographic and tests results data are stored electronically.

The patient, chart, and MOs are handed to a PA for reconciliation (H2). The PA checks what drugs the patient is taking (reviewing the PML), any conflicts with ordered medications, and equivalent drugs in the hospital formulary ("You may take something for your blood pressure that the institution doesn't carry. We have to substitute [. . .] what we carry here, or ask you to bring your own pill"). Errors of completeness (patient fails to report all drugs) or accuracy (patient mistakenly names Xanax instead of Zantac) can occur.

The PA writes reconciled meds orders on a paper form and gives this to a secretary to fax to the pharmacy (H3). This is only an information transfer, not a clinical handoff, since responsibility for the patient's care still resides with a clinician, not with the secretary. The secretary might be distracted (by "taking ten phone calls"), or the fax machine might not work, resulting in errors of both completeness and timelines.

The pharmacist receives the doctor's MO and the PML with the PA's medication reconciliation notes. If the MO is hand-written, legibility affects whether the pharmacist correctly interprets the orders (consistent with other studies; (Jewell and McGiffert, 2009; Reckmann *et al.*, 2009). The pharmacist reviews each order, notes problems (such as missing patient weight, which influences admissible dosage, or an ordered drug which is equivalent to one already on PML), and contacts the provider for resolution ("If the actual order of the medication is wrong, they have to stop and [. . .] call the provider."). He then enters orders into the PS (H4a), reviews and resolves alerts (of potential drug interaction effects, for example), and submits finalized orders (H4b).

A nurse noted that pharmacists sometimes make data-entry errors: "They enter 100 even though she clearly wrote 10." A PA stated: "There have been times when I discontinued a [patient's] medication [. . .] and it wasn't caught by the pharmacy." When an order to discontinue or change a medication occurs, there should be a corresponding system update to discontinue the old order and (if a new dose is issued), issue a new order. Sometimes both records are retained (one order is invalid), sometimes both orders are inadvertently deleted (incomplete), or the wrong order is retained and the new one deleted (invalid). A physician believed pharmacists sometimes ignore PS alerts "Automatic warnings and alerts come up [. . .] so often that they're almost always overridden by the pharmacist (because of) [. . .] alert fatigue." Distractions also reportedly cause pharmacists to make mistakes:

> [. . .] they should be in an uninterruptible area, uncluttered, clean, quiet [. . .] Not paying attention when they sign off is [. . .] pharmacists' [. . .] number one [reason] for making errors; they are distracted. They are required to answer phones [. . .] get up and open doors [. . .].

The PS creates a final MO and sends a message to a computerized medication cabinet on the surgical unit (H5a), authorizing drugs (in unit doses) to be drawn by the nurse assigned to that patient (some drugs are stored in a refrigerator or elsewhere, to ensure tighter control over narcotics and other "high-alert" drugs such as heparin and insulin). The PS also prints a paper MO with prescribed doses and dosage times. This MO form, which has space for recording medication administration steps taken, is hand-delivered to a cabinet mounted adjacent to the patient's room (H5b). This handoff signals that this patient is now the nurse's responsibility. The nurse retrieves the MO form (H6a), withdraws medication and manually records each withdrawal (H6b). Once this happens, the MO becomes a

Medication Administration Record (MAR); for convenience we refer to it as the MO/MAR form. When medications are administered, the nurse records the time (H6e).

Nurses are trained to catch errors, and they expect patients to play a role in error identification (H6d):

> Before you give them their meds, you confirm their name and date of birth by looking at their patient ID band, against [data on MO/MAR]. That's every time, whether you were in there two minutes ago, you have to do it every single time.

> When you get into the room, you've really got to have that double check [. . .] You want to educate the patient [. . .] "Here's what we're going to do" [. . .].

> You tell them [. . .] "I'm giving you 20 milligrams of Lasix." (If) they say, "But I only take 10, I never take 20," now you have to stop, not give them that medication, and go out and call (the doctor). Maybe the doctor wants him to have that higher dose; it's okay, but that can slow it down.

> [. . .] hopefully you will use your judgment; you don't give someone 1000 units of insulin [. . .] We should be the last person in that process to say "That's not quite right." You can question [. . .] If you don't feel comfortable giving that med, you need to call [. . .]".

A nurse recounted a memorable story concerning an inexperienced nurse. The order was to administer nitroglycerine, sublingual (under tongue):

> Nitro is a tiny white tablet, very small. You can fit probably 100 in this little tiny vial. The order said "one dose," but there were many tablets in that one vial [. . .]. The nurse [. . .] God bless her, gave the patient 50 nitro pills under his tongue [. . .] She didn't realize [her big mistake] [. . .] [Now this nurse's shift ends] She doesn't know the poor thing could have crashed and gone into the ICU [. . .] Luckily the patient didn't have any problems. His blood pressure dropped a little [. . .] The next nurse goes in [. . .] to give the patient his nitro and he says, "I only get one? I got a whole bottle before".

By revealing a prior error the patient was an invaluable handoff partner.

Despite signs saying "Quiet Zone," nurses sometimes felt distracted because "we're in the real world. [. . .]" in which interruptions occur ("a phone call, a code, a patient falls, a doctor could ask you to help him with something"). If meds have been drawn but not yet administered because of an interruption, they must be locked in the cabinet outside the patient's room.

When a drug is retrieved from the computerized cabinet, the event is automatically recorded (H6c) and shared with the accounting system for billing. Should a nurse retrieve an incorrect item and realize this before administering it, he should return to the cabinet to "waste" it, triggering a message to adjust the patient's bill – otherwise the bill will be too high and the MAR may also be incorrect. Also, drugs are packaged in unit dosages but orders may be for only parts of a unit. If a nurse misunderstands an order (and does not "waste" the unused portion) the MAR will indicate the patient received the full dose (and the patient might suffer harm). Suppose a doctor orders half a milligram of Dilaudid packaged in one milligram doses:

> [. . .] to give only a half milligram, you have to waste, which requires two nurses. A second nurse has to bioID in [to computerized medication cabinet], and you go through the steps to waste it. That can slow you down. You have to count everything that's left; any narcotic, every single time [. . .]".

A doctor may order new meds or doses, re-starting the process from step H1. Reconciliation (H2) should again take place. When doses change, a PA should record discontinuing the old dosage and list the medication with new dosage on a separate line – although compliance with this rule is not at 100 percent.

Nurses should check that the MO lists the patient's weight and flag illegible orders before they are sent to the pharmacy. The CNO stated: "If you can't read that order, your role is to stop [. . .] and call the provider." Every provider is trained to recognize questionable information and stop the process until verification: pharmacists check doctor's orders, and nurses verify pharmacist's interaction checks against their own chart. On average at CH, nearly 125 orders per day (of about 600 total) need to be verified. "Think of all that work [. . .]!"

Process timeliness (which affects data timeliness) is sometimes sacrificed for the sake of validity, accuracy, or completeness. A nurse commented about the smart medicine cabinet:

> It [. . .] gives you many warnings of allergies of high alert medications like potassium, sound-alike/look-alike meds; be careful. You get a lot of warnings. It can slow you down, but it's good.

Insulin requires two nurses: one signs a form, the other administers it in front of the other nurse "to make sure she gives the correct amount and correct type of insulin. I show her where I drew it from. I show her the vial and the syringe".

Nurse-to-nurse end-of-shift handoffs include a "red lining" procedure (H6f). The nurse:

> [. . .] double checks [prior shift] orders on every patient, to make sure that every order was in fact taken off. [. . .] I check, I initial, and put a red line around the entire order set that says "this is good" [. . .] It's how nurses hand off communication, how we collaborate to make sure the patient got the right care.

Change-of-shift bedside reporting is also done. A nurse explained:

> We report right inside the patient's room [. . .]. During the handoff, we actually go over everything that's going on with the patient. What IVs are hanging? What meds? We do a full thorough review. That's the shift to shift handoff.

Patients may share the same name (common names like "John Smith," or John Smith Jr donating a kidney to John Smith Sr): "I've had three Smiths on the floor at the same time [. . .] We put stickers on the door, the chart, and in the other room: 'Caution: Patient has similar name.'" A physician described a close call involving a clerical error:

> The wrong name was stamped on the order sheet. [. . .] (Orders) are supposed to be pre-stamped with the name of the patient [. . .] In this instance a secretary put the order sheet back in the wrong chart. It was one of the few double rooms, and she put it in the chart of the patient's roommate.

More than half of the time, CH inpatient units are at full capacity. When we visited, more than 20 patients were temporarily bedded in the emergency department. A doctor connected the dots between room assignments, capacity issues, and medication errors:

> We had two Smiths [. . .] across the hall from each other. That's something that might be approached in bed assignment. But when you are boarding people in the hall it's hard to be fussy about where to put your patients [. . .]. That introduces an opportunity for error.

At discharge, flawed reconciliation (D1-D3) was another concern. A nurse said:

> You go home and [. . .] start taking your old blood pressure pill, plus the one we gave you here, because we weren't careful when writing your discharge instructions and reconciling [. . .].

Figure 2 shows these findings. Every stage of the medication administration process is subject to errors and these can occur during the input handoff, the process itself, or the output handoff. If not detected, information errors during admission or early in hospitalization propagate as inputs into later process steps, leading to potentially

Process Steps	Control	Flaw	Risk Description	IQ Impact
			Admission	
A1.		IH	Patient may not report every drug he is currently taking.	C T
		IH, P	Patient reports wrong doses or Admissions Nurse records wrong doses.	A T
		P	Admissions Nurse fails to capture some data about patient history or meds.	C T*
		P, OH	Hospital's patient record is incomplete or incorrect.	A C T
			Hospitalization	
H1.		IH, P	Patient feigns great pain in attempt to get narcotic. MD otherwise fails to capture some data about patient history or meds.	V C T*
H2.	PML - MO reconcile	IH	Patient reports wrong doses or PA or MD record wrong doses. Patient reports wrong drug (e.g., Xanax instead of Zantac).	A A
H3.		P, OH	Unit secretary fails to send reconciled MO to pharmacy, fax error.	C T
H4a, b.	MO check	IH, P	Distracted pharmacist fails to note problems in manually comparing Reconciled MO and other data. Distracted pharmacist works too slowly. Distracted pharmacist fails to enter Reconciled MO into PS. Pharmacist enters Reconciled MO data incorrectly into PS. Pharmacist fails to key in a discontinued med order. (validity: patient will receive doses of a drug no longer ordered; completeness: an order to discontinue is not recorded) Pharmacist ignores automated error alerts.	V A T C T A V C V
H5a.		P, OH	Network crash impedes flow of data to online meds cabinet.	C T
H5b.		P, OH	Printer error, unreliable runner fails to deliver MO to correct nurse cabinet.	C T
H6a		IH, P	Busy nurse forgets MO/MAR form retrieval.	C T
H6b.	Valid meds	IH, P	Busy Nurses queue up at online meds cabinet. Packaging confusion (e.g., light blue HepLock versus dark blue Heparin).	V
H6c.		P, OH	Withdrawal from medication cabinet or refrigerator not manually recorded. Nurse fails to "waste" unneeded/incorrect meds. (an invalid record also will cause a billing inaccuracy)	C T V
H6d.	5 Rights	P	Nurse fails to check 5 Rights.	V
H6e.		P, OH	Nurse fails to record administration information. Nurse records administration information with delay.	C T C T
H6f.	MO/MAR	P, OH	Miscommunication at shift change results in over-or under-dosing a patient. Miscommunication at shift change results in confusion regarding patient identity.	V C T A
			Discharge	
D1		P	MD fails to note conflict in discharge MO, patient history, allergies, existing meds.	V
D2	Discharge MO	P, OH	Nurse fails to verify Patient understands dosage amounts, times, other instructions. Nurse fails to provide Patient with paper discharge orders (including MO).	V C
D3		P, OH,	Secretary fails to fax discharge summary, fax fails	V

Notes: Flaw occurrence: IH – input handoff, OH – output handoff, P – process; information quality attributes: V – validity, A – accuracy, C – completeness, T – timelines

Figure 2.
Medication administration process controls, risks and impact on IQ

harmful medication administration errors (H6d). Fortunately, some detective and corrective controls are in place. For example, medication reconciliation (H2) attempts to catch completeness errors made in admission (A1) or prescribing (H1), and the five rights check, performed before administrating meds, attempts to catch accuracy, completeness or validity errors related to patient and medication information.

5. Discussion: findings and contributions

In this paper, we analyzed medication administration through the combined lenses of BPM and ACT. By taking an end-to-end information-processing view, our case study clarifies how handoffs both lead to medication errors (by passing incomplete, inaccurate, untimely or invalid information) and help reduce them (by detecting and correcting flawed information or prior clinical mistakes).

Our analysis identifies mechanisms through which information is distorted or lost during handoffs, along with the likely impact on subsequent medication administration. Unclear oral communication, misspelled orders and illegible handwriting contribute to problems of validity (e.g. wrong drug, wrong patient) or accuracy (e.g. wrong dosage, wrong route of administration). Distractions, facility limitations (patients bedded in hallways), room assignments (patients with similar names), and limitations of paper-based or manual processes threaten the validity, accuracy, completeness and timeliness of clinical information.

Our analysis also shows how hospital personnel can identify specific contexts that require increased vigilance, locate vulnerable process activities, and institute stronger controls. We identify distractions as contributors to flawed information – even when inputs are perfect, errors can nevertheless occur. It has been suggested (Patterson *et al.*, 2004; Behara *et al.*, 2005; Friesen *et al.*, 2008) that distractions can be prevented by redesigning workspaces and redefining roles and responsibilities. Yet, interviewees indicated that eliminating all distractions is not feasible. Thus, compensatory detective and corrective controls are needed to ensure patient safety, since distractions cannot be completely eliminated.

In addition, our study confirms that handoffs help reduce patient harm by detecting previously committed informational or process errors. During a handoff a pharmacist, nurse, family member, the patient or the PS might notice that an ordered medication could be harmful. By questioning information conveyed in a handoff, participants help detect mistakes (either of omission or commission) and prevent their further propagation.

6. Conclusions, limitations and suggestions

Our field-based case study closely examined clinical handoff processes, which were previously implicated in adverse drug events. Our main contribution lies in our use of ACT to systematically focus on IQ in the context of end-to-end medication administration processes. Our findings suggest that clinical processes and supporting IT systems can benefit from ACT, by virtue of its focus on four key information qualities along with error prevention, detection and correction.

ACT-guided IQ analysis should lead to more successful design and implementation of clinical processes and systems. Controls that prevent, detect, and correct IQ issues can be incorporated into standardized clinical pathways and checklists and into computerized provider order entry (CPOE), electronic medication administration record (EMAR) and barcode medication administration (BCMA) systems. One of the primary objectives of

systems designers should be to encourage clinicians to think and be aware of potential breakdowns in an end-to-end information flow, as well as of the valuable controls embedded in otherwise cumbersome paper-based processes. Our findings can also support development of ontologies for integrated healthcare systems (Kataria *et al.*, 2008).

After implementation of healthcare IT, end-to-end clinical processes can again be evaluated using ACT to identify control strengths and deficiencies that threaten IQ. While automation is generally found to be effective in reducing medical errors (Aron *et al.*, 2011), ACT can show if handoffs automation may inadvertently contribute to the propagation of incorrect information from previous care activities such as flawed medication reconciliation (Reckmann *et al.*, 2009). The translation of information during handoffs within multidisciplinary care teams using IT systems (Oborn *et al.*, 2011) and changes in clinical routines during and after implementation of new IT systems (Goh *et al.*, 2011) can also be evaluated using the approach described here. Such pre- and post-implementation analyses (Yusof *et al.*, 2008), and comparisons of automated systems with low-tech or hybrid approaches can help hospital administrators identify best practices and support improvement efforts.

ACT analysis can also inform training programs, which should focus on how IQ errors propagate and teach nurses and junior doctors to be vigilant in detecting and reporting errors, including those made by more senior clinicians. When healthcare IT solutions are implemented, training programs should stress mindful use of the automated systems and a full understanding of the end-to-end medication administration process, from admission to discharge. The process and IQ analysis tools used in this paper can also be incorporated in quality management training to enhance the error-reducing performance of the automated systems (Aron *et al.*, 2011).

We conducted a single field-based case study at one point in time on one CH medical/surgical unit. A key strength of this methodology is that we closely examined medication administration processes from multiple conceptual angles and informant viewpoints, similar to other health care studies that relied on detailed interview data (Helfert, 2009) and case studies investigating a single department or organization (Snyder *et al.*, 2005; Cinquini *et al.*, 2009). A case study paints a richer picture than can be obtained via other methodologies. The benefits of this approach are "embedded in the process of development of the model" (Cinquini *et al.*, 2009). Through analytic interpretation, we "connected the dots," seeing for example how CH's constrained capacity affects medication administration. However, we were not able to determine to what extent specific IQ lapses are associated with specific types of medication errors (such as wrong dosage versus wrong route of administration). Such questions could be addressed through a large-sample study. We also did not fully examine all aspects of CH's work culture. Ethnographic studies could explore culture's impact on handoff quality and patient safety (Boyer and Pronovost, 2010).

Beyond healthcare, other domains can benefit from combining the process management perspective with ACT. For example, research on global software development reveals handoff challenges in "follow-the-sun" projects (when programmers in India hand off tasks to US workers just starting their workday). Few companies manage these handoffs well (Carmel *et al.*, 2010), which suggests that new approaches are needed to closely analyze handoffs and IQ in the end-to-end development process. Our approach could also be fruitfully applied to analyze how handoffs affect information and process quality in supply chain management, global product development, and other business processes that involve handoffs among multiple participants.

Note

1. An extensive literature review is included in a separate paper, due to this journal's 6,000 word limit for submission.

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