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Resilience and precarious success

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ABSTRACT

This paper presents an empirical case study to illustrate, corroborate, and perhaps extend some key generalizations about resilient performance in complex adaptive systems. The setting is a pediatric hematology/oncology pharmacy, a complex system embedded in the larger complex of the hospital, which provides chemotherapy and other high risk medications to children with cancer, sickle cell disease and autoimmune disorders. Recently the demands placed on this system have dramatically intensified while the resources allocated to the system have remained static. We describe the adaptations of this system in response to this additional stress. In addition, we discuss the risks associated with miscalibration about the system's adaptive capacity, and the tradeoff between the need to invest in adaptive capacity (to sustain performance when the system is stressed) versus the need to invest in efficient production (to sustain performance under normal circumstances and economic pressures).

1. Introduction

Resilient systems may drift too closely to the boundary of failure [1] when the success of adaptations to external or internal challenges masks a loss of adaptive capacity [2,3]. This has been described as the "tragedy of adaptability" [4], in which a system adapts to a stressor, but where the fluency and success of its adaptations belie the difficulties involved, and obscure how close the system is to catastrophic failure [5] We describe a case in which a system's adaptive capacity is gradually consumed, and where the success of its adaptations is misinterpreted, leading the system to operate in a riskier state than its managers would knowingly choose. Without better recognition of the loss of capacity for adaptation, the addition of more resources or a restructuring of the system demands, the system is likely to fail, though the time frame in which this will occur is not predictable.

The case illustrates how actors in a field of practice express resilience by drawing on deep domain knowledge, and how this effort can become invisible to managers and leaders through habituation and a myopic focus on the wrong metrics. Thus resilient success can paradoxically lead to miscalibration, brittleness, and the risk of catastrophic failure. The case demonstrates both how individuals enact resilience, and how these resilient behaviors can mask the loss of adaptive capacity and so lead to drift into failure, codependency, and entrapment [6–8].

2. Case study

Following a minor medication error in a pediatric hematology/oncology pharmacy, the primary pharmacist requested we observe "work as performed" to better understand the threats to the safety of its work. Though the pharmacy has not suffered a serious adverse drug event in recent years, it became clear during the observation that the increasing demands on the system had negatively affected the process of preparing chemotherapy and substantially eroded its capacity to adapt. The system's adaptations to marked changes in work had principally involved the individual pharmacist's response to these demands. The success of this individual's adaptations "… makes dysfunctional work systems and practices appear to be performing better than they actually are", [3] leading the system to operate at levels of risk beyond that which leaders would explicitly accept [9].

2.1. Current work and resources

The observation of the pharmacy occurred for a full day in January 2014 and was followed by several short interviews to clarify observations and pursue further questions. During the observation, the observer asked questions and requested explanation as well as observing the work of the pharmacist.

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A pediatric hematology oncology (HO) pharmacy is a complex microsystem. At baseline, preparation of pediatric chemotherapy is a more complicated and more hazardous process than preparation of adult chemotherapy. The work is intensive and requires precise calculations, measurement and mixing of substances that are essentially poisons. Medications are customized for each patient, and dosing is calculated based on the patient's weight or body surface area (a changing metric in pediatric patients). Drugs must be diluted and mixed for a specific weight rather than using standard dilutions (as in adults). The pharmacist works with 300–400 pediatric chemotherapy protocols as well as protocols that are individually developed for patients with rare conditions. Individualized protocols may be developed based on published research articles.

The pharmacist receives paper orders with varying amounts of lead time before the medication is due (days to hours). The pharmacist must review the orders, assure that they match the patient's protocol, check the orders against previous doses, recalculate the body surface area (BSA) and dosing, reconcile any inconsistencies (for example changes in dosing due to changes in renal function) and transcribe the orders into the computer.

Much of this work is performed "just in time" due to scheduling and the instability of various medications. This means that some chemotherapy can only be mixed after the results of the day's laboratory tests are received and the patient is cleared to receive chemotherapy. Some agents are so unstable they can only be mixed minutes before administration. The pharmacist must also respond to multiple ad hoc requests and assist with patients who become acutely unstable on the inpatient unit.

Current staffing in the HO pharmacy is very limited, with a patient to pharmacist ratio over 3 times greater than comparable pediatric hospital pharmacies. While this level of staffing is low compared to a number of other pediatric HO pharmacies, it is likely that there are HO pharmacies with similar staff limitations. More importantly, pediatric HO pharmacies, for the most part, are subject to the same economic pressures. There is one expert chemotherapy pharmacist and two experienced pharmacy technicians. (Only one pharmacy technician works at a time). Pharmacists and technicians from the main hospital pharmacy are not as experienced with chemotherapy as the regular HO staff. Currently the HO pharmacy is open Monday through Friday from 0800–1630, so chemotherapy is supplied on weekends by the on call pharmacist. The chemotherapy pharmacist works every third weekend, but then is required to take a day off the week before and the week following the weekend.

One example of the special skills of the HO pharmacist is that when he had a day off (due to working the weekend), he received 10 phone calls and was asked to come in to assist those covering the HO pharmacy. Three pharmacists were required to complete the work that the chemotherapy pharmacist usually completes himself.

Despite recent renovation, the physical environment requires a good deal of wasted motion due to a smaller size hood in the chemotherapy mixing room, limiting the ability to place a second diluent dispenser in the chemotherapy mixing hood. In addition it is difficult for pharmacist and pharmacist technician to communicate when located in separate rooms as doors separate them and there is no intercom.

The pharmacist has developed ways to assess patient conditions and changing needs as well as anticipating and monitoring the work; particularly where the team is in the multi-step processes of chemotherapy preparation and dispensing. For example, the renovation plans had called for replacement of a Dutch door with a closed door between the pharmacy and the nursing station. The pharmacist resisted this because he is able to "hear" about patients with the upper half of the door open. For example, by monitoring nursing conversation, he learns which patient has developed a fever (possibly representing a life-threatening infection for an oncology patient) and will need antibiotics emergently. Nurses also come in and out of the pharmacy frequently to share information. (This also represents a source of stress on the system in terms of multiple interruptions for ad hoc requests).

The pharmacist keeps the computer in all three rooms of the HO pharmacy open to a screen showing patients checking into clinic. He knows that he will need to wait for laboratory results on some patients, but, anticipating a future bottleneck, he can prepare the correct volume of diluent when the patient arrives and wait to add the more expensive and less stable chemotherapy agent. For patients who do not need lab results prior to chemotherapy, their arrival is a signal to begin preparing their medication.

In performing high risk work, the pharmacist and technician have identified means to anticipate, monitor and confirm the correctness of their work. They use visible artefacts to mark the points in medication preparation they have reached. For example, bags containing diluents only are capped with blue foil; when medication is added, the bags are capped with green foil; biologic infusions are capped with silver foil.

High risk medications for example intrathecal medications (delivered into the spinal canal in order to reach the central nervous system) are placed on a designated shelf in the rear of the pharmacy. Nurses have learned not to remove medications from this shelf without checking with the pharmacist. The pharmacist personally hands off these medications and nurses must sign for them.

The pharmacist places medication labels only on actual syringes or IV bags containing chemotherapy, not on the outside "hazard bag". The pharmacist wants the nurse to be holding the syringe when verifying medication, not looking at the outside hazard bag. This provides an additional opportunity for the nurse to confirm that the physical characteristics of the medication are consistent with the medication label.

Pharmacist and technician use visual cues (in addition to other checks) to double check medications. For example, the drug etoposide has a "thick, and ropy" texture when injected into the diluent bag. Only a few drugs look like that, and they are yellow or clear and "not ropy". All competed chemotherapy administration bags are weighed and verified against standard weight for the volume; the bags must be within 5% of the standard.

Finally, even after chemotherapy is delivered, the pharmacist continues to verify the process. When inpatient chemotherapy administration is completed, the pharmacist reviews the medication administration record (MAR) to assure that all doses required by the protocol were administered.

The pharmacist is interested in learning from even small errors. (Recall that the pharmacist was the person who requested an observation of the HO pharmacy following a relatively minor event.) He also tries to share learning with covering pharmacists. For example, he has created a reference binder for covering pharmacists that includes special information: drugs that precipitate if drawn up in one ml syringes require special syringes; or certain other medications that require silicon free tubing and syringes; and so on. In addition, the clinical hematology oncology team (including nursing) huddles at 1545 each day and all near misses and "small errors" are reviewed in at that time.

The responses of the pharmacist to the change in workload can be categorized as individual responses (first order problem solving) as well as second order problem solving in terms of creating a standard approach and standard processes for covering pharmacists. In terms of second order problem solving, the pharmacist has attempted to develop standard work instructions for covering pharmacists, but the work instructions change frequently so are often outdated before they are completed.

2.2. Changes in work that have changed the demands on the system

Reimbursement for chemotherapy has changed. This has resulted in shifting more chemotherapy and more complicated chemotherapy to the outpatient setting. Previously outpatient chemotherapy would consist of 1–2 drug infusions (and intravenous hydration). Now, outpatient chemotherapy often includes 3–5 medication infusions. In addition, inpatients receiving chemotherapy have their chemotherapy administration shifted three hours earlier each day that they are hospitalized. The goal is to discharge patients one midnight earlier (thus "saving" a 24 h bed charge).

Inpatient chemotherapy is independently checked by 2 pharmacists. Outpatient chemotherapy is checked by one pharmacist (because in the past it was less complicated), but now outpatient chemotherapy is as complicated as inpatient. Inpatient chemotherapy has a six independent double check process; there are fewer checks for outpatient chemotherapy. Another stress on the system is an increased need for specially compounded oral medications. Oral compounding was required for approximately 100 doses per month in 2010–2011. This has grown to approximately 400 doses per month. Changes in management of sickle cell patients have resulted in many more patients receiving daily hydroxyurea, a medication that requires 4 h to prepare due to a long "stirring period". Previously, patients received a month's supply of the medication with oral syringes to draw up a daily dose, but in order to minimize family members' exposure to chemotherapy agents; these are now dispensed in 30 single dose syringes.

There are additional changes in work anticipated this year that will require increased effort from the pharmacist including:

- Implementing the chemotherapy module of the electronic health record system.
- The oncology department is applying for cellular therapy accreditation.
- There is an audit due by the body that oversees pediatric oncology protocols.
- Outpatient infusion hours will be extended two days per week. (The outpatient infusion center administers biologics, immunosuppressive therapy, etc; though these are not chemotherapy, this work also falls under the HO pharmacy).
- Other high risk medications (previously prepared in the main pharmacy) will be added to the HO pharmacy work load this year. These include: tacrolimus, cyclosporine, lymphocyte immune globulin and mycophenolate.
- Development of a new rapid pre-hydration for chemotherapy to allow patients to start chemotherapy earlier on the day of admission.
- Pharmacy residents will be training for 3–4 days during their rotation in hematology/oncology.
- Processing investigational medications for sickle cell (losartan) and possible phase 1 oncology studies.
- Developing annual chemotherapy safety training for physicians, pharmacists, and technicians.

The absolute number of demands has increased, and the time available to complete critical processes is compressed and shifted earlier in the day. These changes as well as the nature of chemotherapy administration itself – the dependence of administration on acceptable same day lab results and the instability of many chemotherapy agents – combine to increase the demands on HO pharmacy and staff. The cumulative effect of these changes is to decrease the margin or "slack" available. The buffer that allows the team to respond to just in time demands and ad hoc requests is substantially lessened or even eliminated. In this environment, it is predictable that there will be multiple ad hoc and just in time demands, so maintaining buffering capacity or slack is critically important.

In addition, as a result of limited resources and changes in the workload, activities that contribute to an overall shared mental model and situation awareness are reduced or eliminated. The pharmacist previously attended weekly intake rounds "religiously". Patients with new diagnoses and patients who have relapsed and their treatment plans are discussed during intake rounds. For example, a patient with a new diagnosis of acute myeloblastic leukemia will require intrathecal medication, (medication delivered into the spinal canal-a very high risk and labor intensive type of medication to prepare) even before the final pathology is known. Previously, the pharmacist would obtain that information during Monday's intake rounds. Another example is the patient who relapsed over the weekend would be changed to different protocol in preparation for a bone marrow transplant. Now the pharmacist is "lucky" to get there once a month and he is unable to attend tumor board at all.

3. Adaptive performance

The responses of the pharmacist to the change in workload can be categorized as individual responses (first order problem solving) as well as second order problem solving in terms of creating a standard approach and standard processes for covering pharmacists. In terms of second order problem solving, the pharmacist has attempted to develop standard work instructions for covering pharmacists, but the work instructions change frequently so are often outdated before they are completed.

In their study of the remarkable performance of a power distribution center during the California electricity crisis of 2000–01, Schulman and Roe observed four performance modes that were used depending on the degree of instability and available resources: just in time; just in case; just for now and just this way [10,11] (see Fig. 1). In Sections 3.1 and 3.2, we describe examples of adaptive performance utilized by the pharmacist in this system according to this model. A complete description of the observations is available in the appendix.

3.1. Just in case performance

In view of the increased workload and time compression in which to accomplish the workload, the pharmacist has developed several strategies by which he anticipates the intervals of heavier demand and shifts non-time sensitive work to intervals of when there is lower demand. These intervals are associated with higher human resources and lower instability.

When the pharmacist anticipates a heavy chemotherapy schedule for the following day, he will mix cheap and stable drugs a

		System Instability	
		High	*Low*
Network Option Variety	*High*	Just-in-time performance	Just-in-case performance
	Low	Just-for-now performance	Just-this-way performance

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Fig. 1. Adaptive performance modes (used with permission).

day ahead of time. This provides more time (buffer) the following day to mix the expensive and unstable drugs. He advises covering pharmacists to do this as well because it is safer to have that time buffer, but there is resistance to doing that among other pharmacists. It is not clear exactly why they resist, but the HO pharmacist theorizes that it may relate to concern of "wasting" medication or that it is not a recognized standard procedure. This workaround might be thought of as transferring the buffering resource (time) that is not needed currently to another future state where it is more likely to be needed. There is also the risk of waste as the premixed drug may not be needed when it is anticipated. However, the pharmacist restricts this strategy to cheap and stable drugs.

The pharmacist anticipates next steps, even when he has not received the physician's orders for these. For example, when one patient's chemotherapy was unexpectedly moved up three hours, the pharmacist anticipated that the second phase of this regimen would be needed earlier as well, though he had not received orders for the second phase.

When the pharmacist is off, or has the weekend off, he creates a list of the patients needing chemotherapy, the chemotherapy that is due, when it should be mixed, what to look out for and when it should be delivered. This effort creates some slack for the covering pharmacist, increasing the time and energy available for these tasks.

In essence, the chemotherapy pharmacy team is attempting to reestablish some margin or buffer of safety in order to provide enough time to deal with the urgent and just in time requests that predictably occur on a daily basis. This might be thought of as an attempt to move some of the work that would otherwise occur in a just for now performance mode to a just in case performance mode.

3.2. *Just in time and just for now performance.*

The pharmacist and pharmacy technician plan their day according to the scheduled patients, knowledge of chemotherapy protocols, specialized knowledge of medications, lab results that are required prior to administration and knowing "how long things take". At the beginning of the day there is foreknowledge concerning the scheduled patients, the conditions that must be met in order to prepare chemotherapy (including necessary lab results) and the limited time constraints to accomplish this. As described previously, the available resources (i.e.: time) have become more limited as a result of the changes in work. This information with incomplete knowledge of demands and the often simultaneous timing of multiple demands creates a need to shift from just in time to just for now performance. The shift to just for now performance is compounded and further necessitated by the multiple stat and ad hoc requests. In one two hour interval these included:

- Changing an order to dye free acetaminophen.
- A new immunoglobulin infusion for a patient with worsening symptoms.
- Two new hydroxyurea orders. (This is the oral formulation that requires 4 h to prepare).
- A patient coming in 3 days earlier than scheduled and needing an infusion that afternoon rather than 3 days later.
- A new dose of tacrolimus

Many of these requests are delivered verbally, sometimes accompanied by yellow "sticky notes". In addition, if a patient becomes unstable on the floor, the pharmacist must leave the pharmacy to assist with the acute management of the unstable patient. This results in the scheduled activities of the pharmacy coming to a halt. These additional demands on the system and the reality that they can halt the work of the HO pharmacy speak to the increasing instability of the system. Schulman and Roe have described the just for now performance mode as "firefighting" and from the "standpoint of reliability,…untenable" [10]; it also fits the "scrambled" performance mode described by Hollnagel [12]. The pharmacist is concerned that this has become the normal way of operating.

4. Discussion

Human resources are extremely limited in this system. There is a predictably high number of just in time and ad hoc requests. The demands on the staff of the HO pharmacy have intensified in response to a number of factors, many of which are related to reimbursement and economic pressures. This aligns with one of the laws of cognitive work, the *Law of Stretched Systems* [13], that because of resource and performance pressures, we tend to take the benefits of change in the form of increased productivity and efficiency rather than in the form of a more resilient, robust and therefore safer system.

In the case of the HO pharmacy, it is not new technology which is stretching the system, but rather the economic pressures and reimbursement changes for chemotherapy administration, which have placed substantial stress on the system. The pharmacist and pharmacy technicians have employed a significant number of resilient adaptations, and it appears that they are close to (or perhaps already have) exhausted their capacity to adapt to further increases in demands.

In part due to the success of these adaptations, there has not been a serious adverse event in this pharmacy for some time. This gives the illusion that the system is functioning well and that there is no increased risk resulting from the increased demands on the system. In effect, individual resilient behaviors have masked loss of adaptive capacity in the system, as predicted by the *Law of Fluency*: well adapted cognitive work occurs with a facility that belies the difficulty of the demands resolved and the dilemmas balanced [14]. The risk, of course, is that the adaptive behaviors of individuals may be unrecognized by the organization's leaders, who become progressively miscalibrated. In the absence of a deep focus on the front line worker and the everyday "work" of the system, these extraordinary adaptive behaviors also obscure any idea of where the system is functioning relative to the boundary of acceptable performance [15] All compensatory behaviors have a finite limit; when these limits are approached, the system becomes brittle, and will begin to develop characteristic patterns of decompensation: falling behind the tempo of operations (challenges grow faster than they can be met); working at cross purposes (changes introduced at one level (e.g., to improve economic performance)) surface as unintended consequences at another; getting stuck in out-moded and dysfunctional behaviors [5]. These are indicators of impending failure, either gradually or suddenly. [16].

It might be argued that until now, the HO pharmacist and the HO system has demonstrated *graceful extensibility*. Woods has defined graceful extensibility as, "A positive capability to stretch near and beyond boundaries when surprise occurs…in other words, graceful extensibility is the ability to continue to perform, even during periods of disruption"[17]. Graceful extensibility speaks to the positive adaptive capacity and behaviors that exists within a system that experiences unanticipated stress, or opportunity [18]. It may be considered the partner of "graceful degradation" which refers to the ability to direct the failure trajectory into less costly and more recoverable pathways.

In contrast to the resilient compensatory behaviors of frontline providers, economic and production pressures are very visible to

administrators. Though most high risk organizations have safety as a priority, the organizations "do not exist to be safe. They exist to deliver a service or a product" [6].

Most organizations, in fact, have multiple goals and the pressure to achieve multiple goals simultaneously leads to goal conflicts for those working in the organization. The absence of serious failures, coupled with the invisibility of the effort required to maintain performance, falsely confirms the "success of current safety strategies" [6]. Further, it is important to remember that conflicting organizational goals are transmitted through the organizational structure. Individual managers and administrators are in fact at the "sharp end" of the system relative to organizational leadership. This speaks to the robust yet fragile or *optimality-brittleness tradeoff*. Increasing production demands while maintaining the same resources optimizes efficiency, but lessens adaptive capacity [19,20].

An alternative way to consider this is that "fundamental or chronic goals (such as safety or equity) tend to be sacrificed with increasing pressure to achieve acute goals (faster, better, and cheaper)" [20]. In addition, managers who may have developed a sensitivity to operations and a preoccupation with failure are still constrained by the macrosystem's infrastructure and the culture of the parent organization. Given that a particular microsystem appears to be functioning safely, it is unlikely that additional resources will be directed to the microsystem. In fact, this means that increasingly scarce resources (time, personnel) will continue to be stretched with an associated loss of adaptive capacity in pursuit of the overarching acute goal.

There are signals that this system has reached the limit of its ability to respond to increased demands. The HO pharmacist states he feels that the work is becoming fragmented. As a result of the changes in the workload, one pharmacist will check work through the first half of preparations, but a second covering pharmacist completes the check. No one person has the big picture. When a pharmacy technician or pharmacist is ill or takes a day off, the system becomes very inefficient and potentially riskier for patients. In some cases it almost comes to a standstill. The example of the pharmacist receiving 10 phone calls on his day off to answer questions and to prioritize work for the three covering pharmacists illustrates this. In the current state in the HO pharmacy could be described as operating in the marginal or compensation zone [16]. The system, seems to be drifting towards failure and there is some evidence that decompensation is already occurring. The description of this HO pharmacy reflects that challenges grow and cascade faster than responses can be decided on and deployed. More specifically, for much of the work performed, the pharmacist relates that there is difficulty catching up or meeting demands in a timely fashion. This describes a specific pattern of decompensation: *falling behind the tempo of operations* [21]. Though this pattern is often used relative to surges in acute care setting, as mentioned previously, this has become the usual pattern for this HO pharmacy.

Other examples of maladaptation in this system are consistent with *getting stuck in outdated behaviors.* [5]. The current model and resources worked in this HO pharmacy previously, albeit this work is risky by nature. The work demands have changed but the way in which the work is performed has not changed; it continues as before although at a more frenetic pace. Tactics and strategies have not evolved (nor even been scrutinized) to match the new challenges to the system.

The HO pharmacist and pharmacy technicians always feels "on the edge" They often feel overwhelmed when a heavy workload becomes heavier with nurses and physicians coming into pharmacy with multiple ad hoc changes. They are just trying to "get to 4:30 pm without hurting anyone". The pharmacist states that he has entered an entire order set on wrong patient when overwhelmed. He caught it, but then had to reenter on correct patient. The reliance on individual resilience to fill the adaptive shortfalls of the system are clearly exacting a toll on the individuals working in this system. They are aware of this and it is clear that they are personally overwhelmed by this stress.

This feeling of being overwhelmed and on the edge is especially relevant and concerning given the Eric Cropp case. In 2006, Eric Cropp, a chemotherapy pharmacist at an Ohio children's hospital approved an infusion that had been mixed incorrectly. The patient subsequently died. In 2009, Eric Cropp was convicted of manslaughter and served 6 months in prison [22,23]. The pharmacy on the day of this error was overwhelmed and short-staffed. The pharmacy staff in the current description is acutely aware of this case. Given the current state of the system and the challenges faced by the individuals in the system, it is likely that an individually resilient decision for the pharmacy staff would be to leave the organization. Of course this decision would further increase the "brittleness" of the existing system since the pharmacist is the source of much of its adaptive capacity.

5. Conclusion: is there a way forward?

The case described represents a case of both graceful extensibility and a "tragedy of adaptability". The workload of the pharmacy described has intensified and corresponding changes in resources and structure of the pharmacy have not been developed. The result is that the system has come to rely on and survive on the adaptability of the individual(s) working at maximum capacity every day. This leaves no margin to respond to unusual demands; adaptive capacity is exhausted. The likely result is that individuals working in the system become frustrated and burn out, while the "degradation of the system's functioning is not apparent to organizational leaders" [24]. It is possible that administrators' are focused on very distal outcome measures and that they lack understanding of the dynamic resilient strategies employed by frontline providers to achieve these outcomes. Organizations that focus only on distal outcomes, or fail to search for symptoms of breakdown, risk surprise and catastrophic failure when compensatory measures fail [25]. The idea that these activities are not evident to administrators underscores the need for administrators to develop a deeper understanding of frontline processes and system risk. Presently, there is a miscalibration by the leadership both of the adaptive capacity of the system and the individuals working in the system. This likely reflects an underestimate of the challenges and demands on the system as well as an overestimate the adaptive capacity (the graceful extensibility) of the system and the individuals in the system [26]. This miscalibration also contributes to maladaptation as an inaccurate understanding of how adaptive capacity is appropriate to the demands on the system also results in retention of outdated models of the system and the work performed in the system. Paradoxically the Law of Fluency may hinder learning that might otherwise occur at this point.

A slightly different but related explanation is invoked by the fallacy of centrality. This concept, first described by Ron Westrum, posits that managers in central positions (of authority) presume they would know if something important were happening, and so if they are not aware of anything going on, then nothing important is happening [27].

Given what is known about the system, are there proactive strategies that would enable the system and the individuals to regain some capacity for maneuver?. In order to accomplish this, changes need to occur relative to how and with whom information is shared as well as a basic examination of the work and how the work is structured and accomplished in the system. There is a

need to move beyond the current way of doing things. However in order to do this successfully, there is a need to critically examine the "work" of the HO pharmacy: the demands, the structure and the scope of this work. In some ways the system continues to work to plan, but the plan is outdated. There is a need to evaluate both the new conditions and the suitability of the plan for those new conditions.

The pharmacist has perhaps taken the first step in requesting an observation of how work is performed in the HO pharmacy. The content of this observation and the description of the adaptive behaviors of the HO staff has been shared with hospital administration. Though it seems that the direct supervisor of the HO pharmacist has some understanding of the challenges in this system, the supervisor is also constrained by economics and budgets. The description of the system and the risks to the system provide a more realistic view of capacity and demands than what was previously understood, and particularly that an increasing level of effort is being required in order to maintain control. This observation represents a first step towards surfacing the extraordinary efforts of the HO pharmacist and the limits to which the system is currently stretched. This should trigger an extensive evaluation of the work and how it might be restructured to better align with the new demands of it.

If indeed there is recognition of the miscalibration of demands and adaptive capacity, change is possible. This requires both understanding the current work and openness to restructuring of the work. Possibilities might include strategies such as offloading routine work (ie mixing and packaging of individual doses of hydroxyurea to the main pharmacy). In addition, it is conceivable that work could be restructured for example to offload biologic infusions to the main pharmacy, especially when the chemotherapy workload is high. Restructuring of the physical environment to accommodate a second diluent dispenser in the chemotherapy hood and installation of an intercom would decrease walking between the rooms of the HO pharmacy to use the single diluent dispenser and for routine communications.

Alternatively, models to quantitate levels of "routine" work (and unanticipated ad hoc requests) could be calibrated such that additional resources are deployed when the work exceeds a certain level or the HO pharmacy staff feels they are on the edge. This would also require an investment of resources to cross train pharmacy staff to function efficiently in the HO pharmacy and to provide back up to the HO pharmacy on a routine basis, but especially when there is high demand and/or ad hoc demands that exceed the capacity of the current staff.

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Online appendix

Supporting evidence/observations current work and resources

- One Full time pharmacist (4 years' experience as chemotherapy pharmacist, previous experience as pharmacist). (Approximately 2 days a week a second pharmacist assists with preparation, but that person is not as experienced with chemotherapy and requires a lot of assistance from primary HO pharmacist). Full Time pharmacist works every 3rd weekend in inpatient pharmacy and then is required to take one day off during the preceding and the following week surrounding the weekend he works.
- Two Pharmacy techs. Both experienced. Only one works each day. On the day of the observation the pharmacy tech working had 30–35 years of experience. (They are attempting to train a third technician, but current workload makes it difficult to spend the time on training a technician; "they get too far behind").
- Pediatric chemotherapy is substantially more complicated than adult. Diluent is often from bags off shelf in adult vs individualized volumes and additives in pediatrics.
- Recently remodeled chemo pharmacy. Central office and dispensing area with files and file cabinets. One room on each side with hood. Hoods have two openings with sleeves and gloves. All work needs to be done using the sleeves and gloves. On right, room has hood with pump to fill diluent bags for chemotherapy. Infusions such as orencia or remicade are also prepared here.
- Opposite room –across central office- is where chemotherapy is prepared. Also contains hood. Diluent bags need to be carried across office to chemo room.
- In central office, file cabinets placed against back wall. The patient folders for the day are arranged there. Highest shelf has patient folders for the next several days arranged by the day patient is scheduled.
- High risk chemotherapy (i.e. intrathecal medications) are labeled and placed there so pharmacist can personally hand off high risk medications to nurse who picks them up. Nurse must sign for medications. Nurses have learned not to remove medications from back file cabinet until cleared by pharmacist.
- Paper orders are provided to pharmacist who must review, assure orders match patient's protocol roadmap, check against previous doses, recalculate. Body Surface Area (BSA), and dosing, and reconcile any inconsistency (i.e.: change in dosing for renal function, etc) Pharmacist transcribes paper orders into computer.
- May only transcribe one day's orders for patient into computer at a time because of danger of orders being accidentally released.
- Pharmacist receives these orders with varying amount of time prior to patient's scheduled visit (days to hours).
- Paper files for each patient contain protocol, and where patient is on protocol, orders, compounding records, etc.
- Typical day involves 6–10 outpatient chemotherapy patients, 6 inpatient chemotherapy patients and 3–8 biologic infusion patients (orencia, remicade, etc.) Intrathecal drugs range from 8–15 per week; they have done 7 in a day.
- Each day there is a huddle with clinical staff at 3:45.
- Pharmacist prepares list of known next day patients including chemotherapy or infusion. Patient classification, green (will get medication –no barriers), yellow (needs labs checked prior to infusion) or red (chemotherapy or infusion has been rescheduled.), dosing and where patient is on protocol.
  - Labwork may be done same day as scheduled infusion or the day prior.
- There are 300–400 Children's Oncology group protocols but sometimes protocol for individual patient is developed from a journal article. This may be done by pharmacist, physician or nurse practitioner collaboratively.
- Pharmacy tech draws up diluents into labeled bag. Alternatively diluents may be placed in large syringe. Bag with diluent is capped with blue foil. Pharmacist needs to check solution and volumes pumped against label.
  - Chemotherapy medications are added in chemo hood. Pharmacist needs to verify medication, concentration (vials) and volume added. Chemo bags capped with green foil.

- Infusions capped with silver foil.
- All completed chemo bags weighed and verified against known weights must be within 5% of target.
- Stickers regarding handling placed on outside of bag-ie refrigerate, do not refrigerate.
- Label listing patient, medication, concentration, volume affixed directly to infusion bag or syringe. Not placed on outside storage bag.

- Intrathecal (IT) drugs (delivered to the central nervous system via lumbar puncture) require special handling. Syringes must remain sterile on outside and be delivered wrapped in sterile pack for Lumbar Puncture. Must be prepared in chemo hood with sterile gloves over standard sleeve and gloves. Sterile syringe must be repackaged in sterile towels. Two pharmacists must verify medication, concentration, volume and sterile process. All other medications removed from hood while preparing IT drugs.
- Pharmacist keeps computer in all three areas open to patients checking into clinic. This way he knows which patients have arrived. Needs to wait on labs for some. Will draw correct diluent volume (typically D5W or normal saline) into bag but not the infusion or chemotherapy medications-which are expensive.
- All inpatient chemotherapy orders must be hand carried by pharmacy tech or pharmacist to inpatient floor.
- Chemotherapy is administered 7 days a week.
- When inpatient chemotherapy is completed, pharmacist goes back to Medication Administration Record (MAR) and verifies that all doses required by protocol were administered (documented in MAR).
- Must place orders to main pharmacy by 4 pm every day including chemotherapy and infusion agents, diluents, syringes, and tubing.
- Significant specialized knowledge of staff:
  - Certain drugs require special tubing and syringes; i.e. silicon free
  - Some agents are stable for very short period of time i.e.: one hour. Need to be prepared immediately prior to administration.
  - Some drugs (i.e.: cytoxan) require 30 min of mixing to go into solution.

Changes in work

- Reimbursement for chemotherapy has changed. Hospital is now paid per course of chemotherapy rather than by charges for hospital days.
- This has resulted in shifting substantially more chemotherapy to the outpatient clinic.
- Previously, 1–2 drug infusions/patient were administered in outpatient clinic, now individual patient may receive 3–5 drug infusions in single visit. These often begin with IV hydration followed by several infusions separated by periods of hydration and may occur on consecutive days.
  - This has resulted in shifting much of the work to early in the day.
  - Inpatient chemotherapy is independently checked by 2 pharmacists, outpatient chemotherapy (previously being simpler) is checked by one pharmacist, but now has become as complex as inpatient chemotherapy in many circumstances.
  - Inpatient chemotherapy has a 6 independent double step check process. Fewer checks for outpatient chemotherapy.
- Patients receiving chemotherapy as inpatients are having scheduled chemotherapy shifted 3 h earlier each day that they are in house. The goal is to discharge the patient one midnight earlier in order for payment for course of chemotherapy to be more advantageous.
  - This also results in shifting work to earlier in the day.
- Previously oral formulation prescriptions (one month supply) occurred approximately once per month. These are now occurring approximately 30 times/month
  - Previously single bottle of medication dispensed to family with oral syringe for family to draw up individual doses. In order to minimize exposure to oral chemotherapy agents for family, individual doses are now drawn into syringes and individually labeled (i.e.:30 doses of hydroxyurea per patient per month).
  - Some oral formulations like hydroxyurea, take 4 h to prepare due to long “stirring period”.
- Oral compounding accounted for 100 doses/month in 2010–2011. Now it has increased to 400 doses/month. Since the pharmacy is only open 20 days/month, this accounts for approximately 20 oral compounds/day.
- Infusion center hours are being extended to 8 pm two days a week (previously infusion center hours ended at 4 or 5 pm).
- Plan is to have pharmacy begin to prime tubing for chemotherapy-could add up to 20 min preparation time per bag because of complexity of tubing. Need to figure out better way.

Environment and equipment

- Only one pump available to measure diluents. This is located in hood in “positive pressure” room. Tried to place second pump in chemo hood to save carrying bags of diluents across office, but pump occupied too much space and techs found they were at risk of picking up wrong meds because they had no room to work.
  - Larger hoods are available –cost between $15,000–20,000-have asked for that.
- Special tubing and syringes required for certain medications (i.e. silicon free).

Processes

- HO pharmacist also creates a list of chemotherapy for the inpatient pharmacy to make on the weekend or overnight and distributes the list to the pharmacy staff and oncology providers and staff on inpatient unit. Medications for the weekend chemotherapy are also delivered to the inpatient pharmacy by the HO pharmacist.
- When pharmacist is off or has weekend off, Pharmacist creates list showing the patients, what chemotherapy is due for the patient, when it should be mixed, what to look out for, when it should be delivered.
- Supervises the technicians – ensuring outdates are done monthly for all medications
- This am, HO pharmacist was not notified that patient on inpatient chemotherapy schedule is moving up 3 h. Pharmacist knows that second medication will be required 4 h after first medication. Has not received those orders, but prepares second medication.
- Pharmacist notes that they have heavy schedule tomorrow. He will mix cheap and stable drugs today (vincristine and cyclophosphamide) as this will give more bandwidth tomorrow to have time to mix expensive and unstable drugs. Advises covering pharmacists to do this because safer to have that time buffer, but they are sometimes resistant to that.
- With standard dosing (i.e. by BSA or weight) can mix stable drugs ahead of time. Knows dose is 1000 mg/meter squared and pt is 1.5 m squared. Will need 1500 mg.

- Pharmacist and Tech grateful that experienced tech yesterday mixed large volume of hydroxyurea (takes 4 h to mix).
- When placing syringes/bags of chemotherapy in hazard bags, pharmacists only places label on actual syringe or infusion bag. Wants nurse to be holding syringe when verifying medication, not looking at outside of bag.
- Closed loop communication used between tech and pharmacist.
- When pharmacy was remodeled, they wanted the door to the pharmacy to be closed. Pharmacist resisted. Nurses are right outside the door checking in patients. He overhears who is sick as well as changes. Nurses come in and out of pharmacy to share information. Often he overhears and knows a patient is ill, has fever, etc.
- Use visual /alternative cues to validate chemotherapy. Even though they have verified medication vial, concentration, volume, when tech injects etoposide into bag –pharmacist notes thick "ropy" texture. Only 3–4 drugs look like that and the other two drugs in the chemo hood are yellow or clear and not ropy.
- Tech likes working with different colored medications. For example Doxorubicin –red, methotrexate-yellow. Visual confirmation.
- Pharmacist and pharmacy techs plan day according to schedule with knowledge of chemotherapy protocols, specialized knowledge of medications, lab results that are required prior to administration and "how long things take". Covering pharmacists do not see that as easily due to lack of familiarity.
- Pharmacist also gets multiple "ad hoc and stat requests". These included:
  - Changing order for dye free acetaminophen. After pharmacist changed order –called main pharmacy to have them send it as acetaminophen was for premedication.
  - A new immunoglobulin infusion for a patient having additional symptoms.
  - Two new hydroxyurea orders, (this is the oral formulation that requires 4 h to prepare).
  - Nurse arrived with post it note with two medications listed– "I need this at 1030 and this one at 1:30 pm". Pharmacist already knew and had accounted for.
  - RN comes in and asks pharmacist – did you see "Sam"(not patient's real name) is coming in today instead of Friday. We will need his infusion this afternoon.
  - RN comes in asking for dose of tacrolimus.
- When patient becomes unstable on the floor, pharmacist needs to leave pharmacy and go to patient room to help draw up saline boluses, etc. Everything stops in the pharmacy.
- Also responsible for medication dispensing system stocking on floor/rapid assessment. Keep 4 doses of ceftriaxone premeasured there. Not exact, based on weight range, (i.e.: 10–20 kg) gets particular dose. Fastest way to treat patient with fever and neutropenia.
- Modified schedule: techs start at 0730 drawing diluent as this can be verified and need diluents prior to mixing chemo. Pharmacist starts at 0800 so can begin mixing chemo when he arrives. Downside is tech leaves at 4:00 pm. Chemotherapy pharmacist comes in early at 0745 at the latest and routinely stays until 1700 and sometimes as late as 2200.
- Each day pharmacist creates checklist of admits, inpatient chemo, outpatient chemo, and infusions; complements chemo huddle.
- Multiple patients need mesna today. Mixed large bag of diluent with mesna in correct concentration and draw off multiple syringes of correct volume for four patients.
- Created reference binder for covering pharmacists, techs that lists medication, how mixed, storage, stability and special information ie: medication precipitates (Busulfan precipitates if drawn up with one ml syringe) and needs to be mixed in special syringes.
- Chemo huddle at 3:45 each day. Team talks about errors in real time. Also keep log of errors and changes even if minor.
- Pharmacist worked this past weekend and had Tuesday (yesterday) off. He is the only "expert" chemo pharmacist. Three pharmacists were required to complete the work that he typically does. He received 10 phone calls. Had to prioritize the work for them. ("Cytoxan will take 30 min to go into solution; you need to start that now").
- When bed control does not transfer patients from clinic to inpatient unit properly HO pharmacy must re-enter all the medications because they end up being "Read Only" on the MAR.
- Pharmacy tech ill last week. HO pharmacist was going to act as technician and pharmacist from main pharmacy was going to "supervise". Other pharmacy tech came in on day off.
- Work is more difficult when non-HO pharmacist and chemo pharmacy tech are working together due to lack of familiarity with process.
- HO pharmacist states that non-HO pharmacists do not have same familiarity with chemotherapy and the chemotherapy pharmacy technicians. They (non-HO pharmacists) stop flow of work more often to verify technician's work. "HO Pharmacist states," i need to keep things moving and work in the queue. If I did not, we would always be behind and off schedule.
- Trying to train additional pharmacist and technician, but training slows them down. Pharmacy tech in training took 1.5 h to prepare 3 doses of intrathecal methotrexate due to complexity and difficulty of work.
  - Have tried using simulation-having tech prepare with non-hazardous materials and reusing sterile equipment to practice skills in hood. However need hood to prepare medications for patients so not enough time for practice.
- Work is becoming fragmented. Pharmacist checklist for chemo protocol done halfway, needs to be completed by a different pharmacist-does not have big picture.
- Has tried to write standard work instructions, but process changes so frequently that instructions are outdated by the time they are completed.
- Pharmacist previously attended Monday 0830 intake rounds "religiously" – new diagnoses, relapses and plan for week. For example new diagnosis of AML will have IT medication ordered even before final pathology is completed. Would get that information at Monday intake. Also patient who relapsed over weekend would be changed to different protocol in preparation for BMT. Now lucky to get there once a month.
- Unable to attend tumor board.
- Workload can be overwhelming. Hard when already have heavy load and things change.
- Can be bombarded with nurses and physicians coming in with new orders or changes which is the nature of the work.
- Can call to main pharmacy for help, but pharmacist who comes typically is not familiar with HO pharmacy work and requires extensive assistance. Sometimes seems like it is not worth asking for the additional help.
- Has entered entire order set on wrong patient when overwhelmed. Caught it but then had to reenter on correct patient.
- "just trying to get to 4:30 without hurting anyone".

What additional changes are anticipated

- Preparing to implement chemotherapy module for electronic health record.

- The oncology department is applying for a particular type of cellular therapy accreditation this year.
- Audit by pediatric oncology oversight group is scheduled this year.

What HO pharmacist believes would help

- Dedicated second HO pharmacist would allow for back up, alternative weekend staffing, less feeling that they are always "on the edge".
- Double pharmacy technician staff so that one pharm tech can work in each room.
- Install larger chemo hood with room to hold second pump.

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